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GS Collections and Java 8
Functional, Fluent, Friendly & Fun!

GS.com/Engineering
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we
BUILD

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Agenda

- Introductions
- Lost and Found
- Streams
- The Iceberg
  - APIs
  - Fluency
  - Memory Efficiency
  - Method references are awesome
- Framework Comparisons

What is GS Collections?

- Open source Java collections framework developed in Goldman Sachs
  - In development since 2004
  - Hosted on GitHub w/ Apache 2.0 License
    - github.com/goldmansachs/gs-collections
- GS Collections Kata
  - Internal training developed in 2007
  - Taught to > 1,500 GS Java developers
  - Hosted on GitHub w/ Apache 2.0 License
    - github.com/goldmansachs/gs-collections-kata

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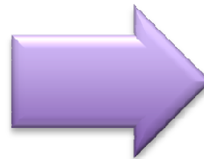
Paradise Lost

1997 - Smalltalk Best Practice Patterns (Kent Beck)

- do:
- select:
- reject:
- collect:
- detect:
- detect:ifNone:
- inject:into:
- …
  (Dr. Seuss API)



2007 - Implementation Patterns (Kent Beck)

- Map
- List
- Set

- The collection iteration patterns disappeared
- All that remained were the types

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Paradise Found

Pattern in Smalltalk-80 | Pattern in Classic Java | Pattern in GS Collections w/ Lambdas

detect

```
list detect: [:each | each > 50].
```

```
for (Integer each : list)
  if (each > 50)
    return each;
return null;
```

```
list.detect(each -> each > 50);
```

select

```
list select: [:each | each > 50].
```

```
List<Integer> result = new ArrayList<>();
for (Integer each : list)
  if (each > 50)
    result.add(each);
```

```
list.select(each -> each > 50);
```

reject

```
list reject: [:each | each > 50].
```

```
List<Integer> result = new ArrayList<>();
for (Integer each : list)
  if (each <= 50)
    result.add(v);
```

```
list.reject(each -> each > 50);
```

any satisfy

```
list anySatisfy: [:each | each > 50].
```

```
for (Integer each : list)
  if (each > 50)
    return true;
return false;
```

```
list.anySatisfy(each -> each > 50);
```

all satisfy

```
list allSatisfy: [:each | each > 50].
```

```
for (Integer each : list)
  if (each <= 50)
    return false;
return true;
```

```
list.allSatisfy(each -> each > 50);
```

collect

```
list collect: [:e | e printString].
```

```
List<String> result = new ArrayList<>();
for (Integer each : list)
  result.add(each.toString());
```

```
list.collect(Object::toString);
```

inject into

```
list inject: 3 into: [:x :y | x + y].
```

```
int result = 3;
for (Integer each : list)
  result = result + each;
```

```
list.injectInto(3, Integer::sum);
```

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Lazy by any other name

	GS Collections LazyIterable		Java 8 Streams
detect	`Integer result = list.asLazy() .detectIfNone(e -> e > 50, () -> null);`	findAny	`Integer result = list.stream() .filter(e -> e > 50).findFirst().orElse(null);`
select	`LazyIterable<Integer> result = list.asLazy().select(e -> e > 50);`	filter	`Stream<Integer> result = list.stream().filter(e -> e > 50);`
reject	`LazyIterable<Integer> result = list.asLazy().reject(e -> e > 50);`	filter	`Stream<Integer> result = list.stream().filter(e -> e <= 50);`
any satisfy	`boolean any = list.asLazy().anySatisfy(e -> e > 50);`	any Match	`boolean any = list.stream().anyMatch(e -> e > 50);`
all satisfy	`boolean all = list.asLazy().allSatisfy(e -> e > 50);`	all Match	`boolean all = list.stream().allMatch(e -> e > 50);`
collect	`LazyIterable<String> result = list.asLazy().collect(Object::toString);`	map	`Stream<String> result = list.stream().map(Object::toString);`
inject into	`Integer result = list.asLazy().injectInto(3, Integer::sum);`	reduce	`Integer result = list.stream().reduce(3, Integer::sum);`

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Eager vs. Lazy

	Eager GS Collections		Java 8 Streams
detect	`Integer result = list.detect(e -> e > 50);`	findAny	`Integer result = list.stream().filter(e -> e > 50).findFirst().orElse(null);`
select	`MutableList<Integer> result = list.select(e -> e > 50);`	filter	`List<Integer> result = list.stream().filter(e -> e > 50).collect(Collectors.toList());`
reject	`MutableList<Integer> result = list.reject(e -> e > 50);`	filter	`List<Integer> result = list.stream().filter(e -> e <= 50).collect(Collectors.toList());`
any satisfy	`boolean any = list.anySatisfy(e -> e > 50);`	any Match	`boolean result = list.stream().anyMatch(e -> e > 50);`
all satisfy	`boolean all = list.allSatisfy(e -> e > 50);`	all Match	`boolean result = list.stream().allMatch(e -> e > 50);`
collect	`MutableList<String> result = list.collect(Object::toString);`	map	`List<String> result = list.stream().map(Object::toString).collect(Collectors.toList());`
inject into	`Integer result = list.injectInto(3, Integer::sum);`	reduce	`Integer result = list.stream().reduce(3, Integer::sum);`

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Java 8 Streams

- Great framework that provides feature rich functional API
- Lazy by default
- Supports serial and parallel iteration patterns
- Support for three types of primitive streams
- Extendable through Collector implementations

- Java 8 Streams is the tip of an enormous iceberg

Iceberg dead ahead!

