Overview of Java 8 Parallel Streams (Part 1)

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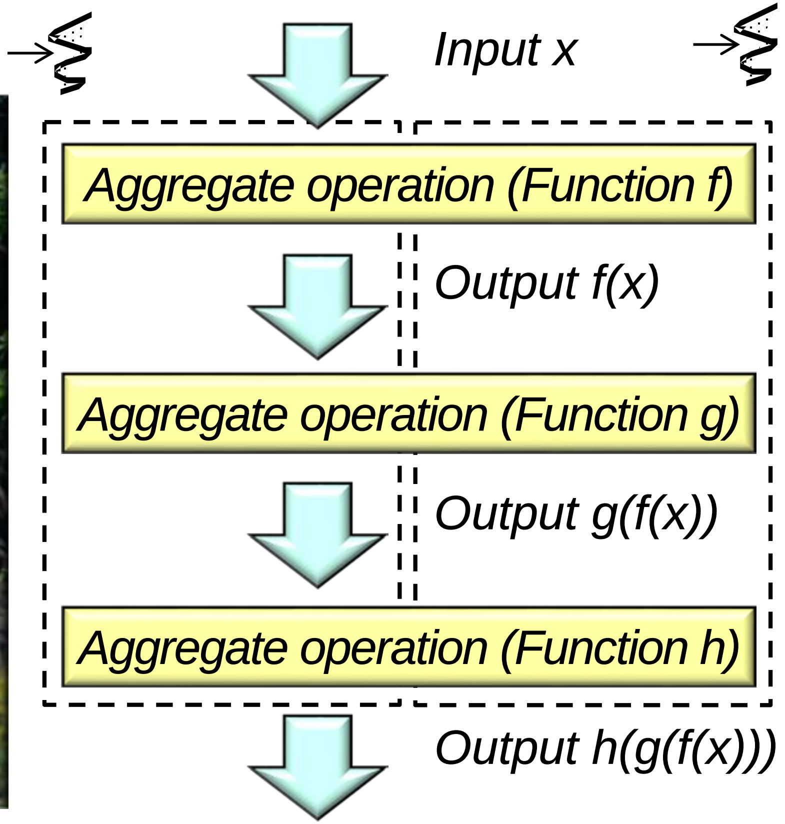
Learning Objectives in this Part of the Lesson

- Recognize how Java 8 applies aggregate operations & functional programming features in the parallel streams framework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Aggregate operation (Function f)
Output f(x)
Aggregate operation (Function g)
Output g(f(x))
Aggregate operation (Function h)
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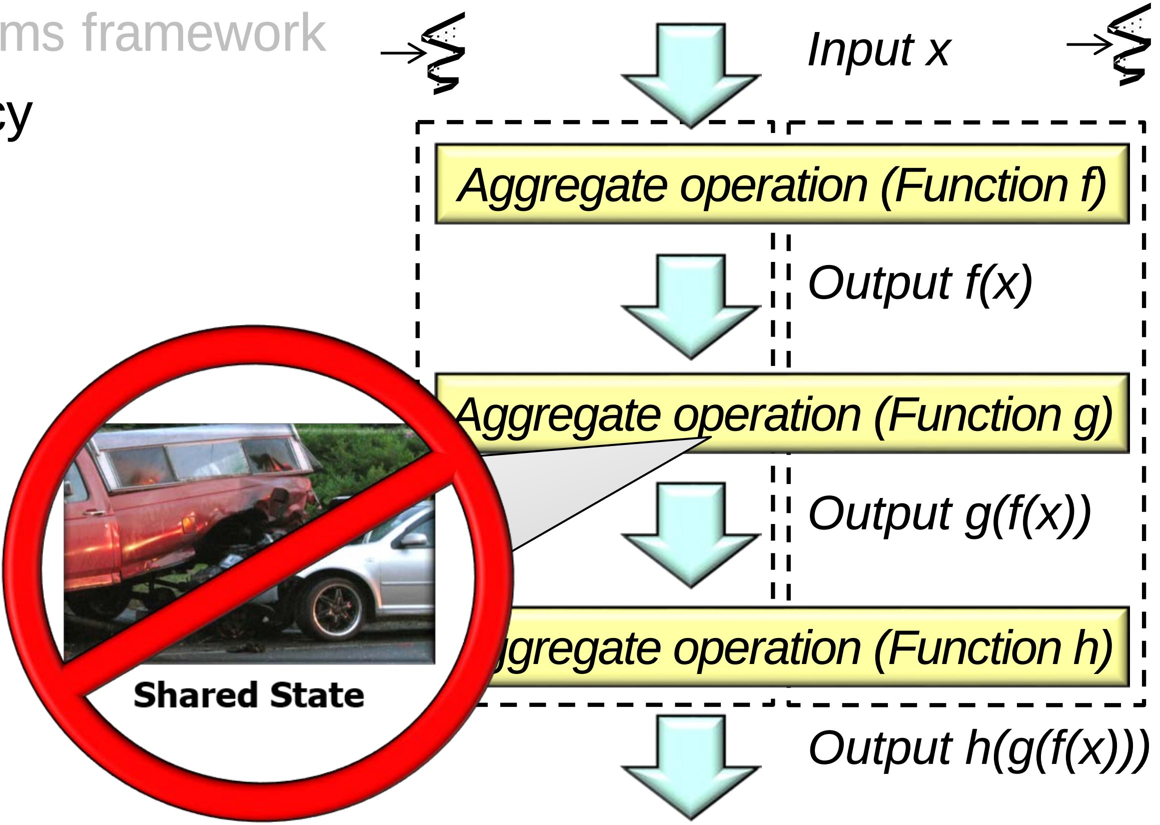
Learning Objectives in this Part of the Lesson

- Recognize how Java 8 applies aggregate operations & functional programming features in the parallel streams framework
- Be able to avoid concurrency hazards in parallel streams



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Shared State

Overview of Java 8 Parallel Streams

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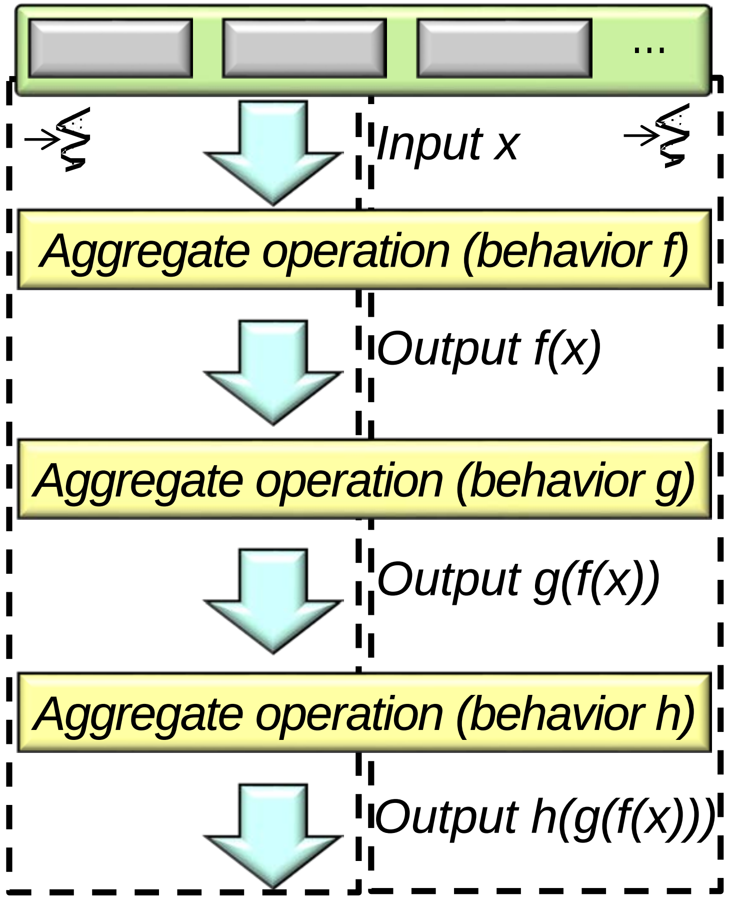
- A Java 8 parallel stream splits its elements into multiple chunks & uses a thread pool to process these chunks independently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See docs.oracle.com/javase/tutorial/collections/streams/parallelism.html

