



Streams & Lambdas



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

Streams & λ 's

API Java 8

Prednáška prevzatá z

1-AIN-430: Programovacie paradigmy

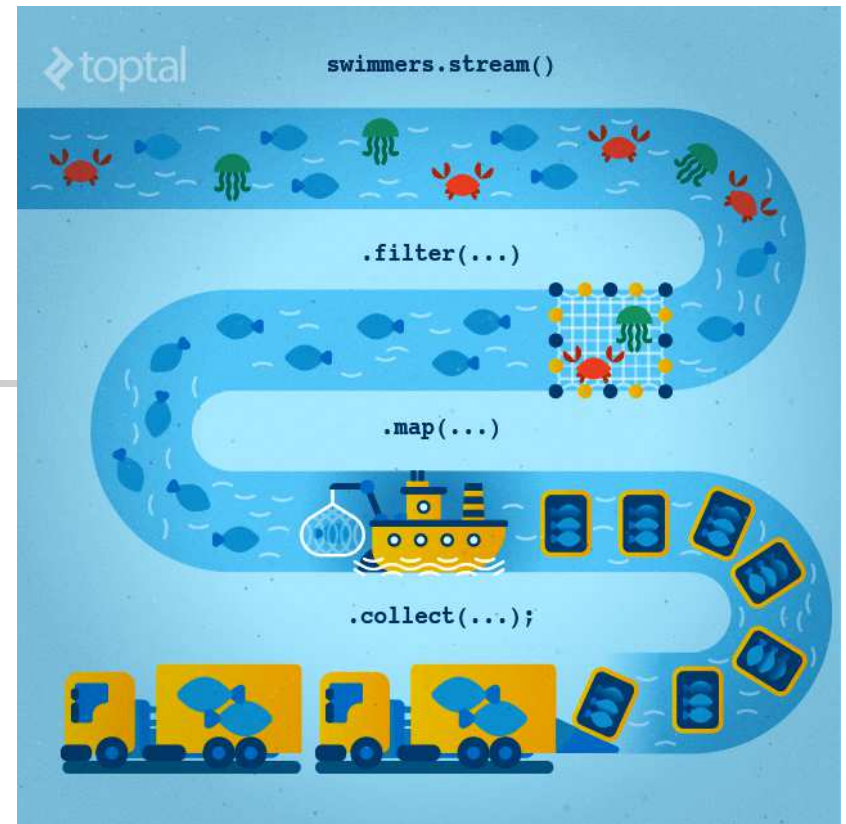
<http://dai.fmph.uniba.sk/courses/PARA/>

dnes bude:

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

Cvičenie (bohužiaľ nemáme):

- práca s kolekciami



~~< Java 8~~

Java 8

Java 9

Java 10



Kolekcie

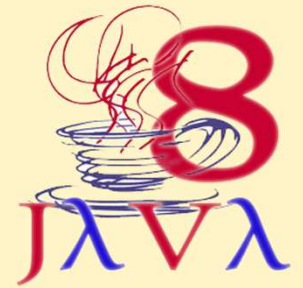
(a práca s nimi – ako to poznáme)

```
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);        // foreach metóda  
lst.forEach(e -> System.out.println(e+e));
```



Anonymné funkcie v Java

(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)

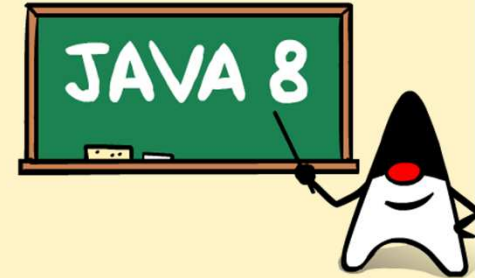
```
(a, b) -> { return Math.sqrt(a*a+b*b); }
```

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
```



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



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"
```



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"
```




Funkcionálny interface

(interface a reálna funkcia)

@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));

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

f^n

Existujúce

@FunctionalInterface



```
java.util.function.Function<T,R>
```

```
java.util.function.Predicate<T>
```

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>
```

```
    square = n ->
```

```
        Math.pow(Math.floor(Math.sqrt(n)),2)==n;
```

miesto `doit()` `apply()`, `test()`

`<R> apply(<T>) // funkcia T -> R`

`boolean test(<T>) // T -> boolean`

```
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
```