- Eager iteration patterns on Collections
- Covariant return types on collection protocols
- New Collection Types
  - Bag, SortedBag, BiMap, Multimap
- Memory Efficient Set and Map
- Primitive containers
- Immutable containers

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Ice is Twice as Nice

	Java 8	GS Collections
Stream vs. LazyIterable Interfaces	5	9
Functional Interfaces	46	298
Object Container Interfaces	11	75
Primitive Container Interfaces	0	309
Stream vs. RichIterable API	47	109
Primitive Stream vs. Iterable API	48 x 3 = 144	38 x 8 = 304
LOC (Streams vs. GSC w/o code gen)	~15k	~400k

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More Iteration Patterns

- flatCollect
- partition
- makeString / appendString
- groupBy
- aggregateBy
- sumOf
- sumBy

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Futility of Utility

- Utility
  - Easy to extend with new behaviors without breaking existing clients
- API
  - Easy to discover new features
  - Easy to optimize
  - Easy to read from left to right
  - Return types are specific and easy to understand
  - Verb vs. gerund

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Joining vs. MakeString

```java
String joined = things.stream()
   .map(Object::toString)
   .collect(Collectors.joining(", "));
```

```java
String joined =
   things.makeString(", ");
```

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SummingInt vs. SumOfInt

```
int total = employees.stream().collect(
  Collectors.summingInt(Employee::getSalary));
```

```
long total =
  employees.sumOfInt(Employee::getSalary);
```

GroupingBy vs. GroupBy

```
Map<Department, List<Employee>> byDept =
  employees.stream()
  .collect(Collectors.groupingBy(
    Employee::getDepartment));
```

```
Multimap<Department, Employee> byDept =
  employees.groupBy(Employee::getDepartment);
```

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GroupingBy/SummingBy vs. SumBy

```
Map<Department, Integer> totalByDept =
  employees.stream()
  .collect(Collectors.groupingBy(
    Employee::getDepartment,
    Collectors.summingInt(Employee::getSalary)));
```

```
ObjectLongMap<Department> totalByDept =
  employees.sumByInt(
    Employee::getDepartment,
    Employee::getSalary);
```

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PartitioningBy vs. Partition

```java
Map<Boolean, List<Student>> passingFailing
  students.stream()
  .collect(Collectors.partitioningBy(
    s -> s.getGrade() >= PASS_THRESHOLD));
```

```java
PartitionList<Student> passingFailing =
  students.partition(
    s -> s.getGrade() >= PASS_THRESHOLD);
```

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How do they stack up?

```
getGrade():1290, FastListTest$Student (com.gs.collections.impl.list.mutable)
lambda$partitionLists$5():1255, FastListTest (com.gs.collections.impl.list.mutable)
test():-1, 1632492873 (com.gs.collections.impl.list.mutable.FastListTest$$Lambda$1
lambda$partitioningBy$146():1139, Collectors (java.util.stream)
accept():-1, 963601816 (java.util.stream.Collectors$$Lambda$6)
accept():169, ReduceOps$3ReducingSink (java.util.stream)
forEachRemaining():116, Iterator (java.util)
forEachRemaining():1801, Spliterators$IteratorSpliterator (java.util)
copyInto():512, AbstractPipeline (java.util.stream)
wrapAndCopyInto():502, AbstractPipeline (java.util.stream)
evaluateSequential():708, ReduceOps$ReduceOp (java.util.stream)
evaluate():234, AbstractPipeline (java.util.stream)
collect():499, ReferencePipeline (java.util.stream)
partitionLists():1254, FastListTest (com.gs.collections.impl.list.mutable)
```

```
getGrade():1290, FastListTest$Student (com.gs.collections.impl.list.mutable)
lambda$partitionLists$dcd4a7c$1():1259, FastListTest (com.gs.collections.impl.list.
accept():-1, 238157928 (com.gs.collections.impl.list.mutable.FastListTest$$Lambda
partition():946, RandomAccessListIterate (com.gs.collections.impl.utility.internal)
partition():1011, ListIterate (com.gs.collections.impl.utility)
partition():262, AbstractMutableList (com.gs.collections.impl.list.mutable)
partitionLists():1258, FastListTest (com.gs.collections.impl.list.mutable)
```

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  - **Fluency**
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  - Method references are awesome
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Anagram tutorial

http://docs.oracle.com/javase/tutorial/collections/algorithms/

- Start with all words in the dictionary
- Group them by their alphagrams
  - Alphagram contains sorted characters
  - alerts → aelrst
  - stelar → aelrst
- Filter groups containing at least eight anagrams
- Sort groups by number of anagrams (descending)
- Print them in this format

```
11: [alerts, alters, artels, estral, laster, ratels,
salter, slater, staler, stelar, talers]
```

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Anagram tutorial

```java
this.getWords()
    .stream()
    .collect(Collectors.groupingBy(Alphagram::new))
    .values()
    .stream()
    .filter(each -> each.size() >= SIZE_THRESHOLD)
    .sorted(Comparator.<List<?>>comparingInt(List::size).reversed())
    .map(each -> each.size() + ": " + each)
    .forEach(System.out::println);
```

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Anagram tutorial

```
this.getWords()
  .groupBy(Alphagram::new)
  .multiValuesView()
  .select(each -> each.size() >= SIZE_THRESHOLD)
  .toSortedListBy(RichIterable::size)
  .asReversed()
  .collect(each -> each.size() + ": " + each)
  .each(System.out::println);
```

