

# Java 9 - The (G1) GC Awakens

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A long time ago in a galaxy (not so) far,  
far away....

# GARBAGE FIRST GARBAGE COLLECTOR



# About Me

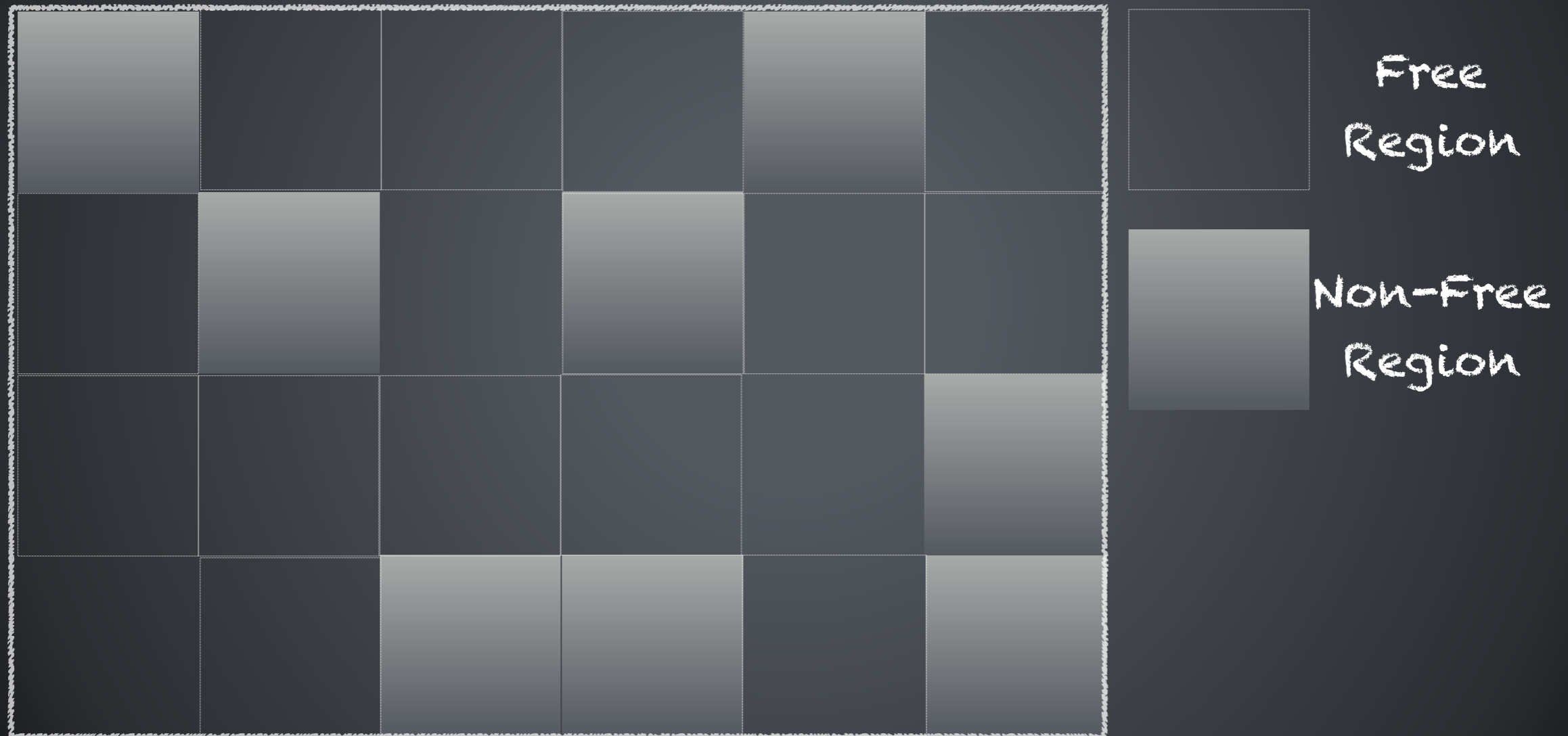
- Java/JVM/GC Performance Consultant
- Have worked with HotSpot for more than a decade.
- Was the performance lead for G1 GC @Oracle.

# Agenda

- Heap Regions
- Additional Data Structures
  - CSet & RSets
- Young Collection
- Marking Threshold & Concurrent Marking Stages
- Mixed Collection
- Evacuation Failures
- Fragmentation
- Humongous Objects
- Tuneables

