Introduction to Functional Reactive Programming

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Assumptions

- You understand basic functional programming concepts
- You know how to read Java code

WTF is FRP?

- Wikipedia says
  - Functional reactive programming (FRP) is a programming paradigm for reactive programming (asynchronous dataflow programming) using the building blocks of functional programming (e.g. map, reduce, filter).

Simpler Definition

- FRP is a functional way to work with asynchronous stream(could be infinite) of events.
    - Here events could be anything from mouse clicks, tweets, etc.
    - Here functional means that you can use functional concepts like higher order functions, lazy evaluation, and rich API like map, filter, etc.

Before we embark on FRP journey

- Lets write a simple program that prints first N positive Natural numbers greater than 0.

```
naturalNumbers :: Int -> [Int]
```

```
Ex. naturalNumbers(5) = [1,2,3,4,5]
```

Imperative way

```
public class Example1 {
    public static void main(String[] args) {
        List<Long> naturalNumbers = naturalNumbers(100);
        for (Long naturalNumber : naturalNumbers) {
            System.out.println(naturalNumber);
        }
    }
    public static List<Long> naturalNumbers(long n) {
        List<Long> naturalNumbers = new ArrayList<>();
        for (long i = 1; i <= n; i++) {
            naturalNumbers.add(i);
        }
        return naturalNumbers;
    }
```

How can we make this code functional?

```
public class Example1 {
    public static void main(String[] args) {
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        for (Long naturalNumber : naturalNumbers) {
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    }
    public static List<Long> naturalNumbers(long n) {
        List<Long> naturalNumbers = new ArrayList<>();
        for (long i = 1; i <= n; i++) {
            naturalNumbers.add(i);
        }
        return naturalNumbers;
    }
```
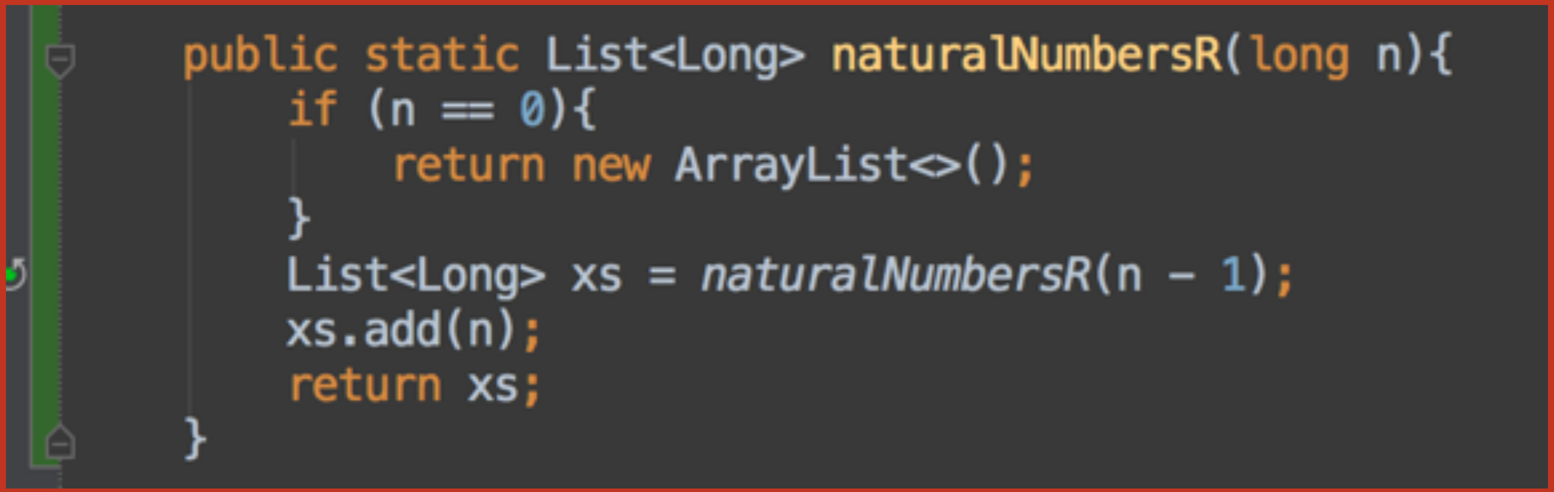

