PG4200: Algorithms And Data Structures

Lesson 08: Iterators, Lambdas and Streams

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Iterators

Iterating Over All Elements

- Many situations in which you need to look at and process all elements in a collection
- For *lists* and *arrays*, can look at indices from *0* to *N-1*
- But what about *maps* and *sets* that are unordered?
  - or other kinds of data structures like *graphs* that we haven't seen yet
- Would like to write loops like "*for(X x : collection){…}*"

java.util.Iterator

```
public interface Iterator<E> {
    /**
     * Returns {@code true} if the iteration has more elements.
     * (In other words, returns {@code true} if {@link #next} would
     * return an element rather than throwing an exception.)
     *
     * @return {@code true} if the iteration has more elements
     */
    boolean hasNext();

    /**
     * Returns the next element in the iteration.
     *
     * @return the next element in the iteration
     * @throws NoSuchElementException if the iteration has no more elements
     */
    E next();
```

java.lang.Iterable

```
public interface Iterable<T> {
    /**
     * Returns an iterator over elements of type {@code T}.
     *
     * @return an Iterator.
     */
    Iterator<T> iterator();
```

Iterators

- The idea is to make our collections to implement *Iterable* interface
- Need to implement an iterator for each collection, which keeps track of *one element at a time*
- Java compiler is aware of *Iterable*, and so can automatically handle "*for(X x : collection){…}*"
    - ie, do not need to call "*hasNext()*" and "*next()*" by yourself
    - but only as long as that collection does implement *Iterable*
- Collection should not be changed (eg, add/remove) while iterating over them

Lambdas

Functions as Parameters

- At times, you need to pass "*code*" as input parameter to another method
- To do that, you need to create a class with a method implementing the code you need
- Writing a whole class definition for just a single line of code is too much boilerplate

Interfaces in *java.util.function.**

- *Runnable.run()*
  - Nothing as input/output, just execute some code with side-effects
- *Consumer<T>.accept(T t)*
  - take an instance of T as input, and do something with it, and return nothing
- *Predicate<T>.test(T t)*
  - input T, and then return a boolean
- *Function<T,R>.apply(T t)*
  - take T as input, and return something of type R
- There are more, but those 4 are enough for what we need

Anonymous Classes

- Because interfaces, need to create concrete instances with our implementations
- If used only once, can create class on the fly
- Note that *Consumer* is an interface with method *accept()*

```
Consumer<String> anonymousClass = new Consumer<String>() {
    @Override
    public void accept(String s) {
        //your code here
    }
};
```

Lambdas

- Anonymous classes work fine, but are tedious to write
- *Lambdas*: syntax sugar to reduce boilerplate
- Java compiler is aware of the interfaces in *java.util.function.**

```
Consumer<String> lambda = s -> {/* your code */}
//this is equivalent to previous example
```

() -> {}

- Left-side: the input parameter name(s), with **()** if none
    - can choose the names you want, but usually a single letter
- Right-side: the instruction to execute. If more than one, should be in a {} block
- Based on input/output types, the compiler will automatically create the right class, eg *Runnable*, *Consumer*, *Predicate* or *Function*

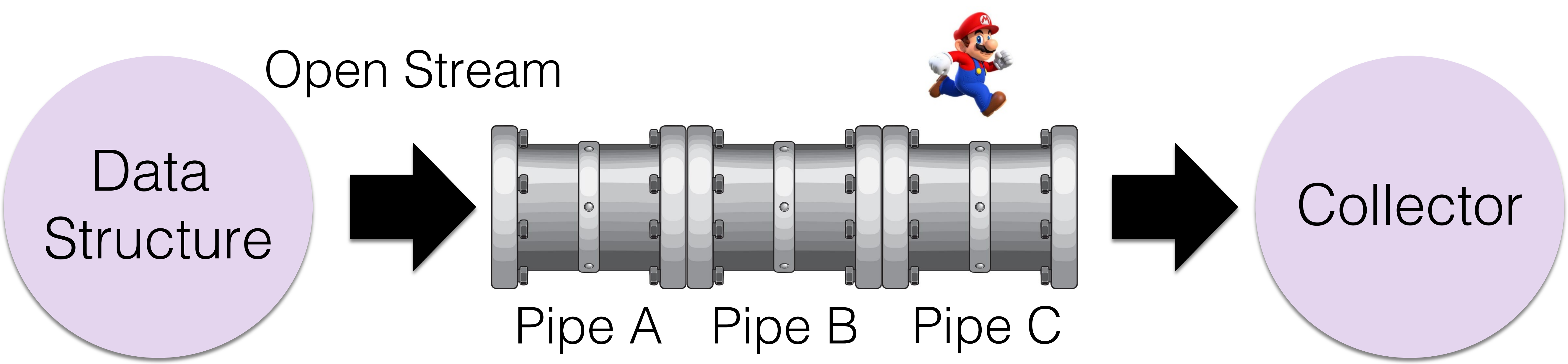
Streams

Iterators + Lambdas

- When a container has an iterator, and once we can write custom code in lambda expressions, we can introduce the concept of Stream
- The idea is that we can iterate over all elements in collection, and *easily* execute code in sequence on each of the elements
- *This can drastically reduce the amount of code you write, and easier to understand* (once you get familiar with it)