# G1 GC Heap Regions

# Heap Regions



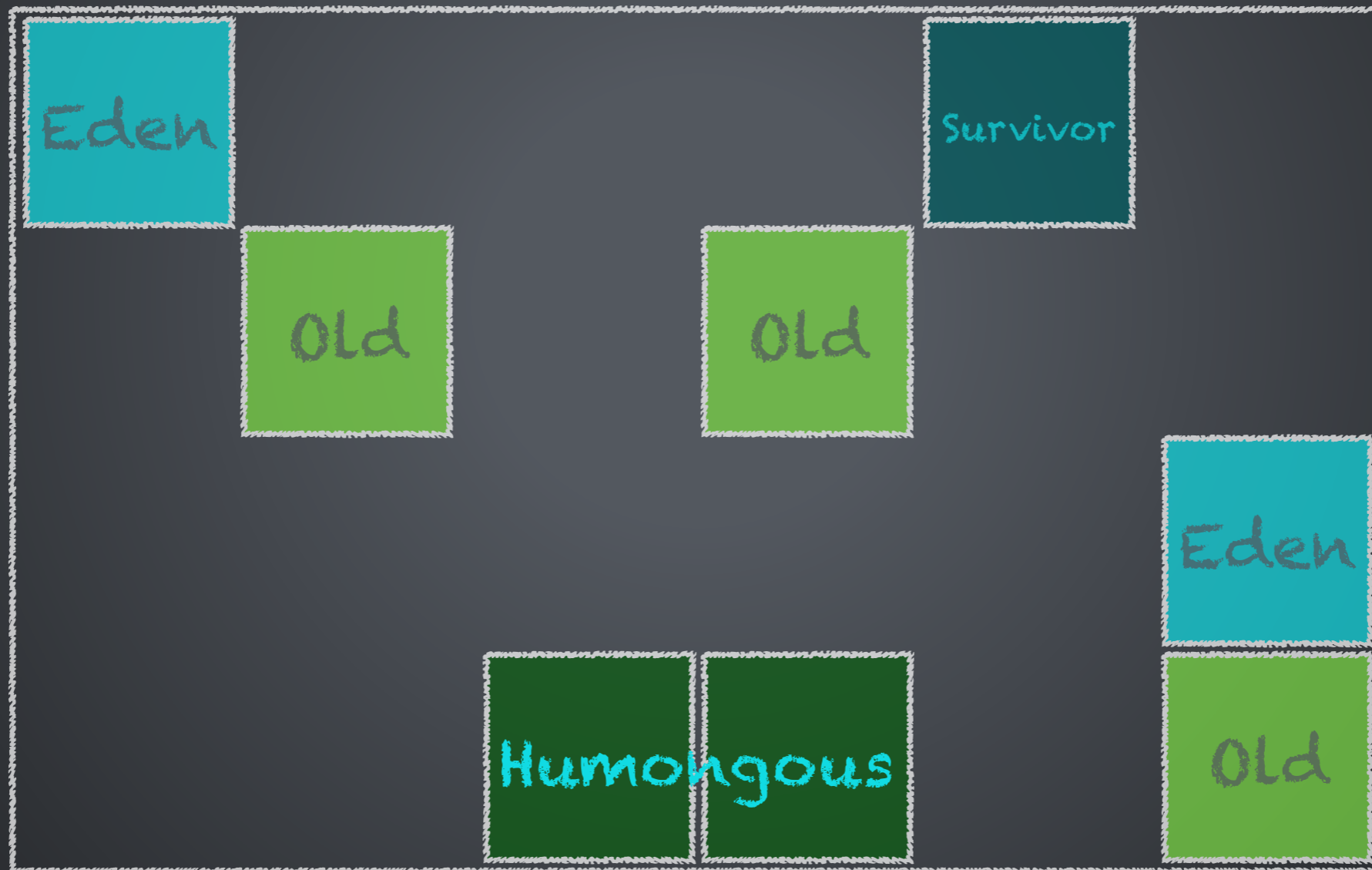
Contiguous Java Heap



# Heap Regions

- Heap region size = heap size/2048
  - can range from 1 MB to 32 MB
  - is a power of 2
  - is aligned

# Heap Regions



# Heap Regions

- Young Regions - Regions that house objects in the Eden and Survivor Spaces
- Old Regions - Regions that house objects in the Old generation.
- Humongous Regions - Regions that house Humongous Objects.

# Additional Data Structures

# G1 GC Collection Set & Remembered Sets

- Additional data structure to help with maintenance and collection
- Add a slight footprint overhead (~5%)