Recursion

(show Java, Scala, and Haskell code)

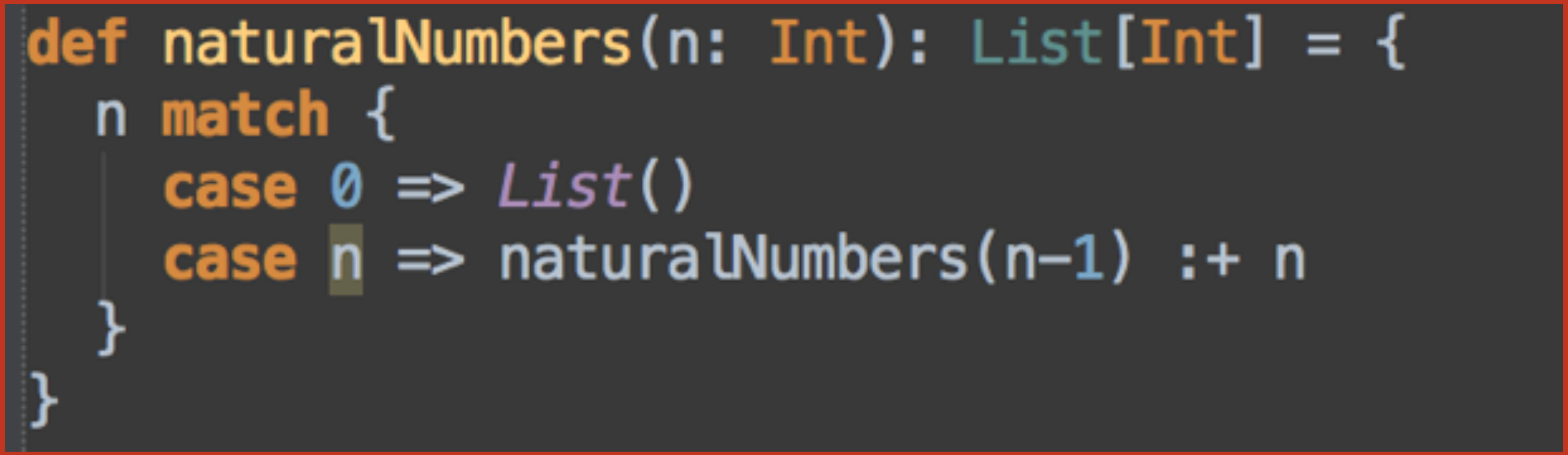
FP in Action



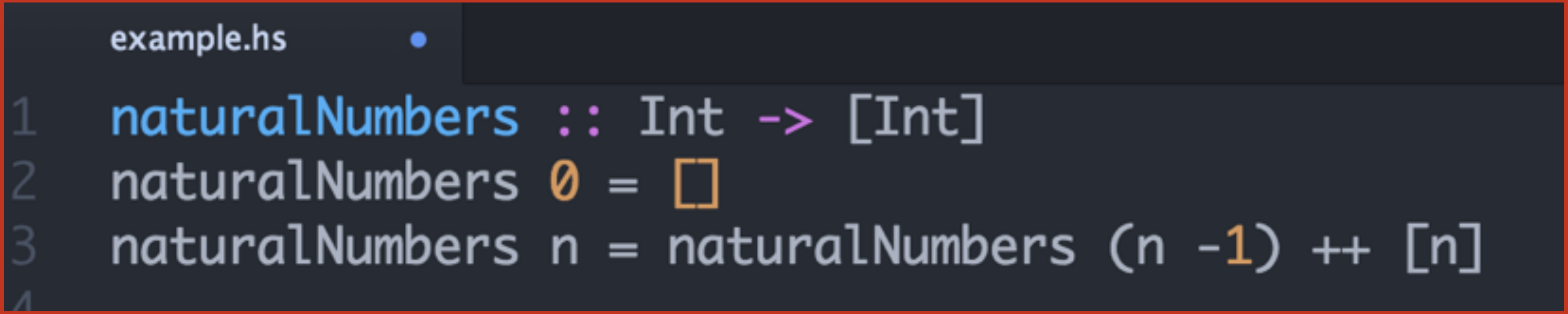
```java
public static List<Long> naturalNumbersR(long n){
    if (n == 0){
        return new ArrayList<>();
    }
    List<Long> xs = naturalNumbersR(n - 1);
    xs.add(n);
    return xs;
}
```