Overview of Java 8 Parallel Streams

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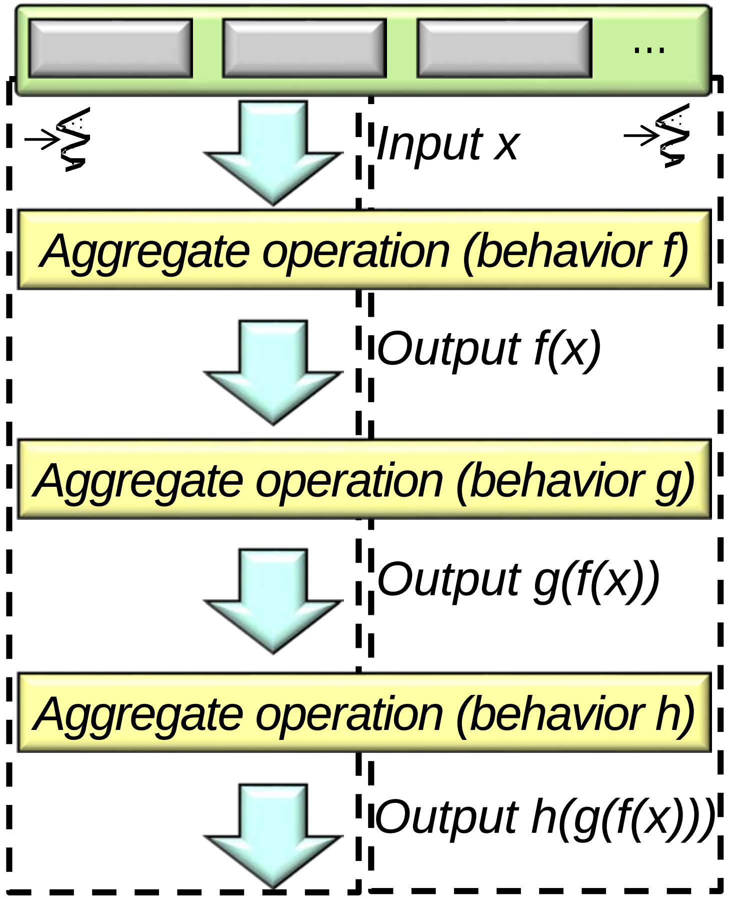
  - This splitting & thread pool are often invisible to programmers



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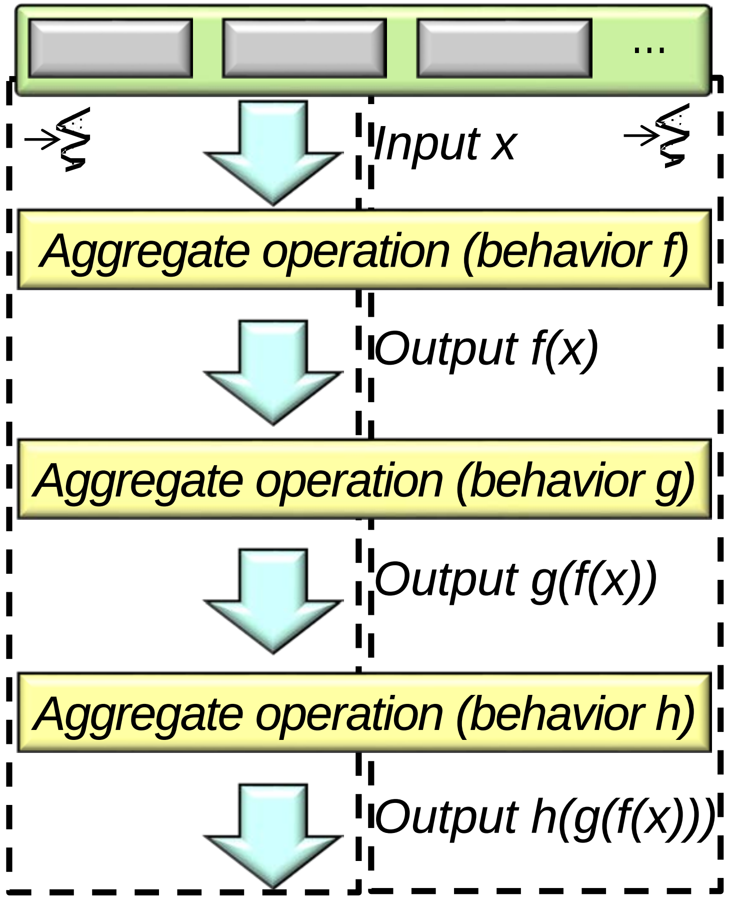

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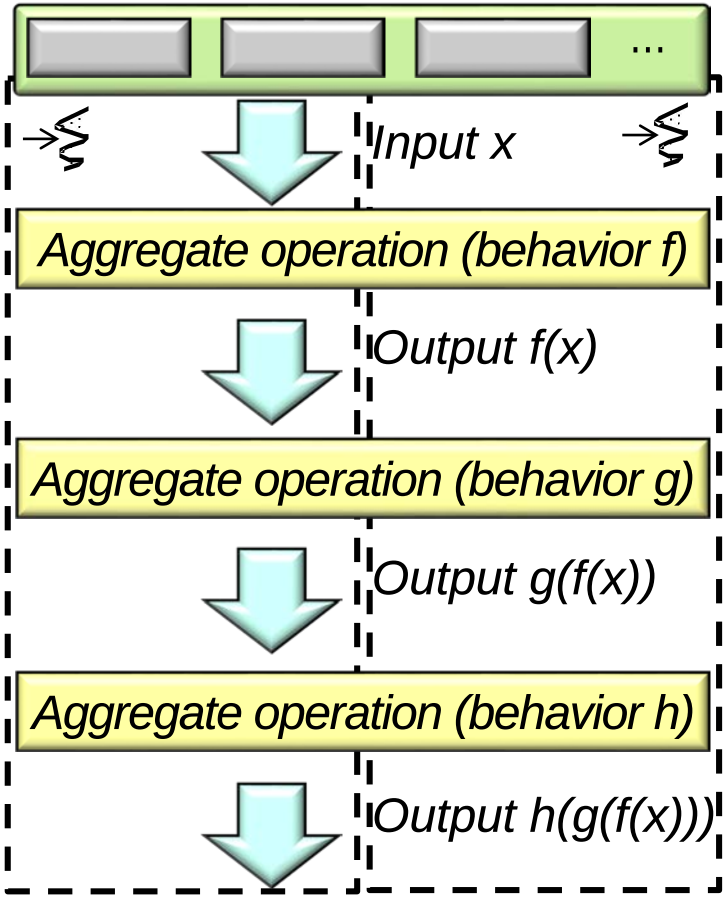
i.e., programmers often have little/no control over how chunks are processed