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

Existujúce

@FunctionalInterface



java.lang.Runnable

java.util.concurrent.Callable<E>

java.util.Comparator<T>

void run()

E call() throws Exception

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()));
```

```
class Karta {
```

```
    int hodnota;
```

```
    String farba;    // konštruktor, gettery, settery...
```

```
    ... }
```

```
List<Karta> karty = new ArrayList<>(Arrays.asList(
```

```
    new Karta(7, "Gula"), new Karta(8, "Zalud"),
```

```
    new Karta(9, "Cerven"), new Karta(10, "Zelen")));
```

```
cerven  
GULA  
ZALUD  
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> vaccieKartyStream =
```

```
    karty.stream().filter(k -> k.getHodnota() > 8);
```

```
List<Karta> vaccieKarty =
```

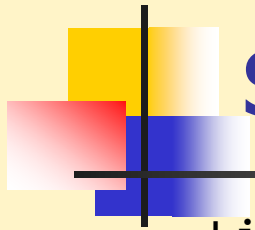
```
    vaccieKartyStream.collect(Collectors.toList());
```

[Cerven/9, Cerven/10]

```
List<Karta> vaccieKarty2 = karty
```

```
    .stream()  
    .filter(k -> k.getHodnota() > 8)  
    .collect(Collectors.toList());
```

[Cerven/9, Cerven/10]



stream()-collect()

```
List<Karta> vacsieKarty3 = karty
```

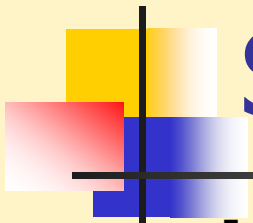
```
.stream()  
.map(k->new Karta(k.getHodnota()+1,k.getFarba()))  
.filter(k -> k.getHodnota() > 8)  
.collect(Collectors.toList());
```

[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]



Sekvenčný a paralelný stream

IntStream je podtrieda Stream pre hodnoty Integer

```
// vyrobí stream obsahujúci 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

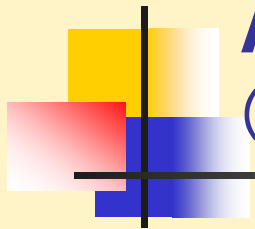
Exception: stream has already been operated upon or closed

```
// toto už nedostaneme v poradí 0, 1, ...
```

```
stream.parallel().forEach(e -> System.out.println(e+e));
```

MapFilter.java

130
132
134
124
126
128
62
...



Aké metódy ma Stream

(Jshell pozná autocompletion)

- Kliknite na TAB

```
Java(TM) Platform SE binary

jshell>

jshell> stream.
allMatch(          anyMatch(          close()          collect(
count()            distinct()        dropWhile(       equals(
filter(            findAny()         findFirst()      flatMap(
flatMapToDouble(   flatMapToInt(      hashCode()       forEach(
forEachOrdered(    getClass()         flatMapToLong(   isParallel()
iterator()          limit(             map(             mapToDouble(
mapToInt(           mapToLong(         max(             min(
noneMatch(          notify()           notifyAll()      onClose(
parallel()          peek(             reduce(          sequential()
skip(               sorted(           spliterator()    takeWhile(
toArray(            toString()         unordered()      wait(

jshell> stream._
```




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);           // 02468101214161820222...  
  
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
```

∀

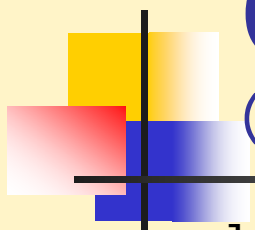
```
lst.stream().noneMatch(e -> (e > 100))           // true
```

```
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

(bud' 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);
0000000000111111111122222222223333333333444444444455555555556666
666666777777777788888888889999999999

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



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();
```

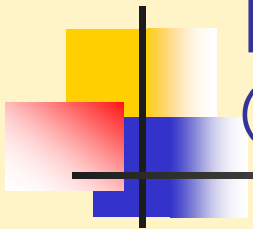
0

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