Java

Scala



```scala
def naturalNumbers(n: Int): List[Int] = {
  n match {
    case 0 => List()
    case n => naturalNumbers(n-1) :+ n
  }
}
```



```haskell
naturalNumbers :: Int -> [Int]
naturalNumbers 0 = []
naturalNumbers n = naturalNumbers (n -1) ++ [n]
```

Haskell

What will happen with Java and Scala version?

- n = 100
- n = 1000
- n = 10000
- n = 100000

Possible issues with imperative code

- We are leaking implementation detail i.e. List
- Imperative code
- Not Lazy (Generate one million and take only first 5 elements)
- Not well encapsulated

Can we use our own class with for..each ?

NaturalNumbers is a sort of factory that produces numbers

```
public class Example2 {

    public static void main(String[] args) {

        NaturalNumbers naturalNumbers =
NaturalNumbers.naturalNumbers(100);

        for (Long naturalNumber : naturalNumbers) {

            System.out.println(naturalNumber);

        }

    }

}
```

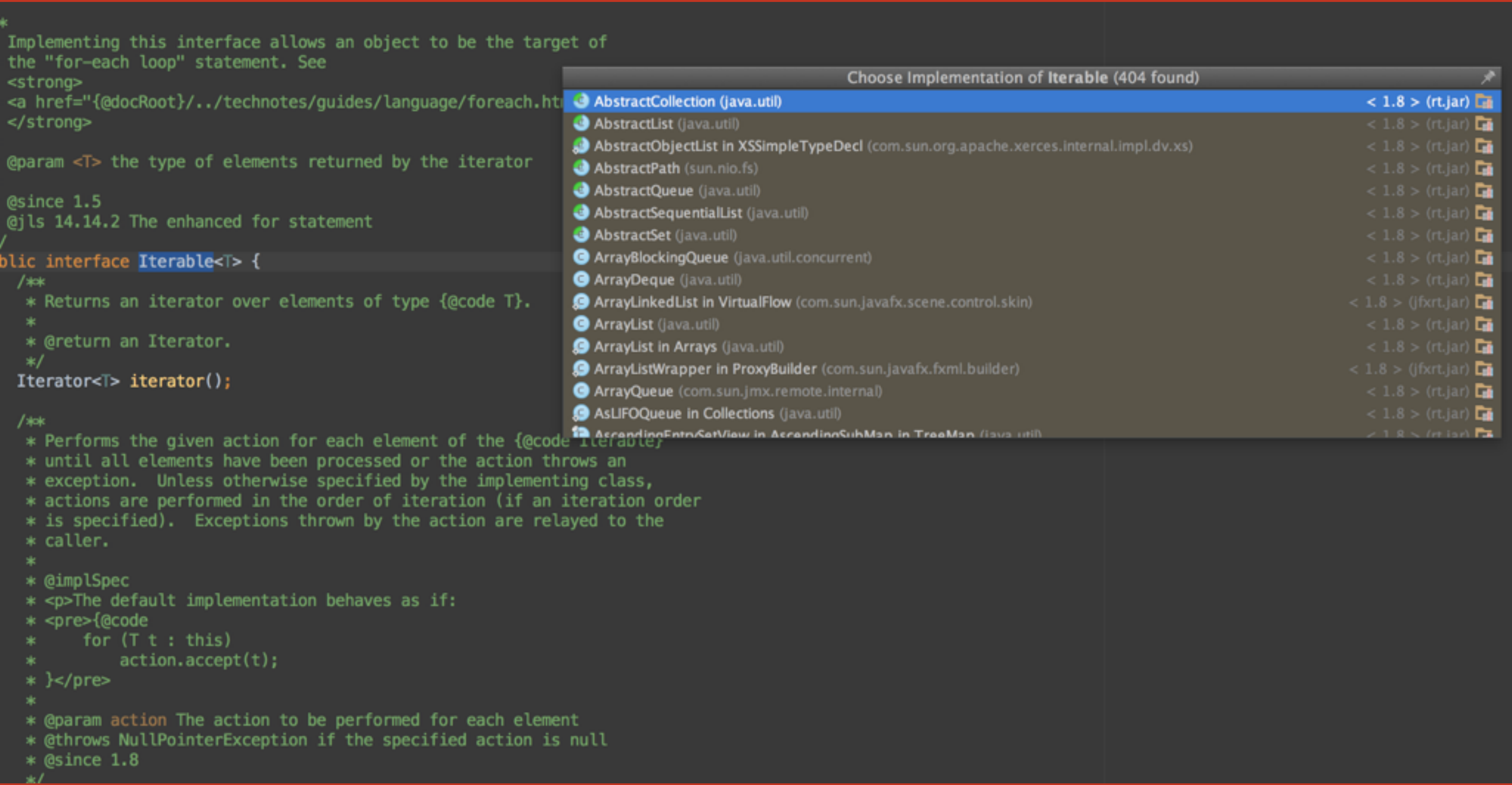
@Sameer, @Aditya, and @Ankur please dont answer

Write the complete Example

Iterables are very powerful type

- They were introduced in Java 5 to allow you to allow an object to be target of for..each statement.
- The full collection API is based on Iterable
- Iterable is a general concept found in most programming languages. .Net, Scala, Java, Ruby, etc.

Iterable implementations in JDK 8



```
*
 Implementing this interface allows an object to be the target of
 the "for-each loop" statement. See
 <strong>
 <a href="{@docRoot}/../technotes/guides/language/foreach.htr
 </strong>

 @param <T> the type of elements returned by the iterator

 @since 1.5
 @jls 14.14.2 The enhanced for statement
/
blic interface Iterable<T> {
   /**
    * Returns an iterator over elements of type {@code T}.
    *
    * @return an Iterator.
    */
   Iterator<T> iterator();

   /**
    * Performs the given action for each element of the {@code Iterable}
    * until all elements have been processed or the action throws an
    * exception.  Unless otherwise specified by the implementing class,
    * actions are performed in the order of iteration (if an iteration order
    * is specified).  Exceptions thrown by the action are relayed to the
    * caller.
    *
    * @implSpec
    * <p>The default implementation behaves as if:
    * <pre>{@code
    *     for (T t : this)
    *         action.accept(t);
    * }</pre>
    *
    * @param action The action to be performed for each element
    * @throws NullPointerException if the specified action is null
    * @since 1.8
    */
```