Overview of Java 8 Parallel Streams

- A Java 8 parallel stream splits its elements into multiple chunks & uses a thread pool to process these chunks independently
  - This splitting & thread pool are often invisible to programmers
  - The *order* in which chunks are processed is likely non-deterministic
  - The *results* of the processing is likely deterministic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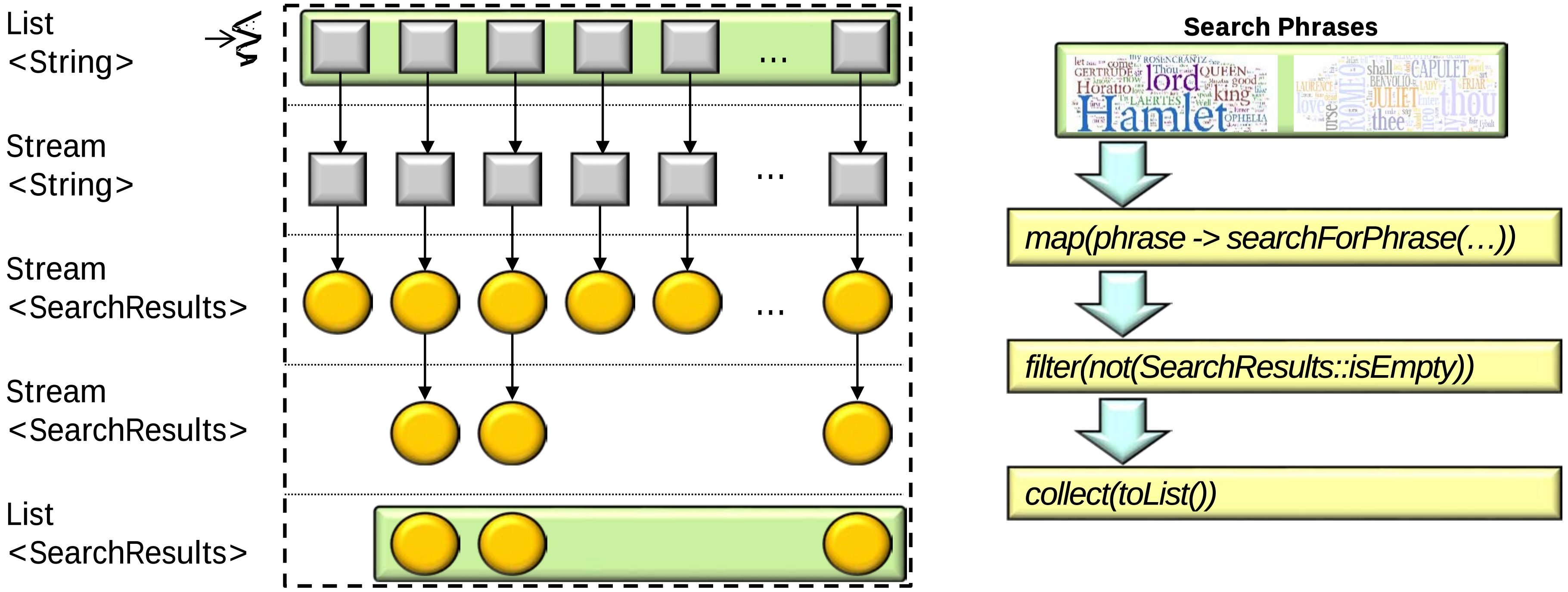
Programmers have more control over how the results are presented

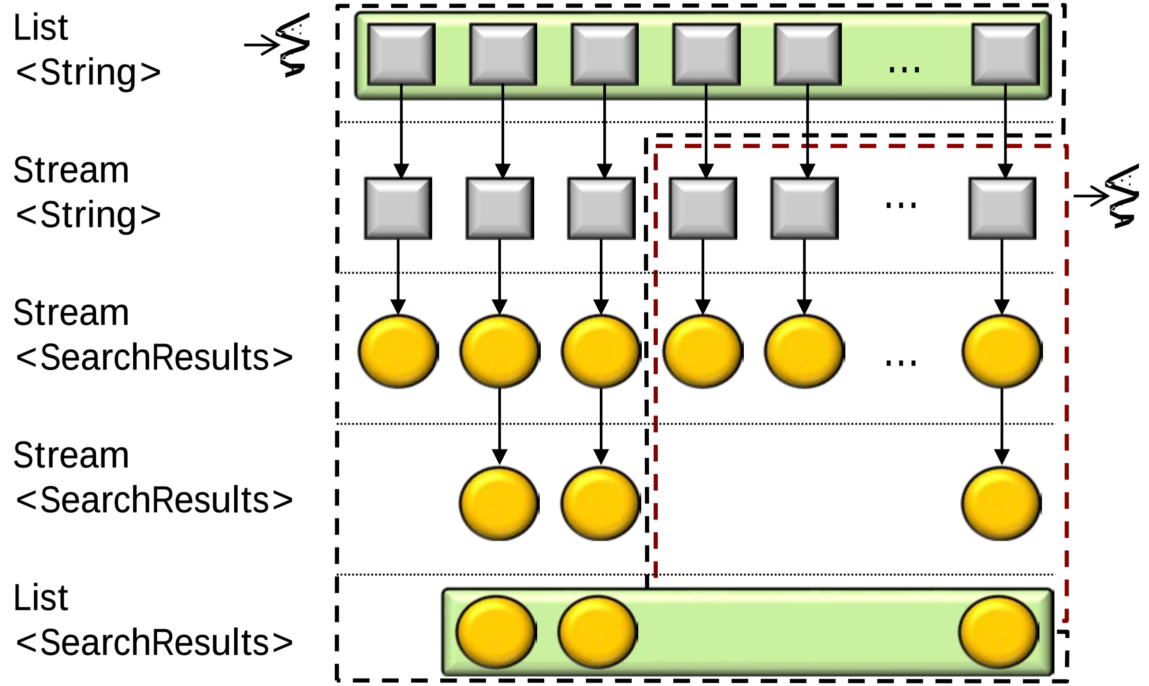
Overview of Java 8 Parallel Streams

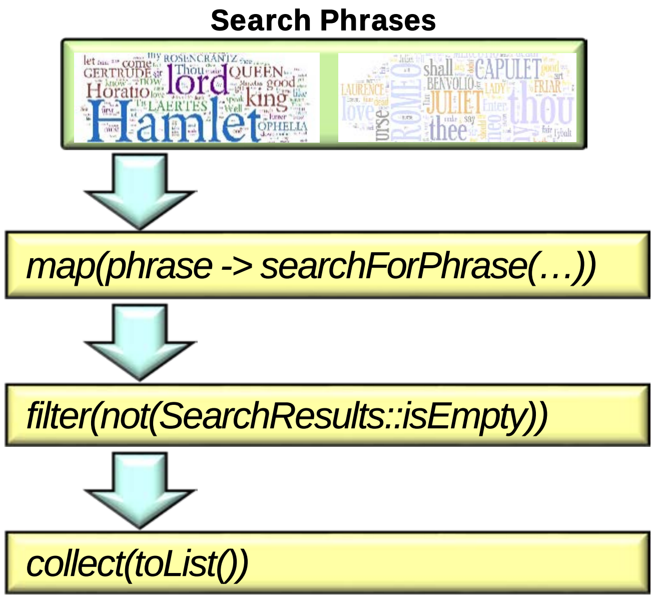
- When a stream executes sequentially all of its aggregate operations run in a single thread