```
Java(TM) Platform SE binary

jshell> lst.stream().map(e -> { System.out.print(e); return e+e;}).
...> collect(Collectors.toList());
012345678910111213141516171819202122232425262728293031323334353637383940414243444546
474849505152535455565758596061626364656667686970717273747576777879808182838485868788
8990919293949596979899$83 ==> [0, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28
, 30, 32, 34, 36, 38, 40, 42, 44, 46, 48, 50, 52, 54, 56, 58, 60, 62, 64, 66, 68, 70
, 72, 74, 76, 78, 80, 82, 84, 86, 88, 90, 92, 94, 96, 98, 100, 102, 104, 106, 108, 1
10, 112, 114, 116, 118, 120, 122, 124, 126, 128, 130, 132, 134, 136, 138, 140, 142,
144, 146, 148, 150, 152, 154, 156, 158, 160, 162, 164, 166, 168, 170, 172, 174, 176,
178, 180, 182, 184, 186, 188, 190, 192, 194, 196, 198]
```

MapFilter.java



ParallelStream

(komutativnosť)

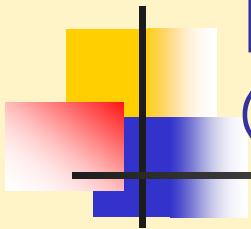
z predošlého príkladu:

```
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
```



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())
```

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



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

Globálne premenné

(sú identifikovaná *smrt'*)

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

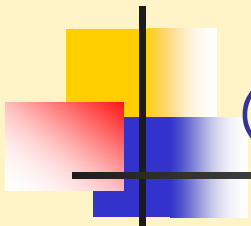
```
Java(TM) Platform SE binary
jshell> globalVariable = 0
globalVariable ==> 0

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, 202,
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).
```

```
    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));
```

```
0123456789101112131415161718192021222324...
```


z predošlého príkladu:

```
List<Integer> lst = 0, 1, ... 99
```

Collectors

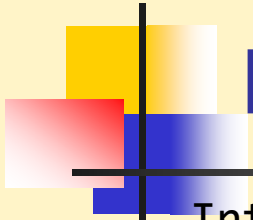
(groupBy, partitioningBy, reducing)

```
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);  
@ABCDEFGH I
```

```
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())
```

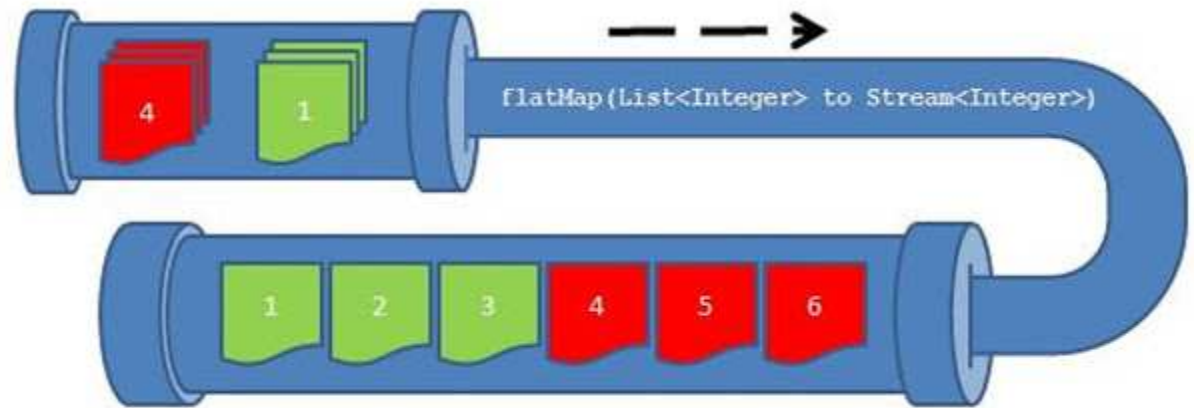
```
[ ]  
[0]  
[0, 1]  
[0, 1, 2]  
[0, 1, 2, 3]  
[0, 1, 2, 3, 4]  
[0, 1, 2, 3, 4, 5]  
[0, 1, 2, 3, 4, 5, 6]  
[0, 1, 2, 3, 4, 5, 6, 7]  
[0, 1, 2, 3, 4, 5, 6, 7, 8]
```