Choose Implementation of **Iterable** (404 found)

```
AbstractCollection (java.util)                                                < 1.8 > (rt.jar)
AbstractList (java.util)                                                      < 1.8 > (rt.jar)
AbstractObjectList in XSSimpleTypeDecl (com.sun.org.apache.xerces.internal.impl.dv.xs)  < 1.8 > (rt.jar)
AbstractPath (sun.nio.fs)                                                     < 1.8 > (rt.jar)
AbstractQueue (java.util)                                                     < 1.8 > (rt.jar)
AbstractSequentialList (java.util)                                            < 1.8 > (rt.jar)
AbstractSet (java.util)                                                       < 1.8 > (rt.jar)
ArrayBlockingQueue (java.util.concurrent)                                     < 1.8 > (rt.jar)
ArrayDeque (java.util)                                                        < 1.8 > (rt.jar)
ArrayLinkedList in VirtualFlow (com.sun.javafx.scene.control.skin)            < 1.8 > (jfxrt.jar)
ArrayList (java.util)                                                         < 1.8 > (rt.jar)
ArrayList in Arrays (java.util)                                               < 1.8 > (rt.jar)
ArrayListWrapper in ProxyBuilder (com.sun.javafx.fxml.builder)                < 1.8 > (jfxrt.jar)
ArrayQueue (com.sun.jmx.remote.internal)                                      < 1.8 > (rt.jar)
AsLIFOQueue in Collections (java.util)                                        < 1.8 > (rt.jar)
AscendingEntrySetView in AscendingSubMap in TreeMap (java.util)               < 1.8 > (rt.jar)
```

How does Iterable<T> work?

- Check if the collection has a value by calling hasNext() method on iterator
- Call next() method to get the value
- Wait for result
- Store the return value from that method in a variable
- Use that variable to do something useful

Limitations of Iterable<T>

- Synchronous
- Pull based
- Low level – lacking functional constructs
- Not lazy

Java 8 made Java Little Functional

- Streams
- Higher order functions using Lambda
- New immutable DateTime API
- Method references

Java 8 made data flow programming easy

```
import java.util.stream.IntStream;

public class Example3 {

    public static void main(String[] args) {


IntStream.rangeClosed(1,100).forEach(System.out::println);

    }

}
```

Java 8 Streams are very powerful abstraction

- Allows you to work with collections in a functional manner using lambdas
- They are lazy by default
- Readonly and immutable

Infinite Stream of Natural Numbers

```java
import java.util.stream.LongStream;

public class Example4 {
    public static void main(String[] args) {
        LongStream.iterate(1, val -> val + 1).forEach(System.out::println);
    }

}
```

Some functional methods

Map ->

```
IntStream.rangeClosed(1, 10).map(num -> num + 10).forEach(System.out::println);
```

Filter ->

```
IntStream.rangeClosed(1, 10).filter(num -> num % 2 ==
0).forEach(System.out::println);
```

Combine Map and Filter ->

```
IntStream.rangeClosed(1, 10).map(num -> num + 10).filter(num -> num % 2 == 0).
forEach(System.out::println);
```

Sum, skip, limit()

```
IntStream.rangeClosed(1, 10).sum()
```

```
IntStream.rangeClosed(1, 100).skip(50).limit(10).forEach(System.out::println);
```

Streams does not solve all the problems

- Streams are pull based
- Streams are synchronous in nature

Lets change the requirement

Think of infinite sequence of natural numbers as an event stream.

We want two consumers one that would add 1 to the number

and second consumer that would square the number.

Teacher == [1,2,3,4,5]

Student 1 (add 1 to n) == [2,3,4,5,6]

Student 2 (square n) == [1,4,9,16,25]

Reactive Programming could help

- Programming model is based on push rather than pull
- Values are emitted asynchronously when ready without any blocking
- Allows multiple consumers to subscribe to the producer stream.

Functional Reactive Programming

- FRP is a functional way to work with asynchronous stream(could be infinite) of events. Applying functions to data stream
- It is replacement of Observer pattern, which is usually implemented using callbacks or listeners.