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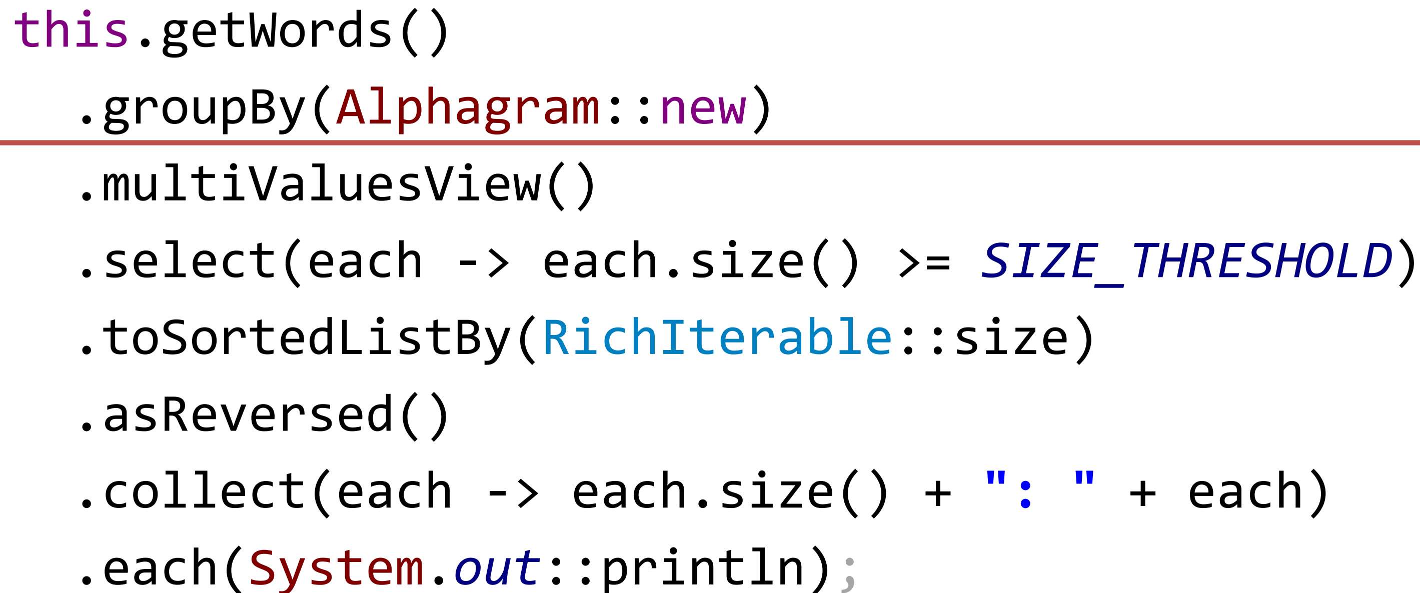
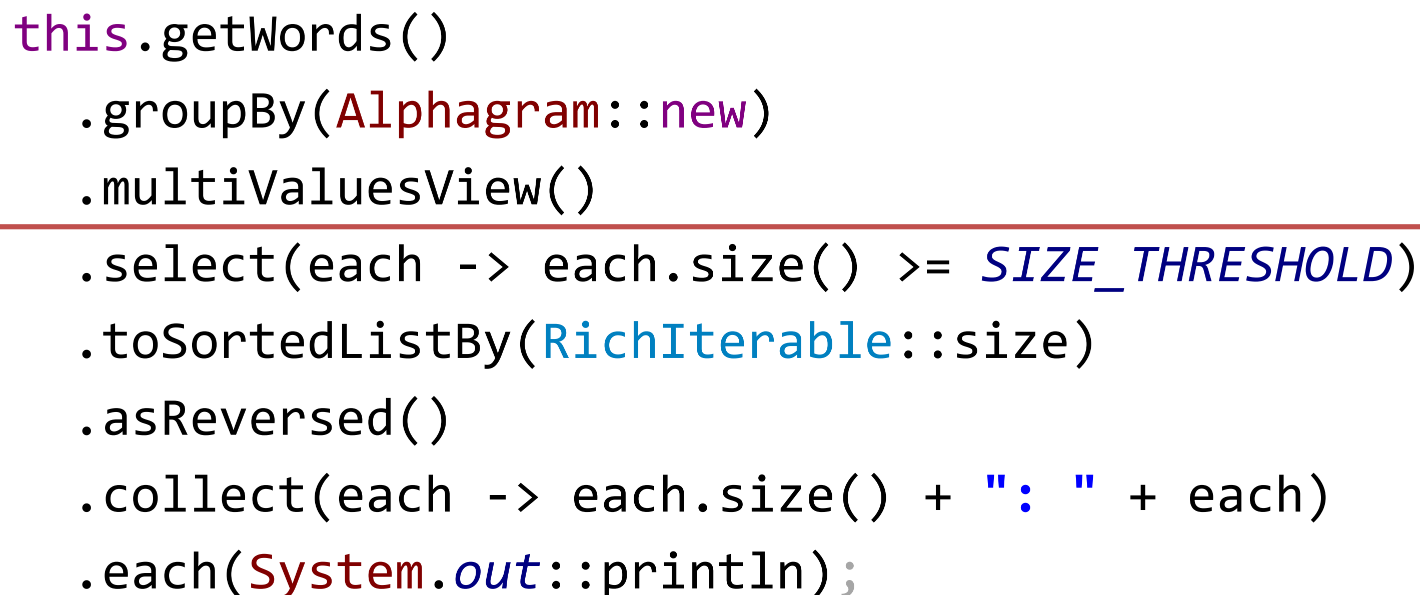
Anagram tutorial