Stream / Pipeline

- At each pipe, the elements can be transformed and/or blocked (ie not going to next pipe)
- At the end of the stream, we need a *collector*, which defines what to do with elements that arrive at the end of the pipeline



Type of Pipes

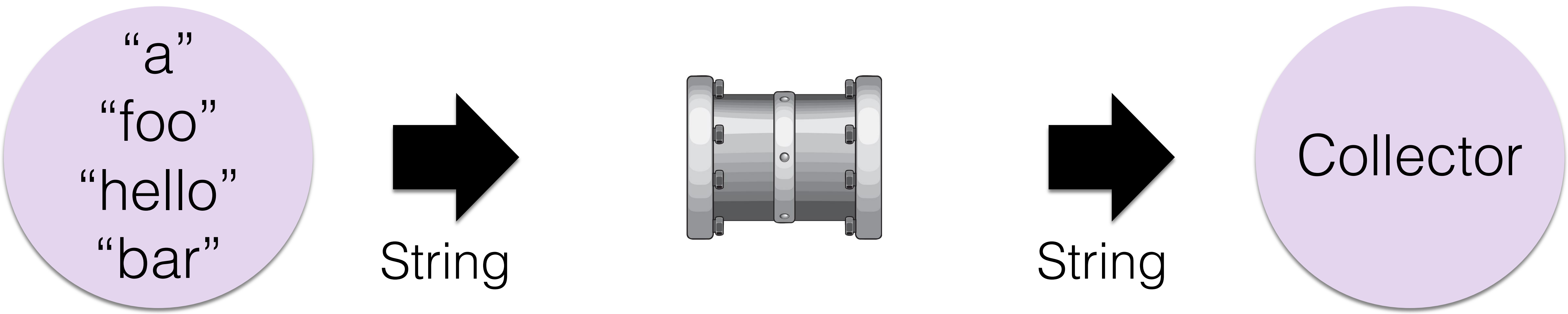
- *Filter*: take as input a *Predicate<T>*, and based on that decide if elements propagate to next pipe

- *Map*: transform input, and also change type, based on a *Function<T,R>*

- *FlatMap*: get a stream from input element, and flatten it into the current stream (examples later)

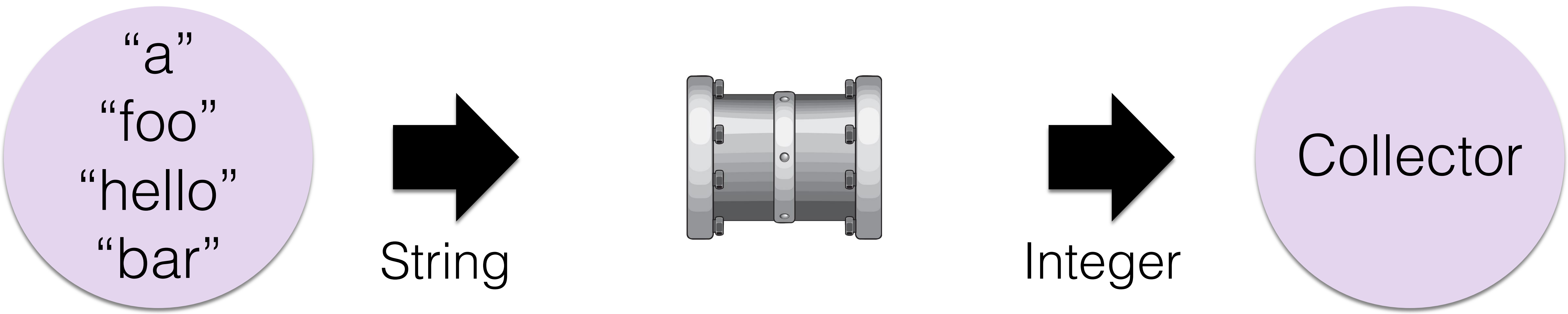
- There are more, but these are the main ones we will see in details