Overview of Java 8 Parallel Streams

- When a stream executes in parallel, the Java runtime partitions it into multiple substream “chunks” that run in a common fork-join pool




Search Phrases
map(phrase -> searchForPhrase(…))
filter(not(SearchResults::isEmpty))
collect(toList())

See docs.oracle.com/javase/8/docs/api/java/util/concurrent/ForkJoinPool.html

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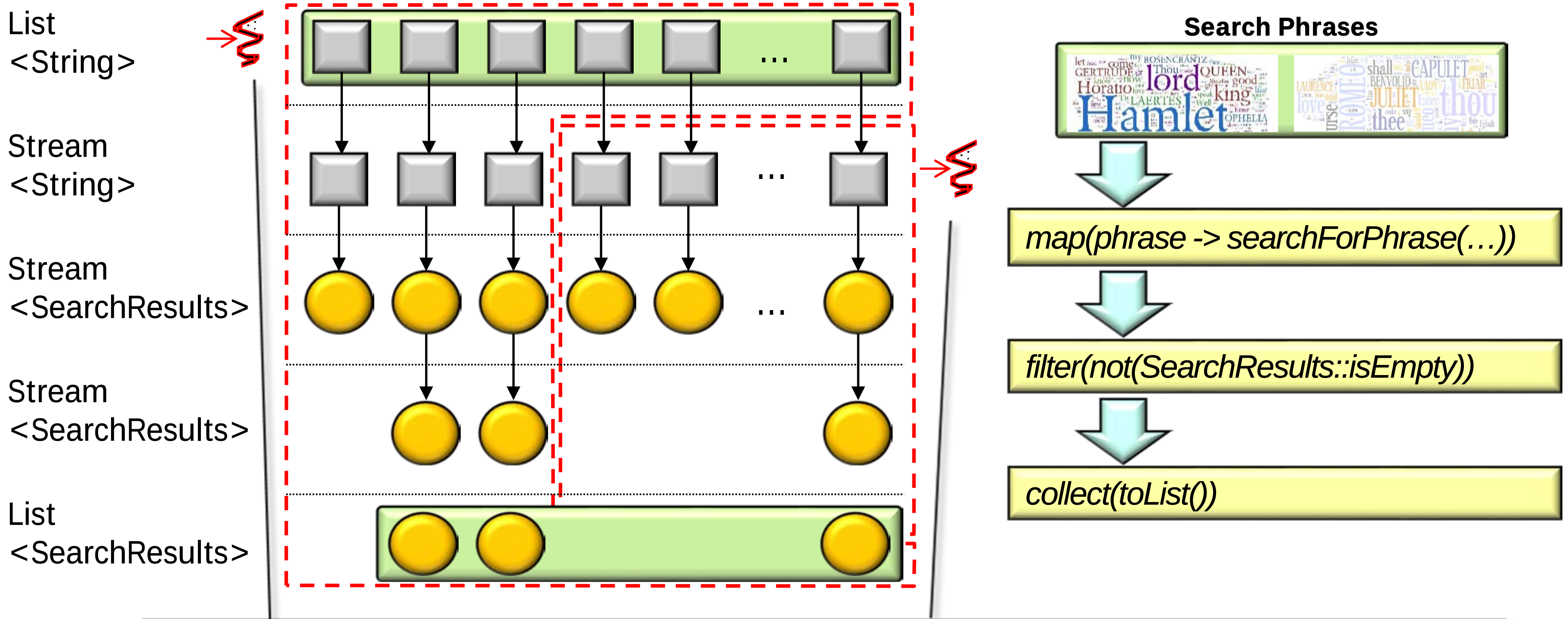

Threads in the pool process different chunks in a non-deterministic order

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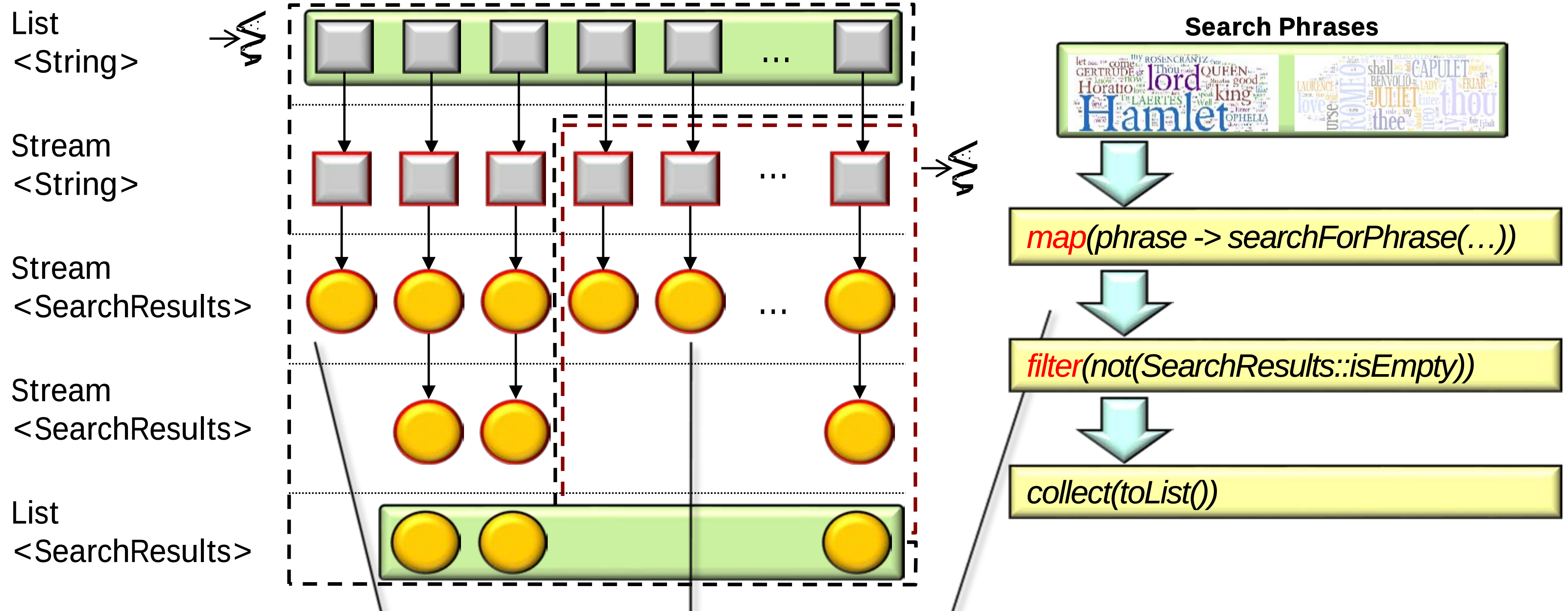