Type: MutableListMultimap<Alphagram, String>

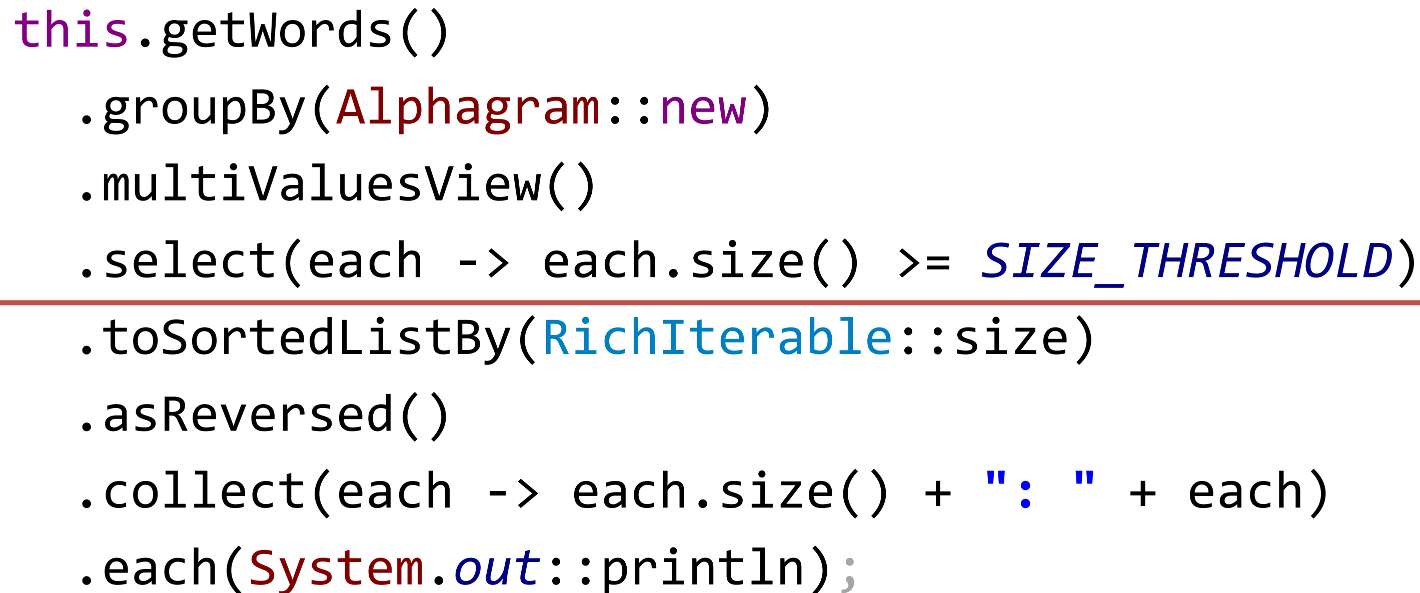
Anagram tutorial



```
this.getWords()
    .groupBy(Alphagram::new)
    .multiValuesView()
    .select(each -> each.size() >= SIZE_THRESHOLD)
    .toSortedListBy(RichIterable::size)
    .asReversed()
    .collect(each -> each.size() + ": " + each)
    .each(System.out::println);
```

Type: `RichIterable<RichIterable<String>>`

Anagram tutorial



Type: RichIterable<RichIterable<String>>

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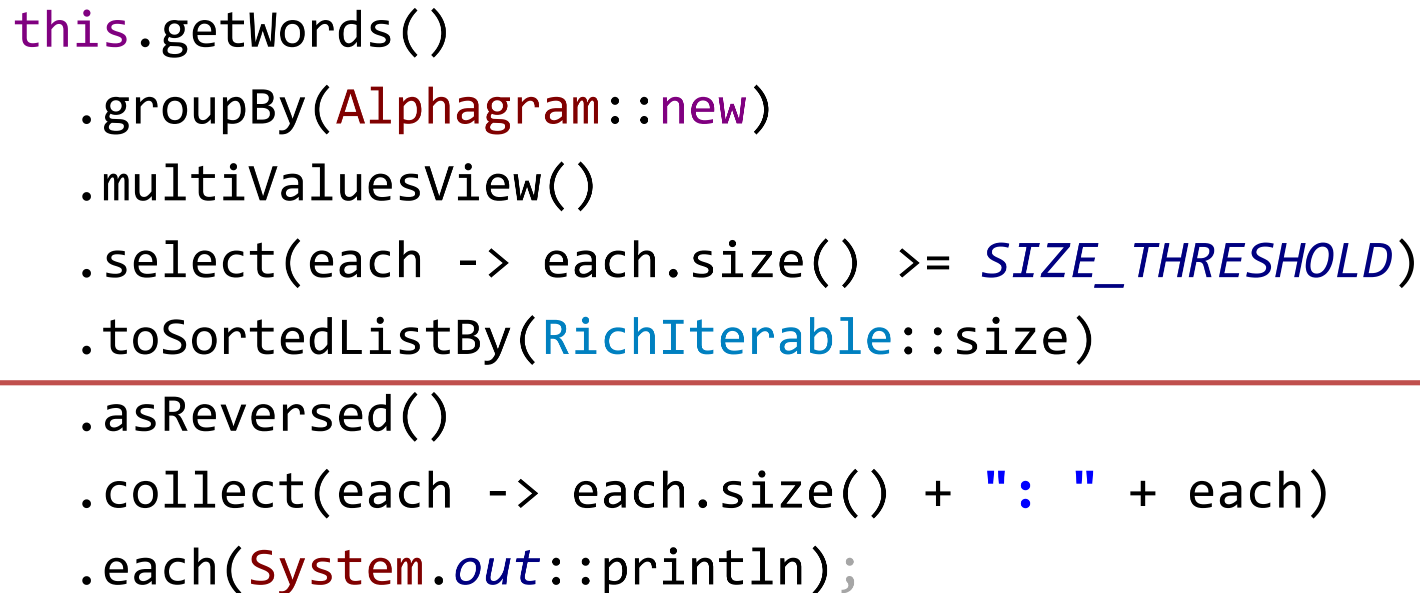
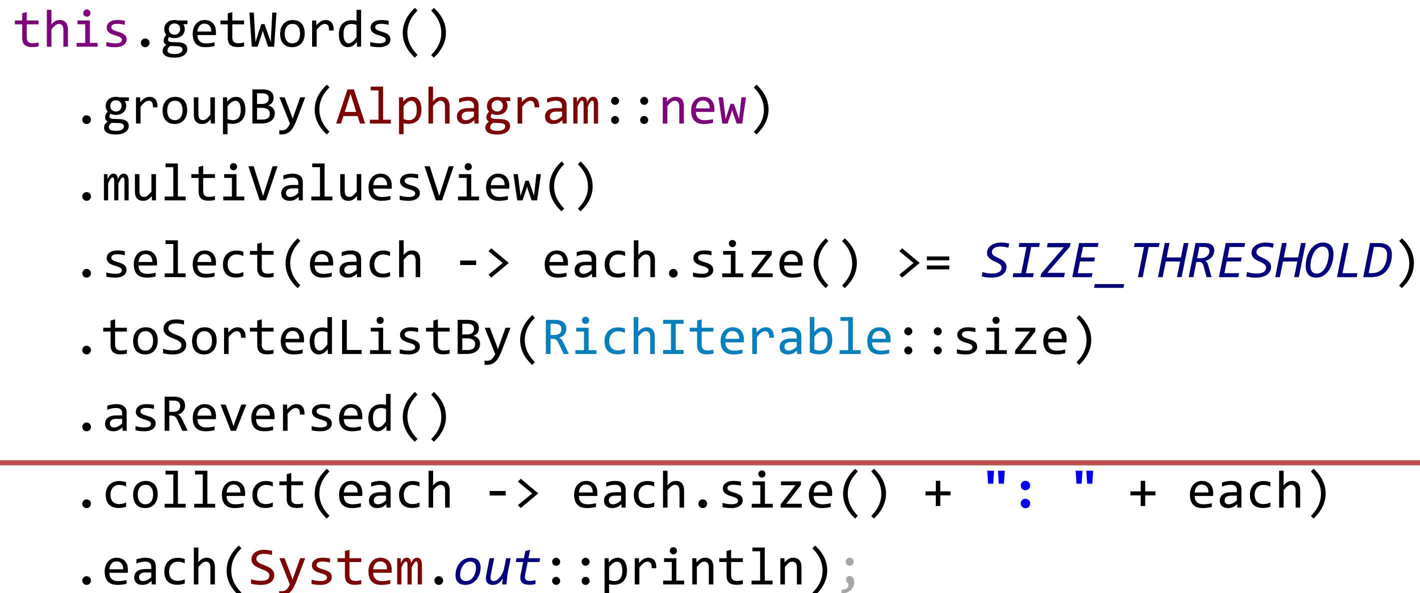
Anagram tutorial



```
this.getWords()
    .groupBy(Alphagram::new)
    .multiValuesView()
    .select(each -> each.size() >= SIZE_THRESHOLD)
    .toSortedListBy(RichIterable::size)
    .asReversed()
    .collect(each -> each.size() + ": " + each)
    .each(System.out::println);
```