Filter



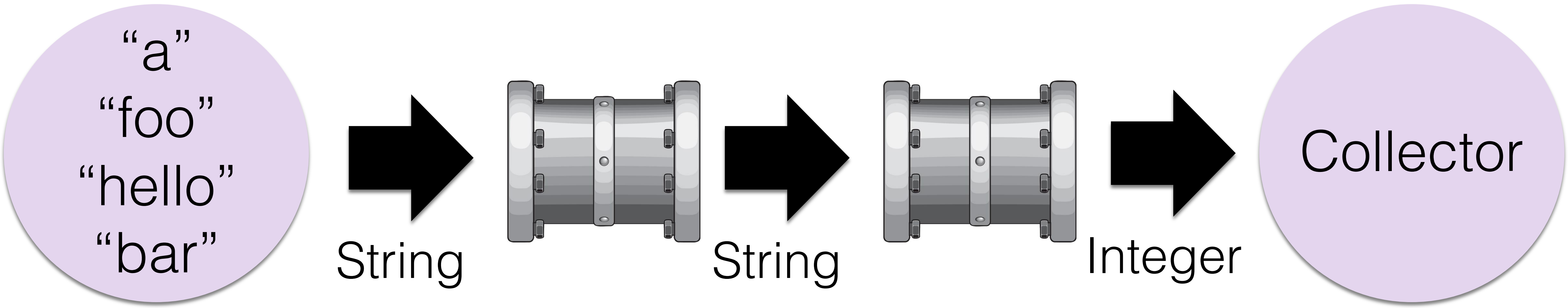
- Example: *collection.stream().filter(s -> s.length() > 3)*
- Input/Output: *String*, does not change
- Blocked: “*a*”, “*foo*”, “*bar*”
- Allowed: “*hello*”
- Collector will only get “*hello*”

Map



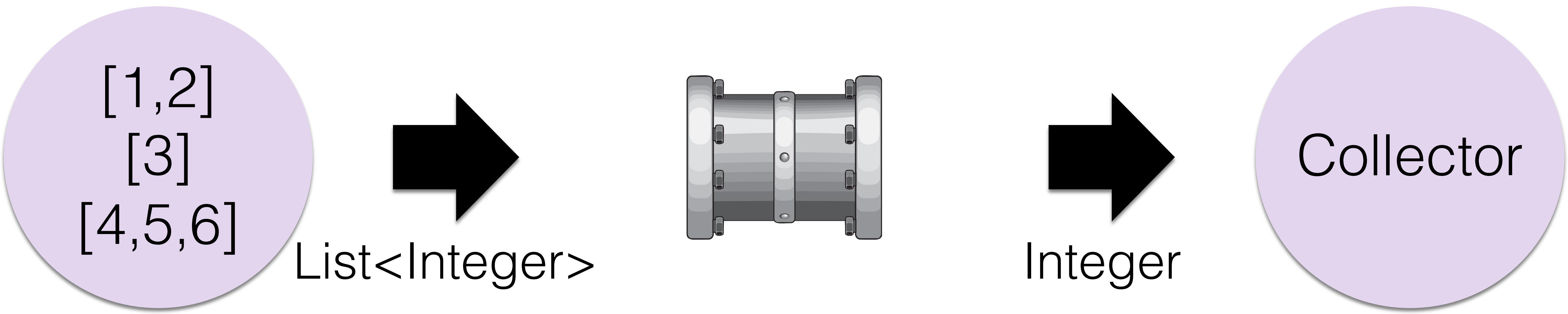
- Example: *collection.stream().map(s -> s.length())*
- Input *String*, Output *Integer*
- Note: compiler automatically infer type *"Integer"* based on the type returned by the function "*String.length()*"
- Collector will receive: 1, 3, 5, 3

Combining Pipes



- Example: *.filter(s -> s.length() > 2).map(s -> s.length())*
- *"a"* is the only blocked element by the filter
- Collector will receive: 3, 5, 3

FlatMap



- Example: *collection.stream().flatMap(l -> l.stream())*
- Input *List<Integer>*, Output *Integer*
- On each of the 3 input lists we open a stream, and propagate its output, one element at a time
- Collector will receive: 1, 2, 3, 4, 5, 6 and NOT [1,2], [3], [4,5,6]
- So the values of the 3 lists are flattened into a single stream of integers, including all values in those lists