# Collection Set

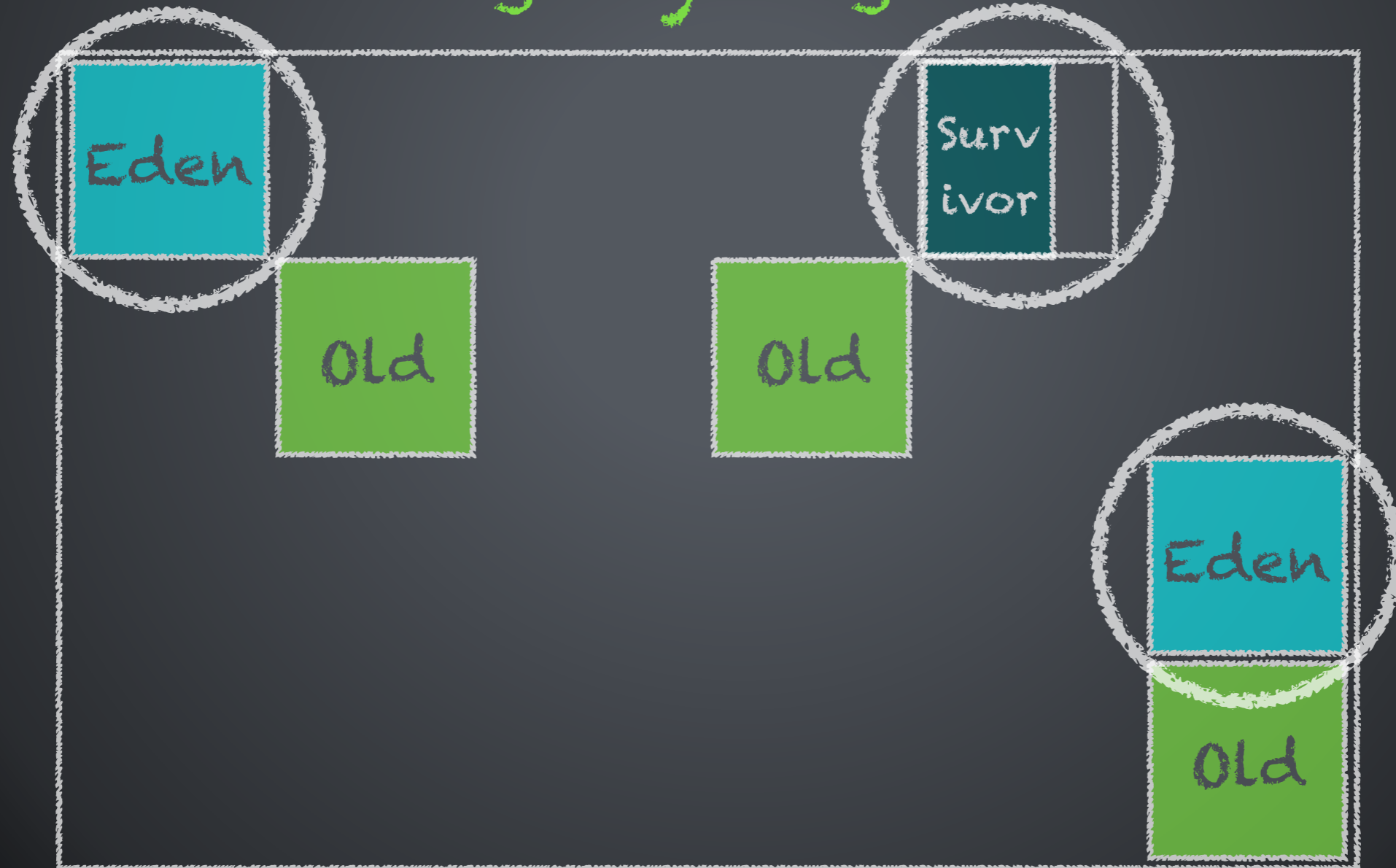


# Collection Set

- A young collection set (CSet) will incorporate all the young regions
- A mixed collection set will incorporate all the young regions and a few candidate old regions based on the “most garbage first” principle.

# Collection Set

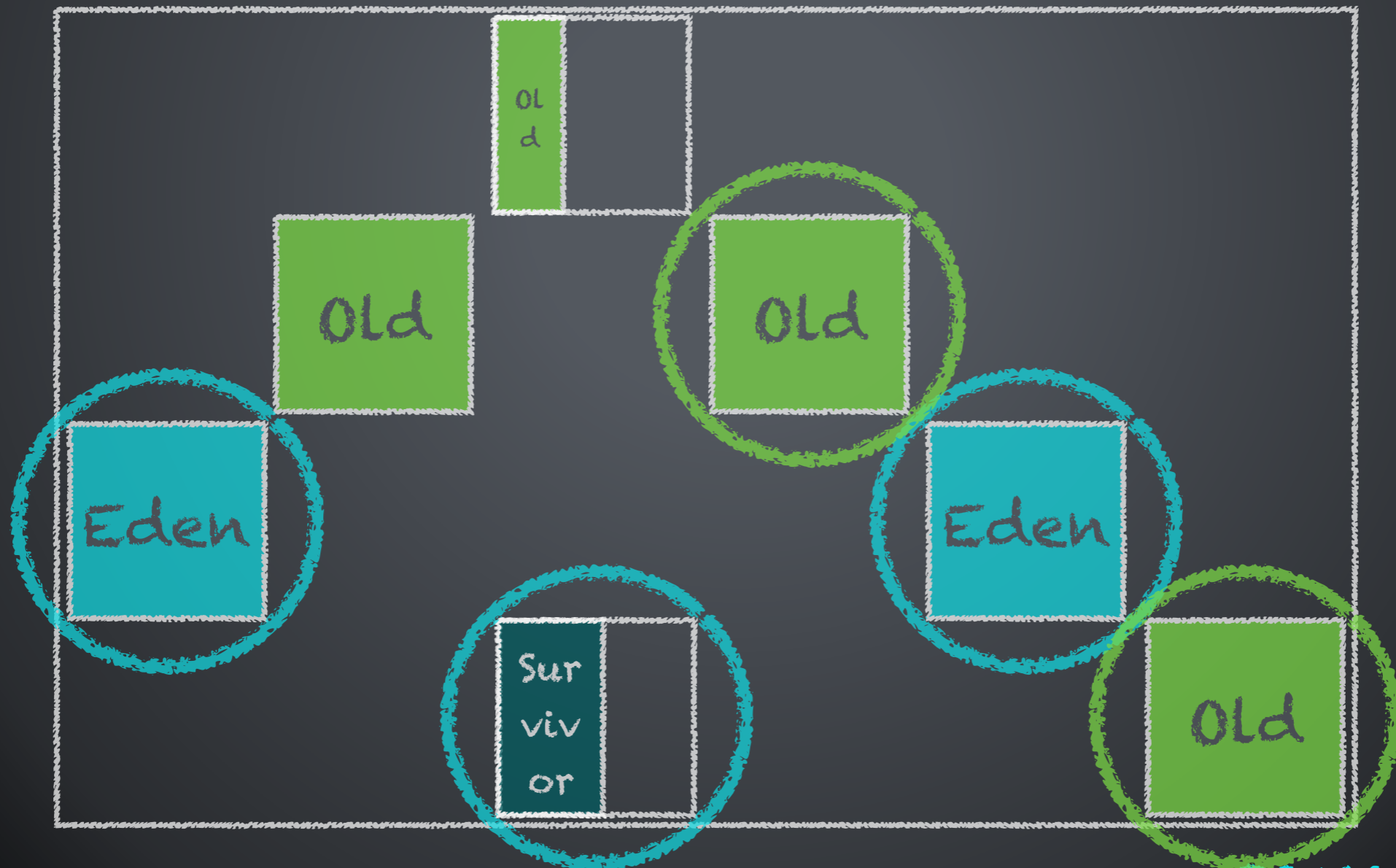
CSet during a young collection -





# Collection Set

CSet during a mixed collection -



# Collection Set

- `G1MixedGCLiveThresholdPercent`

`Enable UnlockExperimentalVMOptions`

# Collection Set

- `G1OldCSetRegionThresholdPercent`

`Enable UnlockExperimentalVMOptions`

# Log Output with - Xlog:gc\*,ergo\*=trace

- G1OldCSetRegionThresholdPercent

```
[86.548s][debug][gc,ergo,cset] GC(71) Finish adding old  
regions to CSet (reclaimable percentage not over threshold).  
old 13 regions, max 68 regions, reclaimable: 35485144B  
(4.98%) threshold: 5%
```