Type: `MutableList<RichIterable<String>>`

Anagram tutorial



```
this.getWords()
    .groupBy(Alphagram::new)
    .multiValuesView()
    .select(each -> each.size() >= SIZE_THRESHOLD)
    .toSortedListBy(RichIterable::size)
    .asReversed()
    .collect(each -> each.size() + ": " + each)
    .each(System.out::println);
```

Type: `LazyIterable<RichIterable<String>>`

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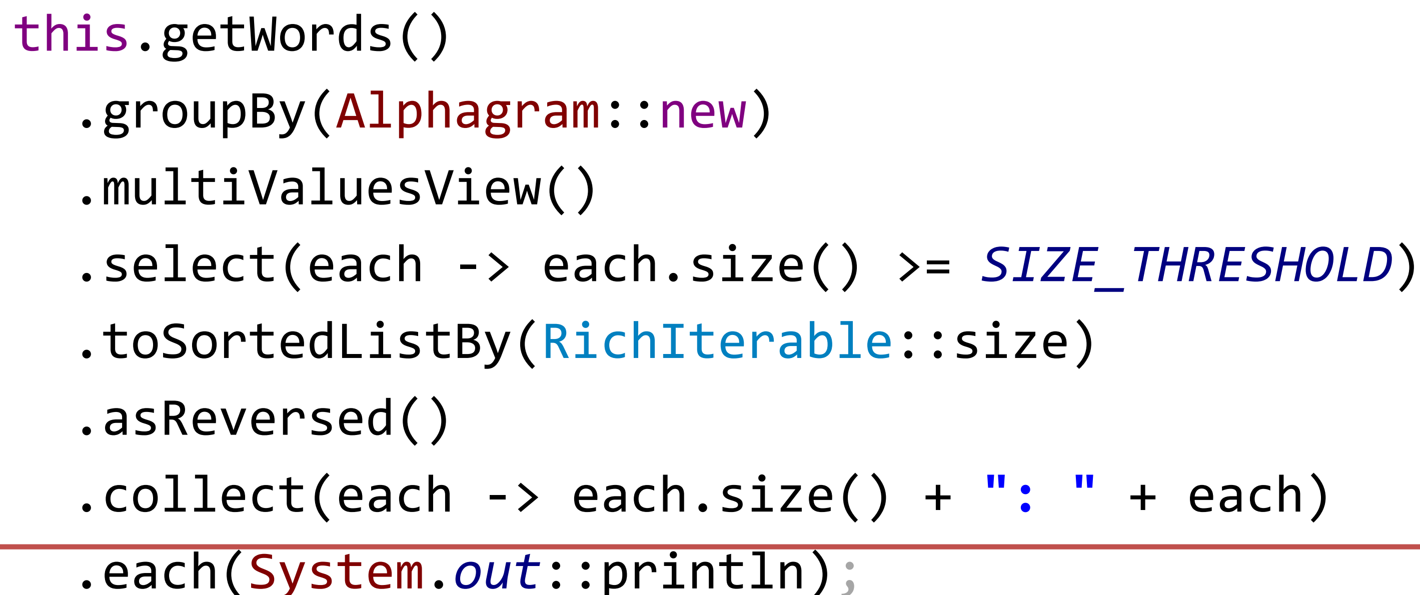
Anagram tutorial