Intermediate operations iterate over & process these chunks in parallel

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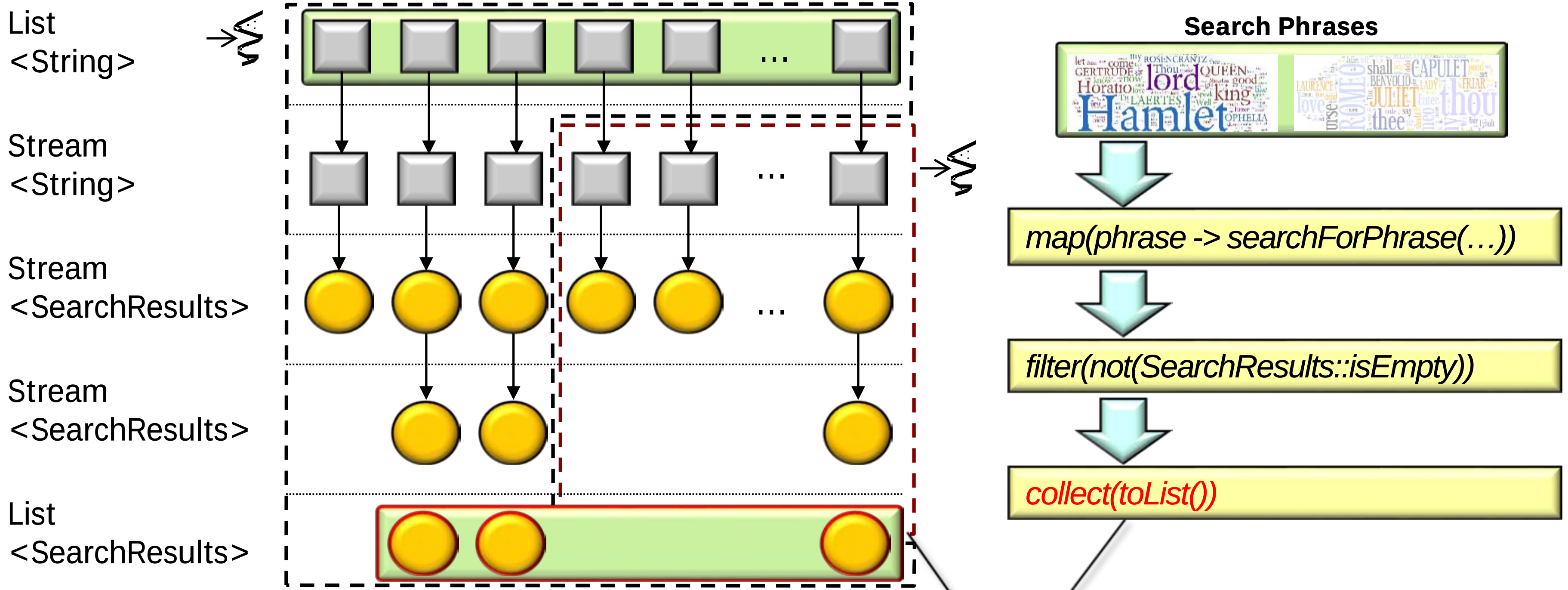

A terminal operation then combines the chunks into a single result

Overview of Java 8 Parallel Streams

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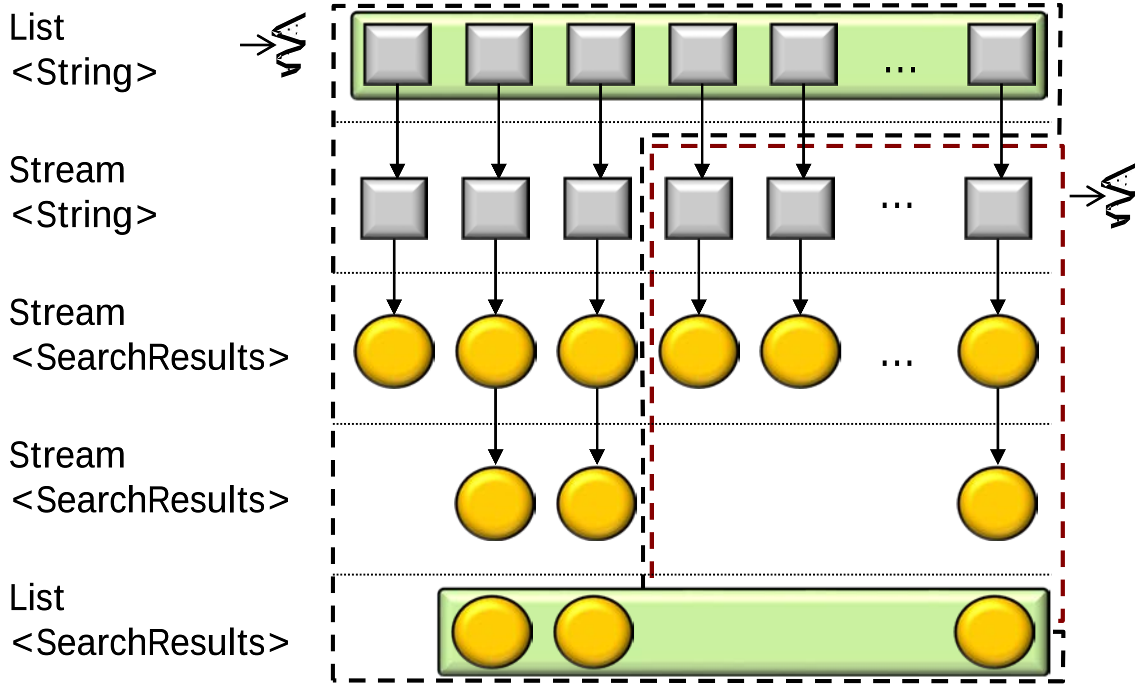