Collectors

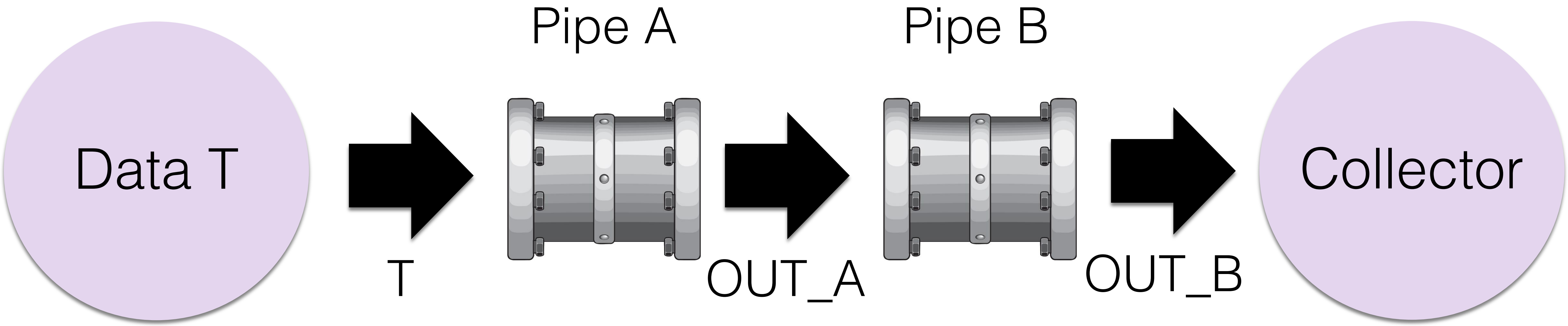
- *collectToList()*: each element that arrives at the end of the pipeline will be added to a new List container
- *forEach(Consumer<X> action)*: for each element that arrives at the end of the pipeline, execute the action specified by the user, which takes as input type X being the output of the last pipe in the pipeline
- There are more, but these are the main ones we will see in details

Implementation

- The collector is the one that starts pulling data from the collection using its iterator

- At each step, the output of a pipe is going to be the input to the next pipe

- Going to represent it with a *chain* of Consumers



- *IN_A* is *T,* and *IN_B* is *OUT_A*

- Collector has a *Consumer<OUT_B>,* as it consumes data from Pipe B

- Pipe B has a *Consumer<OUT_A>*, which will call *Consumer<OUT_B>* in Collector (ie, chained)

- Pipe A has a *Consumer<T>*, which will call *Consumer<OUT_A>* of Pipe B (ie, chained)

Collector Call

- Get iterator from collection of type T
- On each element of type T, call consumer of the first pipe

Pipe A: Consumer<T>

- Compute output of type OUT_A
- Call consumer of Pipe B with such output

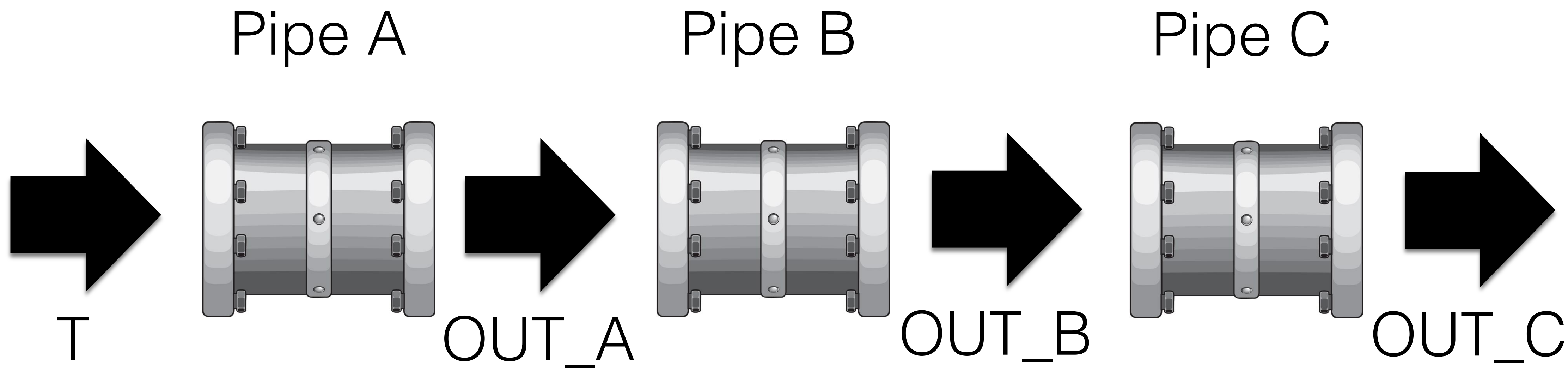
Pipe B: Consumer<OUT_A>

- Compute output of type OUT_B
- Call consumer of Collector with such output

Collector: Consumer<OUT_B>

- Do its computation
- End of the chain

- The collector is what starts the stream by pulling data
- The consumer of the first pipe is called, and that will trigger a chain until the last consumer
- However, the collector itself has to define a Consumer for the last pipe




```
//Pipe A
Consumer<T>.accept(T in){
    … //process in, compute out
    pipeB.accept(out)
}
```

```
// Pipe B
Consumer<OUT_A>.accept(OUT_A in){
    … //process in, compute out
    pipeC.accept(out)
}
```

- Each Pipe has a Consumer<IN>, and also a *downstream* reference to the Consumer<OUT> in the next pipe

Homework

- No Book Chapter
- Study code in the *org.pg4200.les07* package
- Do exercises in *exercises/ex07*