Type: LazyIterable<String>

Parallel Lazy Iteration

```
Stream<Address> addresses =
  people.parallelStream()
    .map(Person::getAddress);
```

```
ParallelListIterable<Address> addresses =
  people.asParallel(executor, batchSize)
    .collect(Person::getAddress);
```

http://www.infoq.com/presentations/java-streams-scala-parallel-collections

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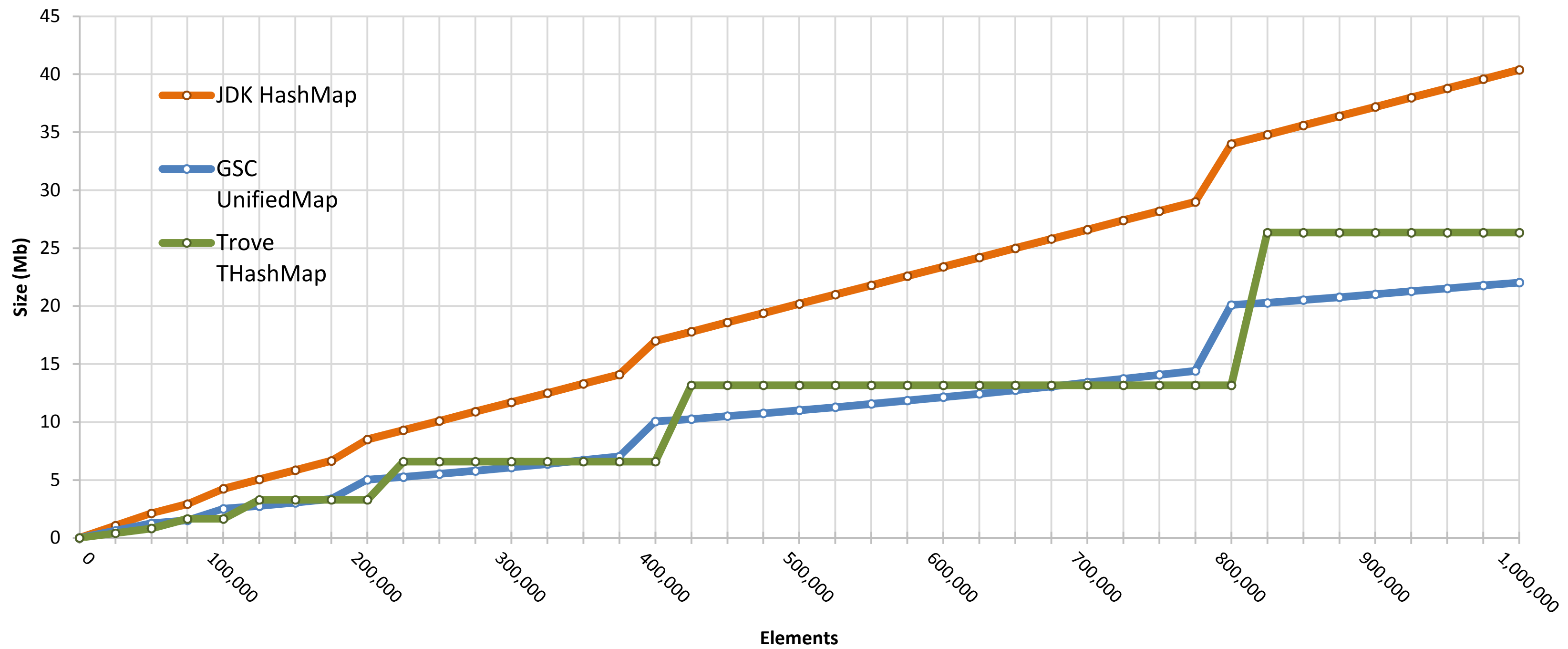
Comparing Maps



- `Entry` holds key, value, next, and hash.
- Better to put the keys and values in the backing array.
- Uses half the memory on average.
- But watch out for `Map.entrySet()`.
  - Leaky abstraction
    - The assumption is that Maps are implemented as tables of Entry objects.
  - It’s now O(n) instead of O(1).
  - Use `forEachKeyValue()` instead.

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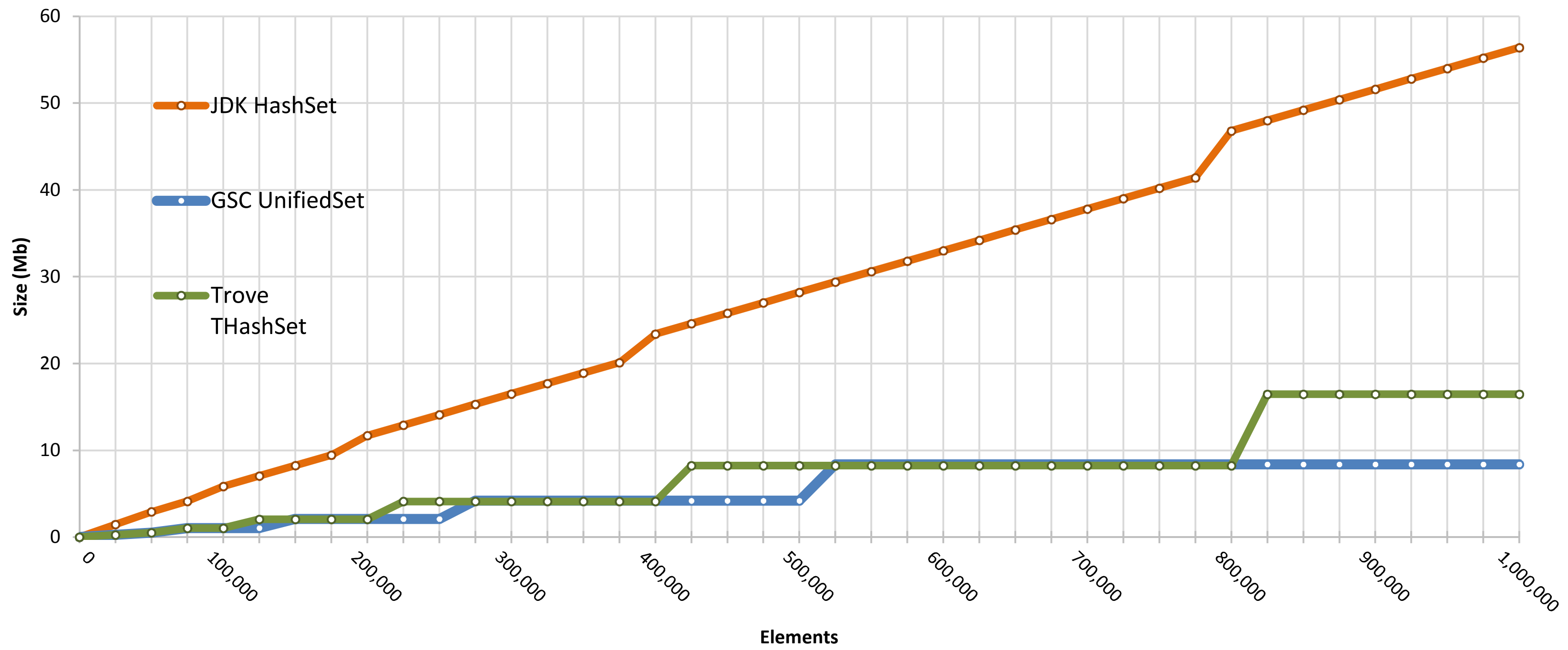
Comparing Sets