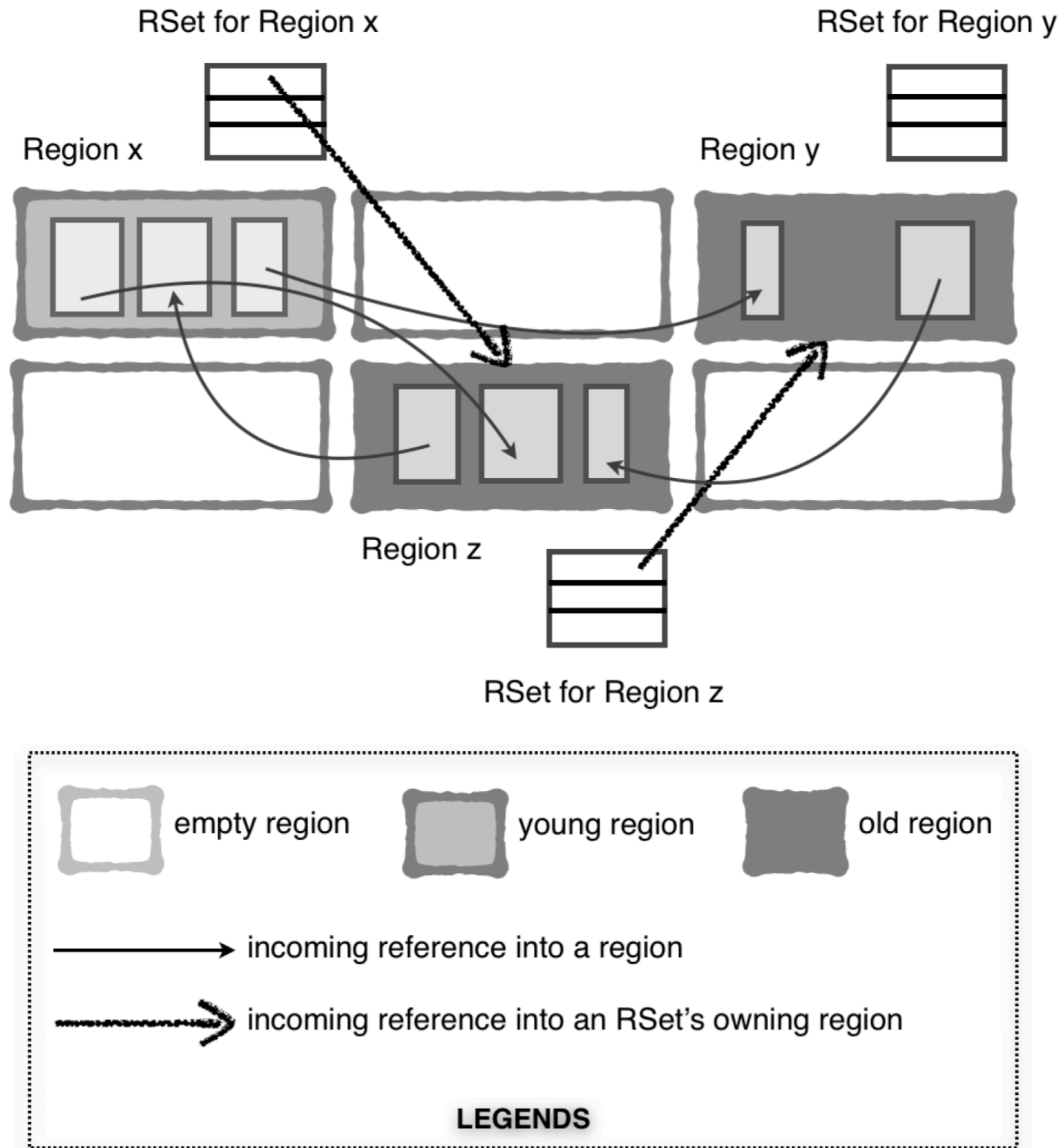
# Remembered Sets



# Remembered Sets

- Maintains and tracks incoming references into its region
  - old-to-young references
  - old-to-old references
- Remembered sets have varying granularity based on the “popularity” of objects or regions.

Quick Info: The next few figures and log outputs are from chapters 2 and 3 of the upcoming Java Performance Companion and will be marked with \*\*.



**Figure 2.3** Remembered sets with incoming object references\*\*



# Remembered Sets

- Different granularities:
  - sparse per-region-table (PRT)
  - fine-grained PRT
  - coarse-grained bitmap

# Log Output with `-Xlog:gc +remset=trace`

Recent concurrent refinement statistics

Processed 23270 cards

Of 96 completed buffers:

96 (100.0%) by concurrent RS threads.