Reactive Extensions(Rx)

- Collection of helpful functions that let you do reactive programming with ease.
- It was created by .NET team in 2009
- Netflix in 2014 released RxJava
- Netflix uses RxJava to make all their service API asynchronous

What makes RxJava

- Observable – event stream source(producer)
- Observer – it subscribes to the Observable and listen for events
- Observer can react to events emitted by Observable
- More than one observers can subscribe to a single Observable

Observer Interface

- onNext - This method is called by Observable zero or many times whenever Observable emits a value
- onError - To indicate failure scenarios. This stops the Observable and it wont make further calls
- onCompleted - To mark successful completion

Say Hello to Observable

```
import rx.Observable;

public class Examples {

    public static void main(String[] args) {

        Observable<String> observable =
Observable.create(subscriber -> subscriber.onNext("Hello world"));

        observable.subscribe(System.out::println);

    }

}
```

Observable are very powerful..

- They are composable in nature. They can be chained together or combined
- They can emit - single event, multiple events, or infinite events
- Free from callback hell: you can transform one Observable into another

Code

Infinite natural number sequence with multiple subscribers.

One subscriber calculate factorial

Second factorial add 10 to the number

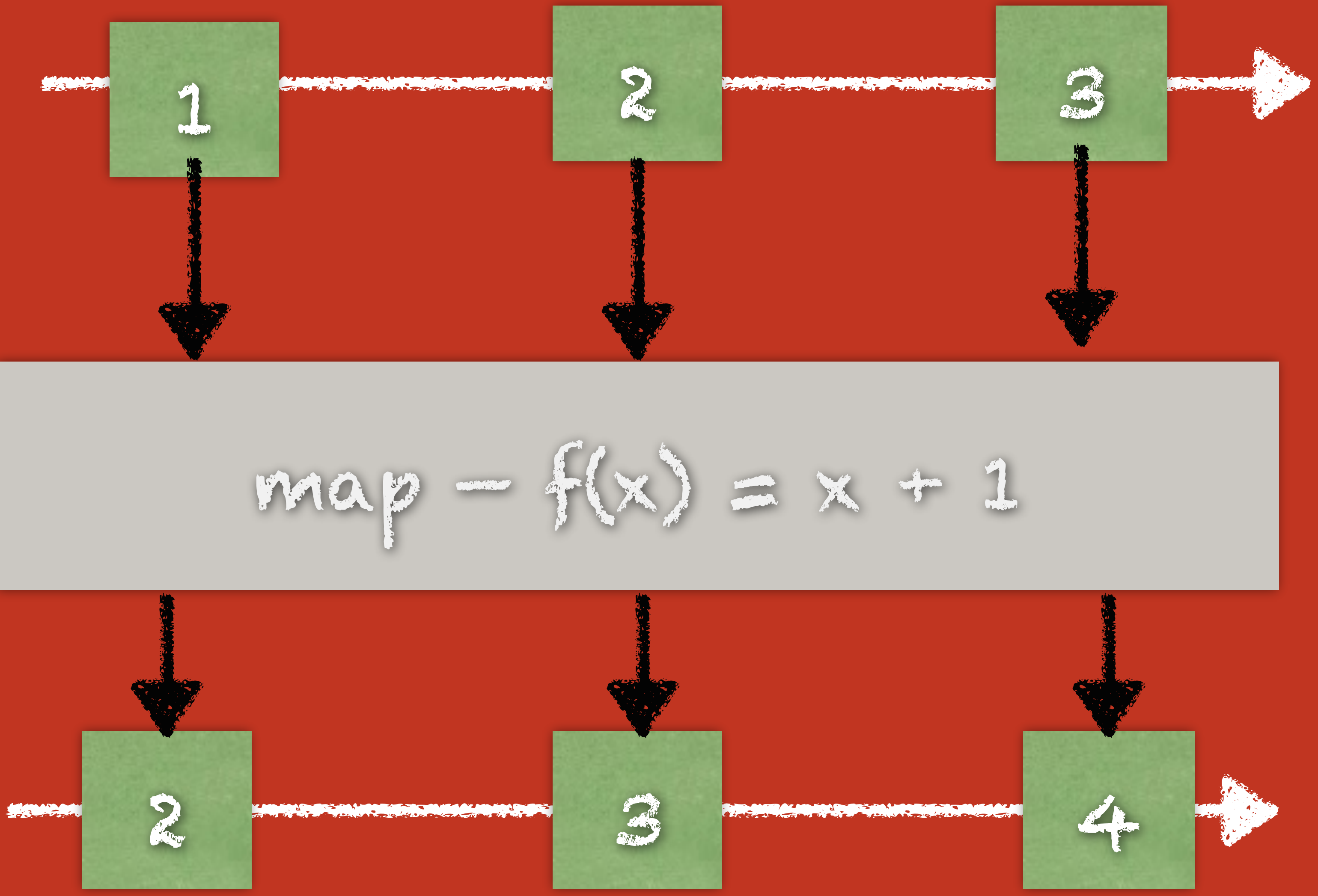
Real world example

Sentiment analysis of twitter stream

Thanks

https://github.com/shekhargulati/frp-xke

It is just a Map



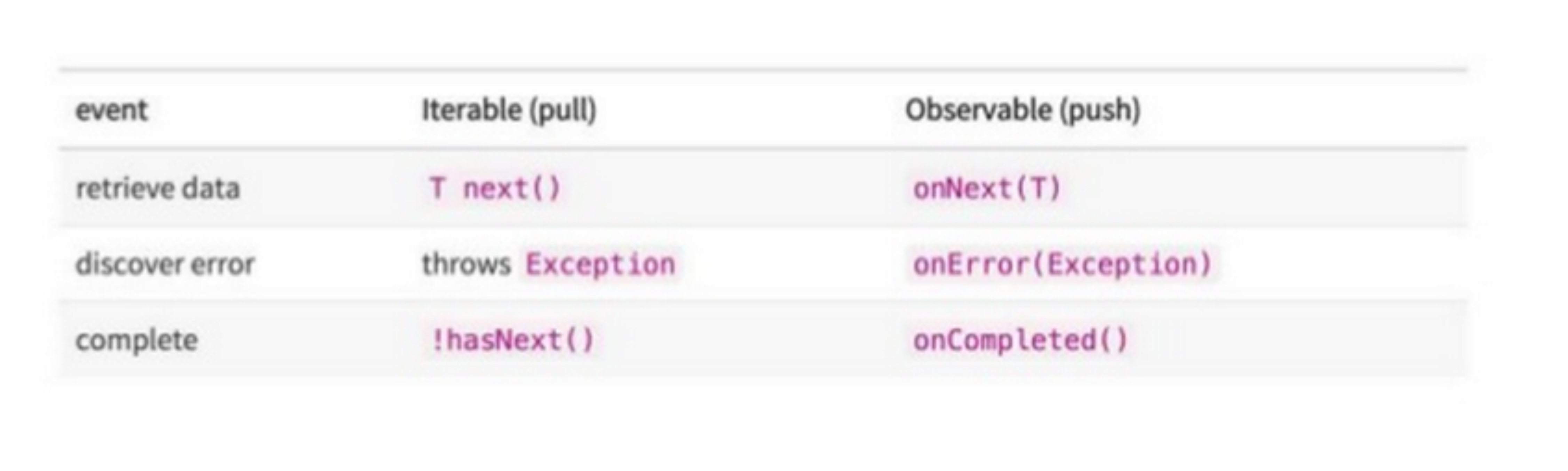
Iterables vs Observables

- Iterables allow you to query data at rest where as Observables allows you to query data in motion

Event	single item	multiple items
sync	T getData()	Iterable<T> getData
async	Future<T> getData	Observable<T> getData

Iterable vs Observable

- Observable is push/async dual of Iterable



event	Iterable (pull)	Observable (push)
retrieve data	`T next()`	`onNext(T)`
discover error	throws `Exception`	`onError(Exception)`
complete	`!hasNext()`	`onCompleted()`