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Memory Optimizations

- HashSet is implemented by delegating to a HashMap.
- Entries are still a waste of space.
- Values in each (key, value) pair are a waste of space.
- Uses 4x the memory on average.

Bad decisions from long ago

Map with collision.

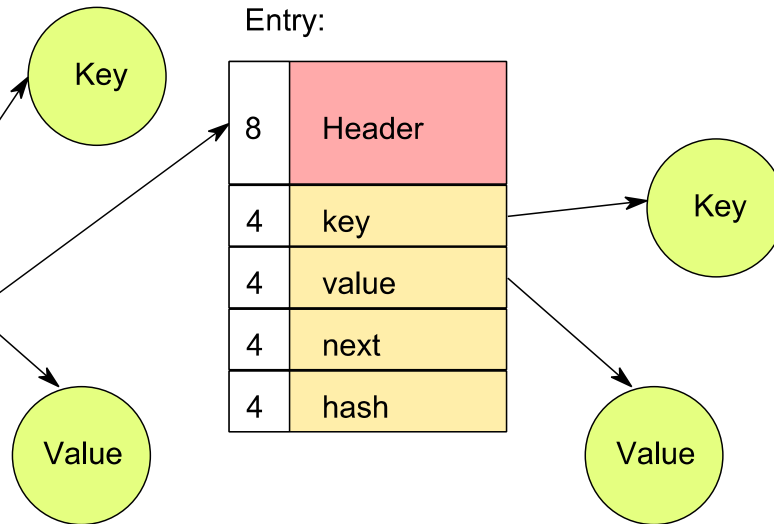
HashMap:

Array of Entry:

8	Header
4	Length
4	Padding
4	(null)
4	(null)
4	reference
4	(null)

Entry:

8	Header
4	key
4	value
4	next
4	hash



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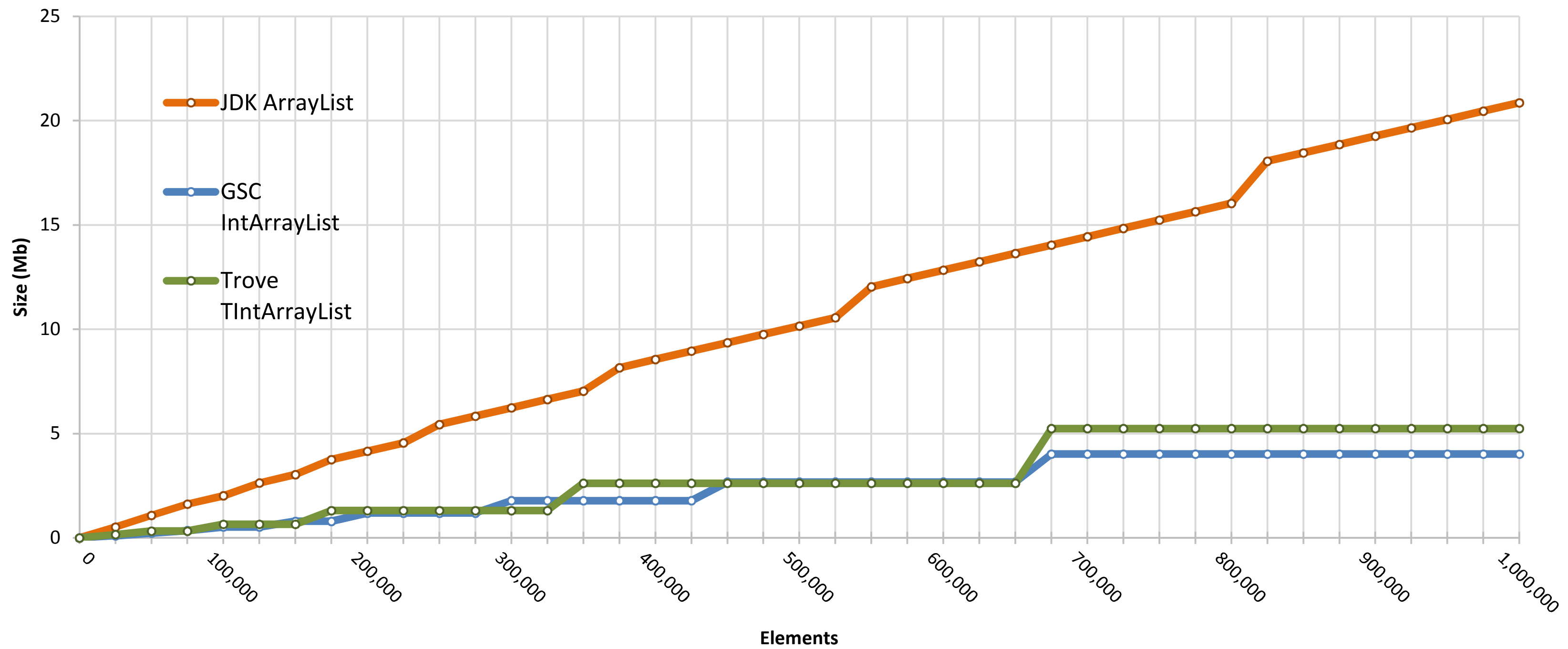
Save memory with Primitive Collections