Konverzie `IntStream <-> Stream<Integer>`

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

flatMap

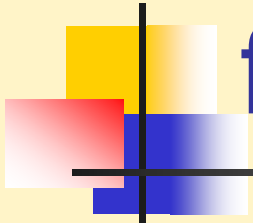
- The flatMap operation



```
List<Integer> together = Stream.of(asList(1, 2, 3), asList(4, 5, 6))
    .flatMap(numbers -> numbers.stream())
    .collect(toList());
assertEquals(asList(1, 2, 3, 4, 5, 6), together);
```

```
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]
```



flatMap

```
IntStream.range(0,10).  
    flatMap(e -> IntStream.range(0, e)).  
    forEach(System.out::print);  
001012012301234012345012345601234567012345678
```

```
IntStream.range(0,10).  
    flatMap(e -> IntStream.range(0, e).  
        filter(i->i%2==0)).  
    forEach(System.out::print);  
0002020240240246024602468
```



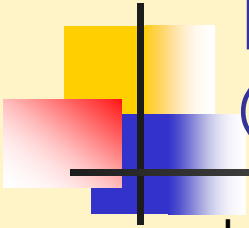
z predošlého príkladu:

```
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());
```



Binárne vektory {0,1}

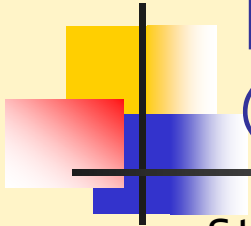
(klasické riešenie)

```
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]

Počet = 2^n



Binárne vektory {0,1}

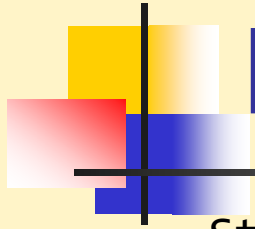
(streamové riešenie)

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

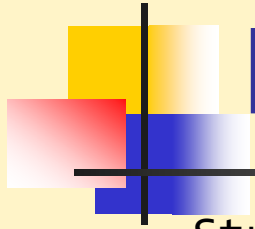


Permutácie

```
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 = $n!$

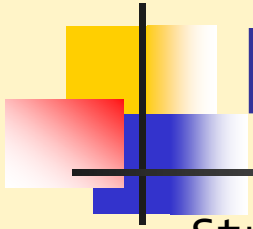
```
Stream<String> perms(int n) {  
    if (n <= 0) {  
        return Stream.of("");  
    } else {  
        return  
            perms(n-1).  
            flatMap(s->IntStream.range(0, n).  
                mapToObj(i -> insert(i, n, s)) );  
    }  
}  
  
String insert(int i, int n, String s) {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

Kombinácie bez opakovania

Počet = n nad k

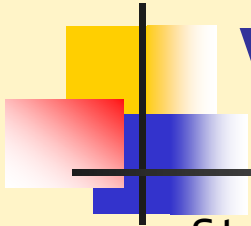
```
Stream<String> kbo(int k, int n) {  
    if (k > n) {  
        return Stream.of();  
    } else if (k == 0) {  
        return Stream.of("");  
    } else {  
        return Stream.concat(  
            kbo(k, n-1),   
            kbo(k-1, n-1).map(s -> s + String.valueOf(n-1)));  
    }  
}  
  
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]
```



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(  
            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]
```



Variácie s opakovaním

```
Stream<String> kso(int k, int n) {  
    if (k > n) {  
        return Stream.of();  
    } else if (k == 0) {  
        return Stream.of("");  
    } else {  
        return Stream.concat(  
            kso(k, n-1),  
            kso(k-1, n).map(s -> s + String.valueOf(n-1)));  
    }  
}
```

Počet = n^k

```
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]
```



Variácie bez opakovania

```
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))));  
    }  
}
```

Počet = $n(n-1)\dots(n-k+1)$

```
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



Ak by vám (v 1.semestri) neprezradili priradenie (=) a cyklus (for/while),
tak tu máme spústu šikovných funkcionálnych programátorov...