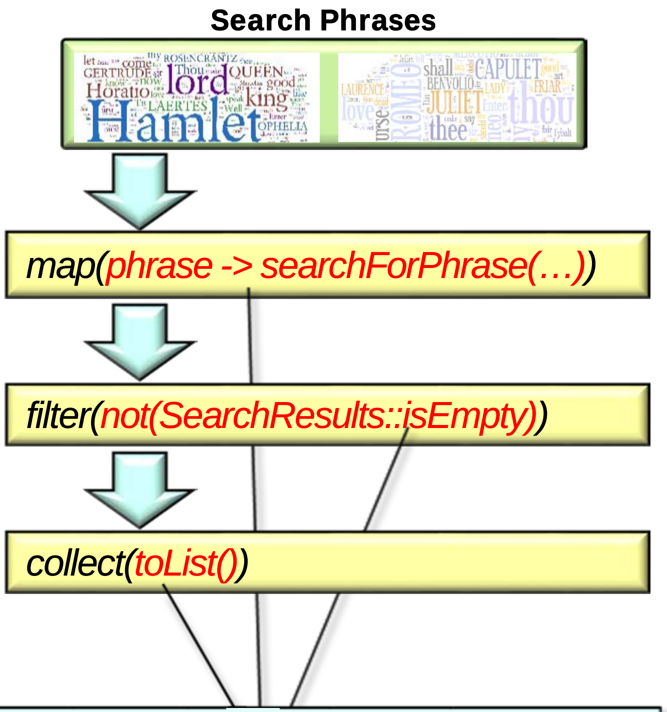
Search Phrases
map(phrase -> searchForPhrase(…))
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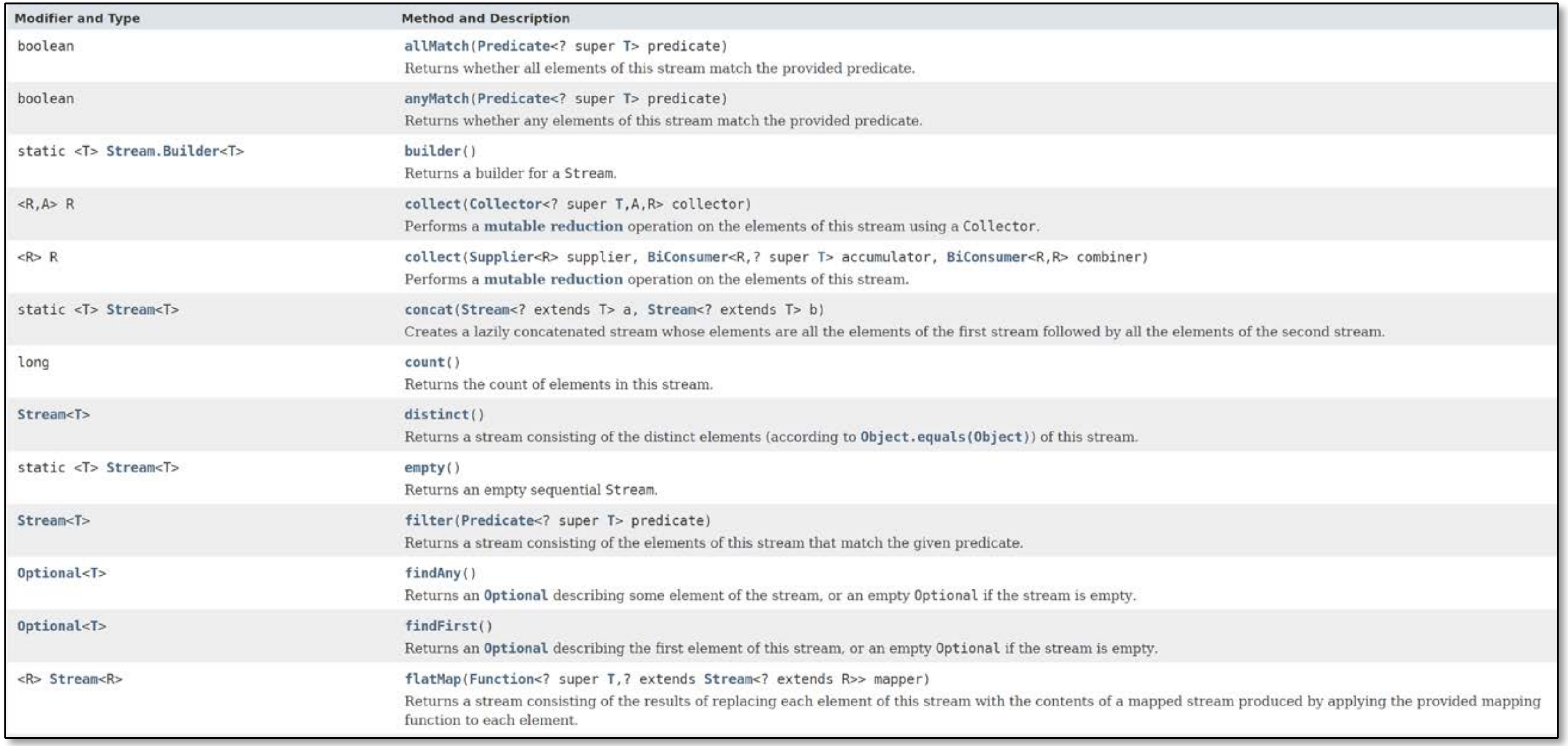
(Stateless) Java 8 lambda expressions & method references are used to pass behaviors

Overview of Java 8 Parallel Streams

- The same aggregate operations can be used for sequential & parallel streams



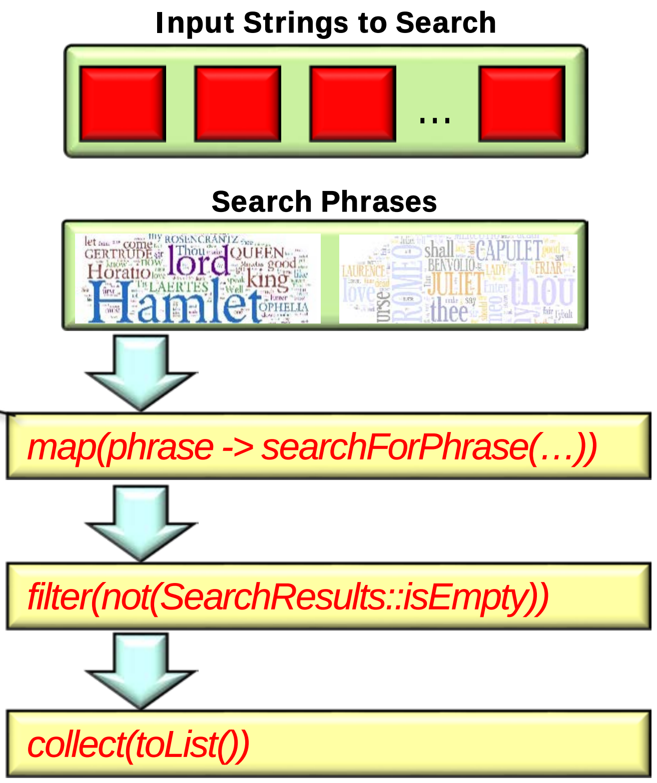
Modifier and Type	Method and Description
`boolean`	`allMatch(Predicate<? super T> predicate)` Returns whether all elements of this stream match the provided predicate.
`boolean`	`anyMatch(Predicate<? super T> predicate)` Returns whether any elements of this stream match the provided predicate.
`static <T> Stream.Builder<T>`	`builder()` Returns a builder for a `Stream`.
`<R,A> R`	`collect(Collector<? super T,A,R> collector)` Performs a **mutable reduction** operation on the elements of this stream using a `Collector`.
`<R> R`	`collect(Supplier<R> supplier, BiConsumer<R,? super T> accumulator, BiConsumer<R,R> combiner)` Performs a **mutable reduction** operation on the elements of this stream.
`static <T> Stream<T>`	`concat(Stream<? extends T> a, Stream<? extends T> b)` Creates a lazily concatenated stream whose elements are all the elements of the first stream followed by all the elements of the second stream.
`long`	`count()` Returns the count of elements in this stream.
`Stream<T>`	`distinct()` Returns a stream consisting of the distinct elements (according to `Object.equals(Object)`) of this stream.
`static <T> Stream<T>`	`empty()` Returns an empty sequential `Stream`.
`Stream<T>`	`filter(Predicate<? super T> predicate)` Returns a stream consisting of the elements of this stream that match the given predicate.
`Optional<T>`	`findAny()` Returns an `Optional` describing some element of the stream, or an empty `Optional` if the stream is empty.
`Optional<T>`	`findFirst()` Returns an `Optional` describing the first element of this stream, or an empty `Optional` if the stream is empty.
`<R> Stream<R>`	`flatMap(Function<? super T,? extends Stream<? extends R>> mapper)` Returns a stream consisting of the results of replacing each element of this stream with the contents of a mapped stream produced by applying the provided mapping function to each element.