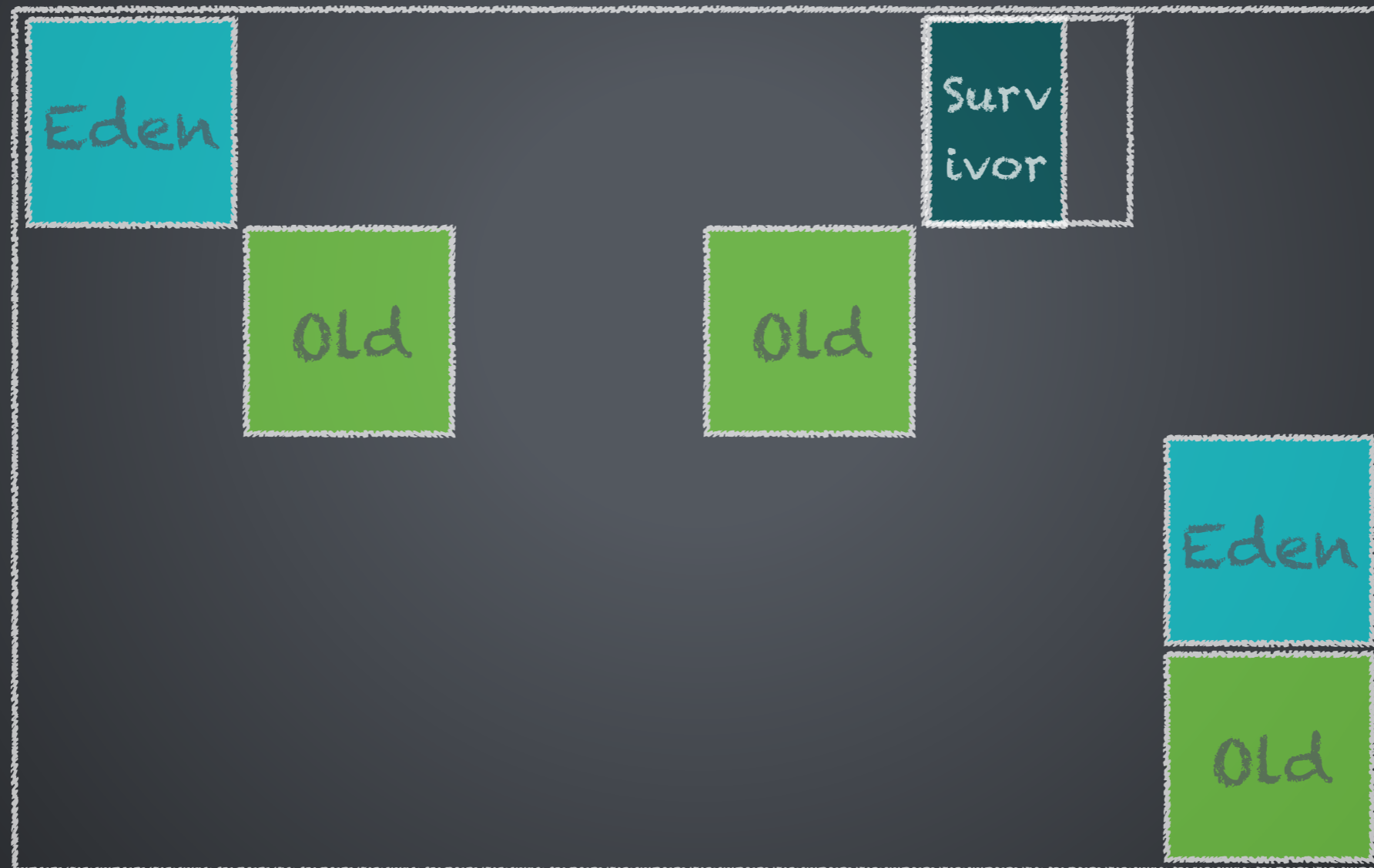
0 ( 0.0%) by mutator threads

Did 0 coarsenings.

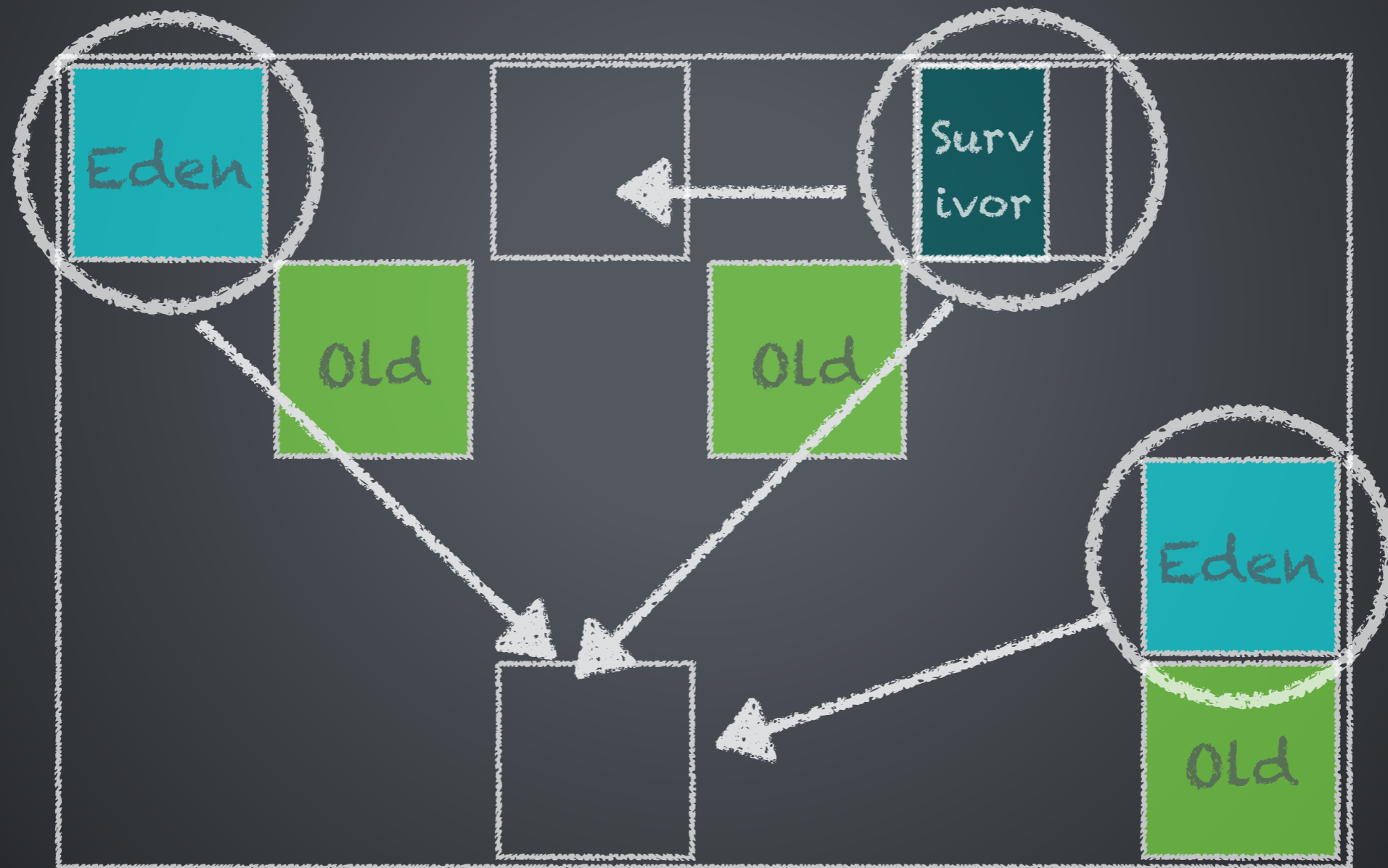
```
** -XX:+UnlockDiagnosticVMOptions -  
XX:G1SummarizeRSetStatsPeriod=1
```