List<Integer> vs. IntList

- Java has object and primitive arrays
  - Primitive arrays have no behaviors
- Java does not have primitive Lists, Sets or Maps
  - Primitives must be boxed
  - Boxing is expensive
    - Reference + Header + alignment

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  - Memory Efficiency
  - **Method references are awesome**
- Framework Comparisons

Lambdas and Method References

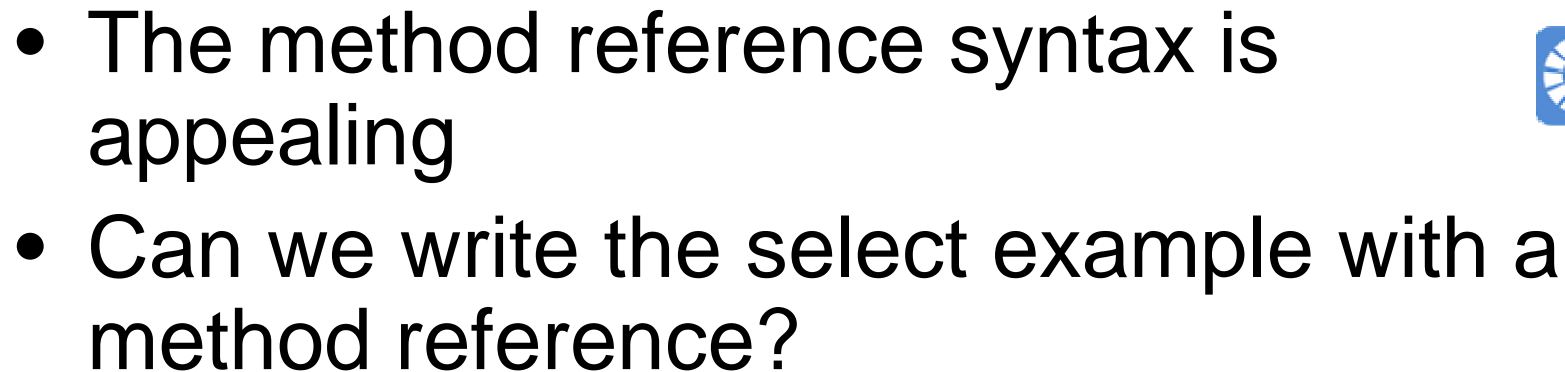
- We upgraded the Kata (our training materials) from Java 7 to Java 8
- Some anonymous inner classes converted easily into Method References

```
MutableList<String> customerCities =
  customers.collect(Customer::getCity);
```

- Some we kept as lambdas

```
MutableList<Customer> customersFromLondon =
  customers.select(customer -> customer.livesIn("London"));
```

Lambdas and Method References



- The method reference syntax is appealing
- Can we write the select example with a method reference?

```
MutableList<Customer> customersFromLondon =
  customers.select(Customer::livesInLondon);
```

- No one writes methods like this.

Lambdas and Method References

- Now we use method references
- We used to use constants

```
MutableList<String> customerCities =
  customers.collect(Customer.TO_CITY);
```

```
public static final Function<Customer, String> TO_CITY =
  new Function<Customer, String>() {
    public String valueOf(Customer customer) {
      return customer.getCity();
    }
  };
```

Lambdas and Method References

- The select example would have created garbage

```
MutableList<Customer> customersFromLondon =
  customers.select(new Predicate<Customer>()
  {
    public boolean accept(Customer customer)
    {
      return customer.livesIn("London");
    }
  });
```

Lambdas and Method References

- So we created `selectWith(Predicate2)` to avoid garbage

```
MutableList<Customer> customersFromLondon =
  customers.selectWith(Customer.LIVES_IN, "London");

public static final Predicate2<Customer, String> LIVES_IN =
  new Predicate2<Customer, String>()
  {
    public boolean accept(Customer customer, String city)
    {
      return customer.livesIn(city);
    }
  };
```

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Lambdas and Method References

- The *With() methods work perfectly with Method References

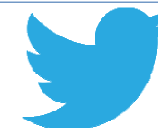
```
MutableList<Customer> customersFromLondon =
  customers.selectWith(Customer::livesIn, "London");
```

- This increases the number of places we can use method references.

Framework Comparisons

Features	GS Collections	Java 8	Guava	Trove	Scala
Rich API	✔	✔	✔		✔
Interfaces	Readable, Mutable, Immutable, FixedSize, Lazy	Mutable, Stream	Mutable, Fluent	Mutable	Readable, Mutable, Immutable, Lazy
Optimized Set & Map	✔ (+Bag)			✔	
Immutable Collections	✔		✔		✔
Primitive Collections	✔ (+Bag, +Immutable)			✔	
Multimaps	✔ (+Bag, +SortedBag)		✔ (+Linked)		(Multimap trait)
Bags (Multisets)	✔		✔		
BiMaps	✔		✔		
Iteration Styles	Eager/Lazy, Serial/Parallel	Lazy, Serial/Parallel	Lazy, Serial	Eager, Serial	Eager/Lazy, Serial/Parallel (Lazy Only)

More Information



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stackoverflow.com/questions/tagged/gs-collections

github.com/goldmansachs/gs-collections
github.com/goldmansachs/gs-collections/wiki
github.com/goldmansachs/gs-collections-kata

Parallel-lazy Performance: Java 8 vs Scala vs GS Collections
infoq.com/presentations/java-streams-scala-parallel-collections

GS Collections Memory Benchmark
goldmansachs.com/gs-collections/presentations/GSC_Memory_Tests.pdf

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