See docs.oracle.com/javase/8/docs/api/java/util/stream/Stream.html

Overview of Java 8 Parallel Streams

- The same aggregate operations can be used for sequential & parallel streams

e.g., SearchStreamGang uses the same aggregate operations for both SearchWithSequentialStreams & SearchWithParallelStreams implementations

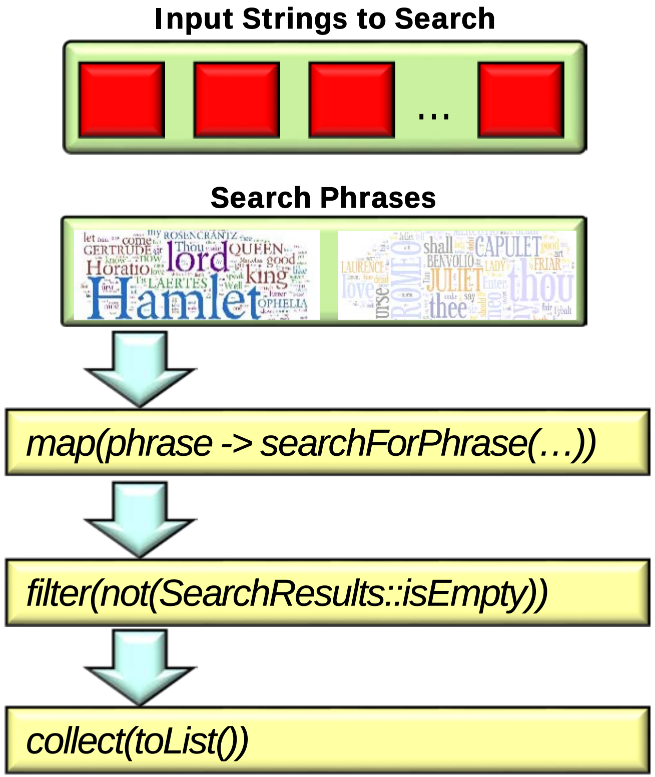


Input Strings to Search
...
Search Phrases
map(phrase -> searchForPhrase(…))
filter(not(SearchResults::isEmpty))
collect(toList())

See github.com/douglascraigschmidt/LiveLessons/tree/master/SearchStreamGang

Overview of Java 8 Parallel Streams

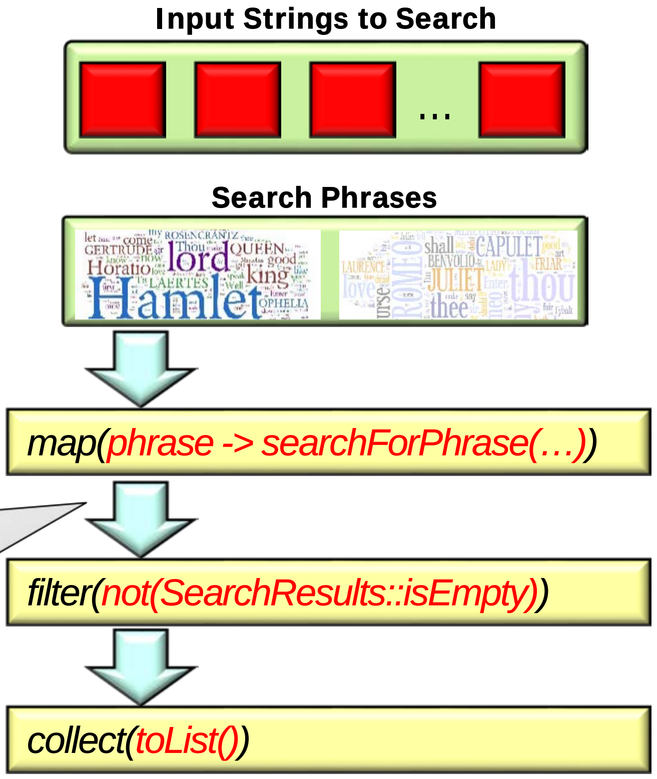
- The same aggregate operations can be used for sequential & parallel streams
  - Java 8 streams can thus treat parallelism as an optimization & leverage all available cores!



See qconlondon.com/london-2017/system/files/presentation-slides/concurrenttoparallel.pdf

Overview of Java 8 Parallel Streams

- The same aggregate operations can be used for sequential & parallel streams
  - Java 8 streams can thus treat parallelism as an optimization & leverage all available cores!
  - Naturally, behaviors run by these aggregate operations must be designed carefully to avoid accessing unsynchronized shared state..