# A Young Collection

# G1 GC Heap

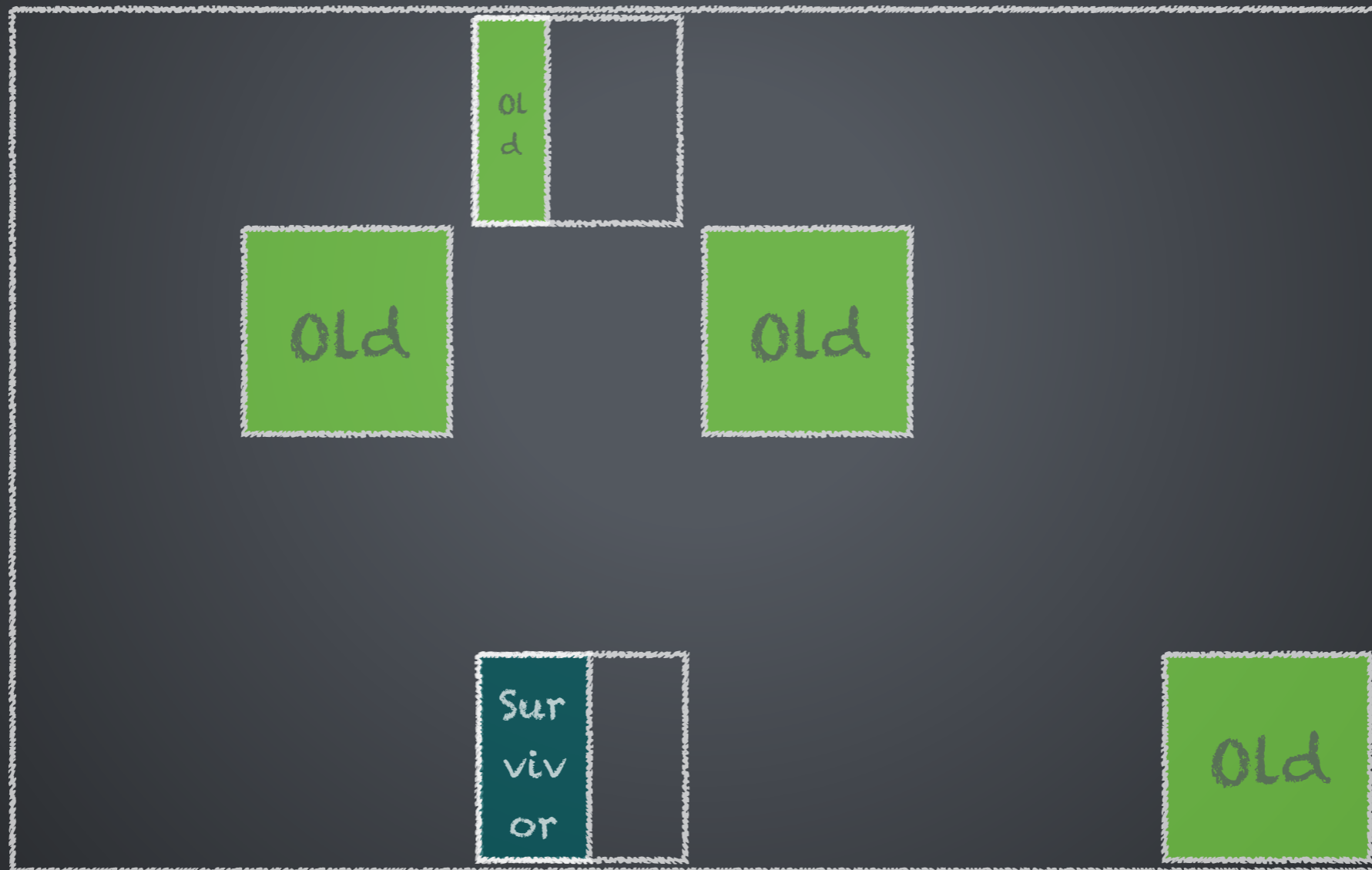


# During a Young Collection





# After a Young Collection



A Young Collection Log  
Snippet with `-Xlog:gc*,gc  
+phases=debug`

# Young Collection

```
[10.578s][info ][gc,start ] GC(20) Pause Mixed (G1 Evacuation Pause) (10.578s)
[10.603s][debug ][gc,phases ] GC(20) Parallel Time: 24.1 ms
[10.603s][debug ][gc,phases ] GC(20) GC Worker Start: Min: 10578.1, Avg: 10578.1, Max: 10578.1, Diff: 0.0
[10.603s][debug ][gc,phases ] GC(20) Ext Root Scanning: Min: 0.2, Avg: 0.2, Max: 0.3, Diff: 0.1, Sum: 1.9
[10.603s][debug ][gc,phases ] GC(20) Thread Roots: Min: 0.0, Avg: 0.1, Max: 0.3, Diff: 0.3, Sum: 0.6
[10.603s][debug ][gc,phases ] GC(20) StringTable Roots: Min: 0.0, Avg: 0.1, Max: 0.2, Diff: 0.2, Sum: 1.1
[10.603s][debug ][gc,phases ] GC(20) Universe Roots: Min: 0.0, Avg: 0.0, Max: 0.0, Diff: 0.0, Sum: 0.0
[10.603s][debug ][gc,phases ] GC(20) JNI Handles Roots: Min: 0.0, Avg: 0.0, Max: 0.0, Diff: 0.0, Sum: 0.0
[10.603s][debug ][gc,phases ] GC(20) ObjectSynchronizer Roots: Min: 0.0, Avg: 0.0, Max: 0.0, Diff: 0.0, Sum: 0.0
[10.603s][debug ][gc,phases ] GC(20) FlatProfiler Roots: Min: 0.0, Avg: 0.0, Max: 0.0, Diff: 0.0, Sum: 0.0
[10.603s][debug ][gc,phases ] GC(20) Management Roots: Min: 0.0, Avg: 0.0, Max: 0.0, Diff: 0.0, Sum: 0.0
[10.603s][debug ][gc,phases ] GC(20) SystemDictionary Roots: Min: 0.0, Avg: 0.0, Max: 0.0, Diff: 0.0, Sum: 0.0
[10.603s][debug ][gc,phases ] GC(20) CLDG Roots: Min: 0.0, Avg: 0.0, Max: 0.2, Diff: 0.2, Sum: 0.2
[10.603s][debug ][gc,phases ] GC(20) JVMTI Roots: Min: 0.0, Avg: 0.0, Max: 0.0, Diff: 0.0, Sum: 0.0
[10.603s][debug ][gc,phases ] GC(20) CM RefProcessor Roots: Min: 0.0, Avg: 0.0, Max: 0.0, Diff: 0.0, Sum: 0.0
[10.603s][debug ][gc,phases ] GC(20) Wait For Strong CLD: Min: 0.0, Avg: 0.0, Max: 0.0, Diff: 0.0, Sum: 0.0
[10.603s][debug ][gc,phases ] GC(20) Weak CLD Roots: Min: 0.0, Avg: 0.0, Max: 0.0, Diff: 0.0, Sum: 0.0
[10.603s][debug ][gc,phases ] GC(20) SATB Filtering: Min: 0.0, Avg: 0.0, Max: 0.0, Diff: 0.0, Sum: 0.0
[10.603s][debug ][gc,phases ] GC(20) Update RS: Min: 3.9, Avg: 4.0, Max: 4.2, Diff: 0.3, Sum: 32.3
[10.603s][debug ][gc,phases ] GC(20) Processed Buffers: Min: 5, Avg: 6.2, Max: 8, Diff: 3, Sum: 50
[10.603s][debug ][gc,phases ] GC(20) Scan HCC: Min: 0.4, Avg: 0.5, Max: 0.5, Diff: 0.1, Sum: 3.8
[10.603s][debug ][gc,phases ] GC(20) Scan RS: Min: 6.0, Avg: 10.4, Max: 11.2, Diff: 5.2, Sum: 82.9
[10.603s][debug ][gc,phases ] GC(20) Code Root Scanning: Min: 0.0, Avg: 0.7, Max: 5.2, Diff: 5.2, Sum: 5.3
[10.603s][debug ][gc,phases ] GC(20) Object Copy: Min: 8.6, Avg: 8.7, Max: 8.8, Diff: 0.2, Sum: 69.4
[10.603s][debug ][gc,phases ] GC(20) Termination: Min: 0.0, Avg: 0.1, Max: 0.1, Diff: 0.1, Sum: 0.7
[10.603s][debug ][gc,phases ] GC(20) Termination Attempts: Min: 1, Avg: 12.2, Max: 16, Diff: 15, Sum: 98
[10.603s][debug ][gc,phases ] GC(20) GC Worker Other: Min: 0.0, Avg: 0.0, Max: 0.0, Diff: 0.0, Sum: 0.0
[10.603s][debug ][gc,phases ] GC(20) GC Worker Total: Min: 24.0, Avg: 24.1, Max: 24.1, Diff: 0.0, Sum: 192.5
[10.603s][debug ][gc,phases ] GC(20) GC Worker End: Min: 10602.2, Avg: 10602.2, Max: 10602.2, Diff: 0.0
```



# Young Collection

```
[10.603s][debug ][gc,phases ] GC(20) Code Root Fixup: 0.1 ms
[10.603s][debug ][gc,phases ] GC(20) Code Root Purge: 0.0 ms
[10.603s][debug ][gc,phases ] GC(20) Clear CT: 0.1 ms
[10.603s][debug ][gc,phases ] GC(20) Expand Heap After Collection: 0.0 ms
[10.603s][debug ][gc,phases ] GC(20) Other: 0.7 ms
[10.603s][debug ][gc,phases ] GC(20) Choose CSet: 0.0 ms
[10.603s][debug ][gc,phases ] GC(20) Ref Proc: 0.1 ms
[10.603s][debug ][gc,phases ] GC(20) Ref Enq: 0.0 ms
[10.603s][debug ][gc,phases ] GC(20) Redirty Cards: 0.1 ms
[10.603s][debug ][gc,phases ] GC(20) Parallel Redirty: Min: 0.1, Avg: 0.1, Max:
0.1, Diff: 0.0, Sum: 0.8
[10.603s][debug ][gc,phases ] GC(20) Redirtied Cards: Min: 7563, Avg: 8703.4, Max:
10349, Diff: 2786, Sum: 69627
[10.603s][debug ][gc,phases ] GC(20) Humongous Register: 0.0 ms
[10.603s][debug ][gc,phases ] GC(20) Humongous Reclaim: 0.0 ms
[10.603s][debug ][gc,phases ] GC(20) Free CSet: 0.3 ms
[10.603s][info ][gc,heap ] GC(20) Eden regions: 14->0(164)
[10.603s][info ][gc,heap ] GC(20) Survivor regions: 11->1(4)
[10.603s][info ][gc,heap ] GC(20) Old regions: 202->203
[10.603s][info ][gc,heap ] GC(20) Humongous regions: 6->6
[10.603s][info ][gc,metaspace] GC(20) Metaspace: 9996K->9996K(1058816K)
[10.603s][info ][gc ] GC(20) Pause Mixed (G1 Evacuation Pause) 232M->209M(500M) (10.578s,
10.603s) 25.329ms
[10.603s][info ][gc,cpu ] GC(20) User=0.19s Sys=0.00s Real=0.03s
```