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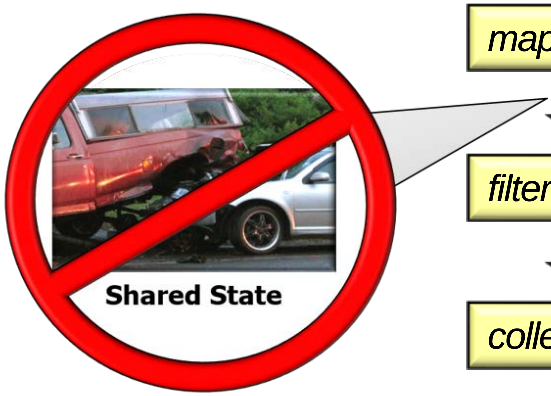
```



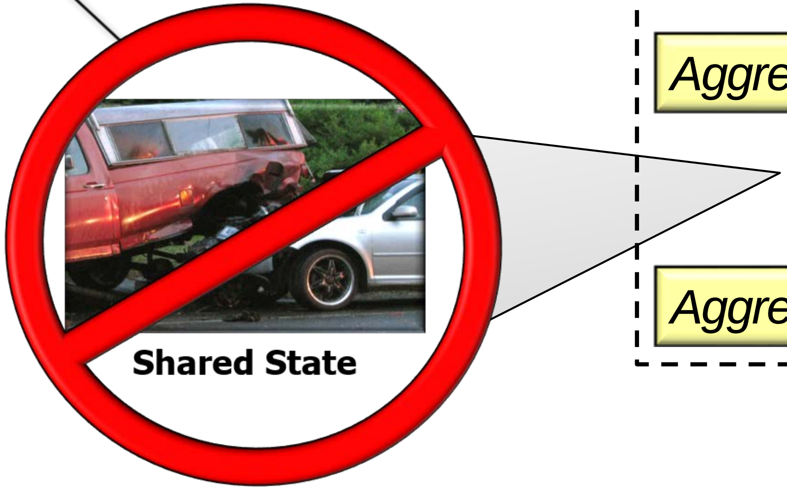
See henrikeichenhardt.blogspot.com/2013/06/why-shared-mutable-state-is-root-of-all.html

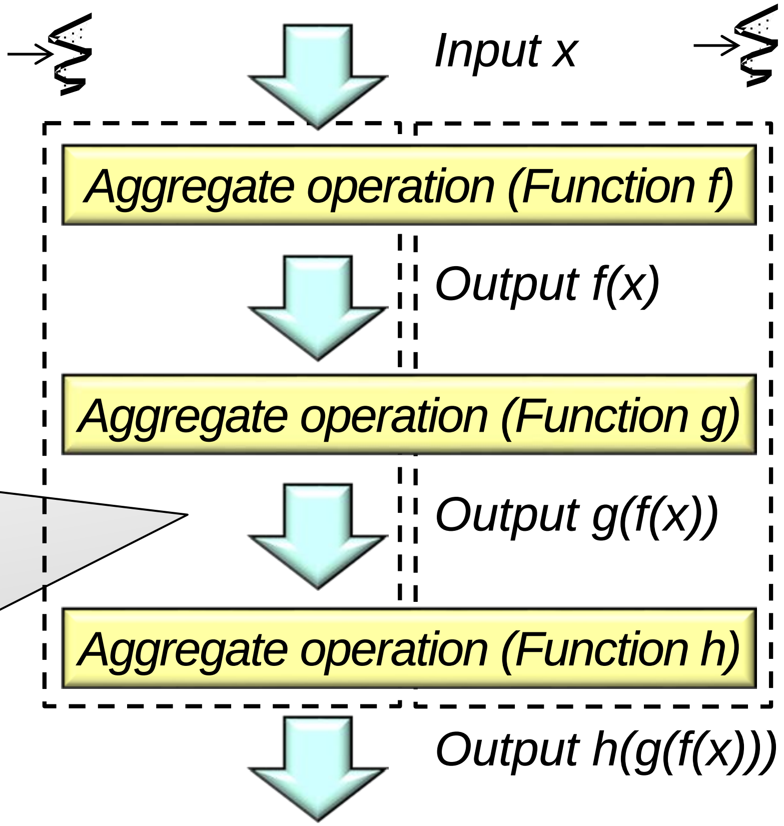
Avoiding Concurrency Hazards in Java 8 Parallel Streams

Avoiding Concurrency Hazards in Java 8 Parallel Streams

- Java 8 parallel streams assume behaviors incur no race conditions

Race conditions arise when an app depends on the sequence or timing of threads for it to operate properly

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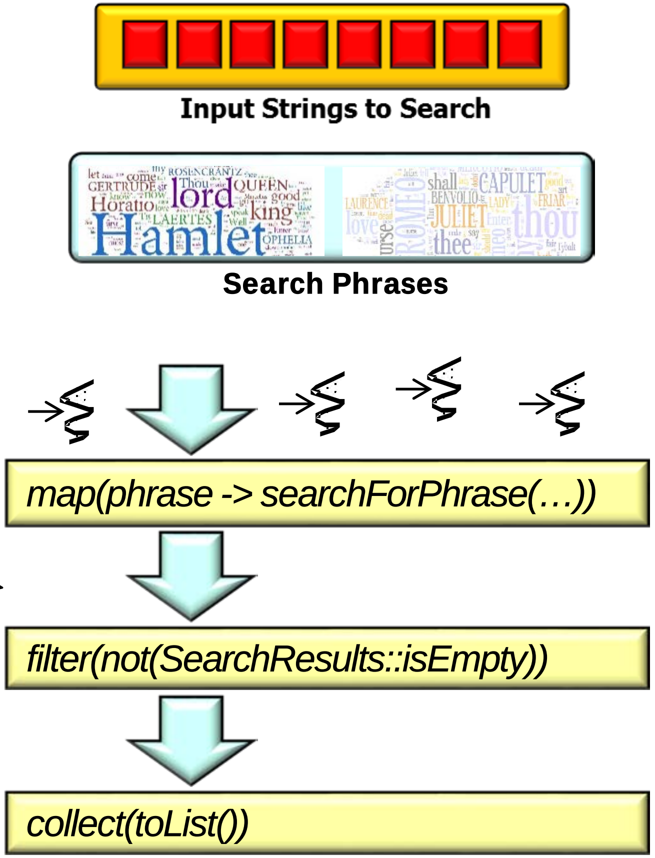
See en.wikipedia.org/wiki/Race_condition#Software

Avoiding Concurrency Hazards in Java 8 Parallel Streams

- Parallel streams should therefore avoid operations with side-effects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See docs.oracle.com/javase/tutorial/collections/streams/parallelism.html#side_effects

Avoiding Concurrency Hazards in Java 8 Parallel Streams

- Parallel streams should therefore avoid operations with side-effects, e.g.
  - *Stateful lambda expressions*
    - Where results depends on state that may change in concurrent execution of a pipeline

```
class BuggyFactorial {
  static class Total {
    long mTotal = 1;
    void multiply(long n)
    { mTotal *= n; }
  }

  static long factorial(long n){
    Total t = new Total();
    LongStream
      .rangeClosed(1, n)
      .parallel()
      .forEach(t::multiply);

    return t.mTotal;
  } ...
```

See docs.oracle.com/javase/8/docs/api/java/util/stream/package-summary.html#Statelessness

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```

Race conditions can arise due to the unsynchronized access to mTotal field

See github.com/douglascraigschmidt/LiveLessons/tree/master/Java8/ex16

Avoiding Concurrency Hazards in Java 8 Parallel Streams

- Parallel streams should therefore avoid operations with side-effects, e.g.
  - *Stateful lambda expressions*
  - *Interference w/the data source*
    - Occurs when the source of a stream is modified while a pipeline processes the stream

```
List<Integer> list = IntStream
  .range(0, 10)
  .boxed()
  .collect(toList());

list
  .parallelStream()
  .peek(list::remove)
  .forEach(System.out::println);
```

See docs.oracle.com/javase/8/docs/api/java/util/stream/package-summary.html#NonInterference

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Aggregate operations enable parallelism with non-thread-safe collections provided the collection is not modified while it's being operated on..

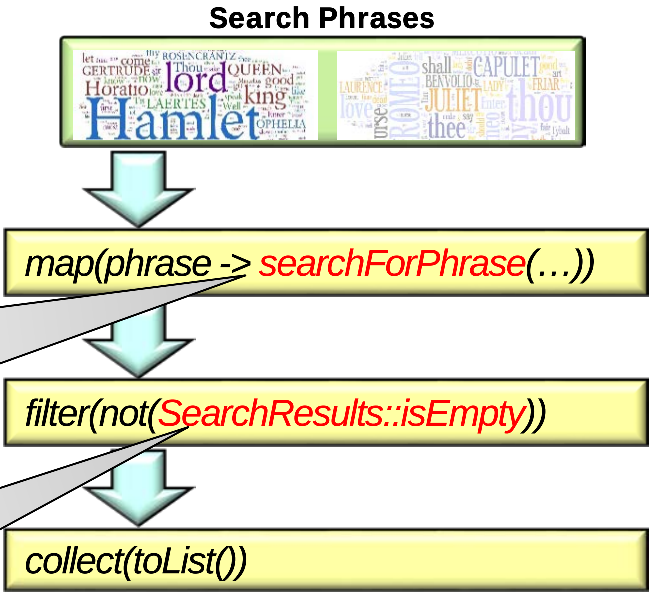
See github.com/douglascraigschmidt/LiveLessons/tree/master/Java8/ex11

Avoiding Concurrency Hazards in Java 8 Parallel Streams

- Java 8 lambda expressions & method references containing no shared state are useful for parallel streams since they needn't be explicitly synchronized

```
return new SearchResults
  (Thread.currentThread().getId(),
   currentCycle(), phrase, title,
   StreamSupport
     .stream(new PhraseMatchSpliterator
                  (input, phrase),
                parallel)
     .collect(toList()));
```

```
return mList.size() == 0;
```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End of Overview of Java 8 Parallel Streams (Part 1)