A Young Collection Log  
Snippet with -XX:  
+PrintGCDetails

# Young Collection

```
154.431: [GC pause (G1 Evacuation Pause) (young), 0.2584864 secs]
  [Parallel Time: 253.2 ms, GC Workers: 8]
    [GC Worker Start (ms): Min: 154431.3, Avg: 154431.4, Max: 154431.5, Diff: 0.1]
    [Ext Root Scanning (ms): Min: 0.1, Avg: 0.2, Max: 0.3, Diff: 0.1, Sum: 1.4]
    [Update RS (ms): Min: 3.3, Avg: 3.5, Max: 3.8, Diff: 0.6, Sum: 28.2]
      [Processed Buffers: Min: 3, Avg: 3.5, Max: 5, Diff: 2, Sum: 28]
    [Scan RS (ms): Min: 46.1, Avg: 46.4, Max: 46.7, Diff: 0.6, Sum: 371.2]
    [Code Root Scanning (ms): Min: 0.0, Avg: 0.1, Max: 0.1, Diff: 0.1, Sum: 0.5]
    [Object Copy (ms): Min: 202.7, Avg: 202.8, Max: 202.9, Diff: 0.3, Sum: 1622.4]
    [Termination (ms): Min: 0.0, Avg: 0.1, Max: 0.1, Diff: 0.1, Sum: 0.5]
    [GC Worker Other (ms): Min: 0.0, Avg: 0.1, Max: 0.1, Diff: 0.1, Sum: 0.6]
    [GC Worker Total (ms): Min: 253.0, Avg: 253.1, Max: 253.1, Diff: 0.1, Sum: 2024.7]
    [GC Worker End (ms): Min: 154684.5, Avg: 154684.5, Max: 154684.5, Diff: 0.1]
  [Code Root Fixup: 0.1 ms]
  [Code Root Purge: 0.0 ms]
  [Clear CT: 0.7 ms]
  [Other: 4.4 ms]
    [Choose CSet: 0.0 ms]
    [Ref Proc: 0.3 ms]
    [Ref Enq: 0.0 ms]
    [Redirty Cards: 0.3 ms]
    [Humongous Reclaim: 0.0 ms]
    [Free CSet: 3.2 ms]
  [Eden: 4972.0M(4972.0M)->0.0B(4916.0M) Survivors: 148.0M->204.0M Heap: 5295.8M(10.0G)-
  >379.4M(10.0G)]
  [Times: user=1.72 sys=0.14, real=0.26 secs]
```

# Young Collection

```
154.431: [GC pause (G1 Evacuation Pause) (young), 0.2584864 secs]
  [Parallel Time: 253.2 ms, GC Workers: 8]
    [GC Worker Start (ms): Min: 154431.3, Avg: 154431.4, Max: 154431.5, Diff: 0.1]
    [Ext Root Scanning (ms): Min: 0.1, Avg: 0.2, Max: 0.3, Diff: 0.1, Sum: 1.4]
    [Update RS (ms): Min: 3.3, Avg: 3.5, Max: 3.8, Diff: 0.6, Sum: 28.2]
      [Processed Buffers: Min: 3, Avg: 3.5, Max: 5, Diff: 2, Sum: 28]
    [Scan RS (ms): Min: 46.1, Avg: 46.4, Max: 46.7, Diff: 0.6, Sum: 371.2]
    [Code Root Scanning (ms): Min: 0.0, Avg: 0.1, Max: 0.1, Diff: 0.1, Sum: 0.5]
    [Object Copy (ms): Min: 202.7, Avg: 202.8, Max: 202.9, Diff: 0.3, Sum: 1622.4]
    [Termination (ms): Min: 0.0, Avg: 0.1, Max: 0.1, Diff: 0.1, Sum: 0.5]
    [GC Worker Other (ms): Min: 0.0, Avg: 0.1, Max: 0.1, Diff: 0.1, Sum: 0.6]
    [GC Worker Total (ms): Min: 253.0, Avg: 253.1, Max: 253.1, Diff: 0.1, Sum: 2024.7]
    [GC Worker End (ms): Min: 154684.5, Avg: 154684.5, Max: 154684.5, Diff: 0.1]
  [Code Root Fixup: 0.1 ms]
  [Code Root Purge: 0.0 ms]
  [Clear CT: 0.7 ms]
  [Other: 4.4 ms]
    [Choose CSet: 0.0 ms]
    [Ref Proc: 0.3 ms]
    [Ref Enq: 0.0 ms]
    [Redirty Cards: 0.3 ms]
    [Humongous Reclaim: 0.0 ms]
    [Free CSet: 3.2 ms]
  [Eden: 4972.0M(4972.0M)->0.0B(4916.0M) Survivors: 148.0M->204.0M Heap: 5295.8M(10.0G)->379.4M(10.0G)]
  [Times: user=1.72 sys=0.14, real=0.26 secs]
```



# Young Collection

154.431: [GC pause (G1 Evacuation Pause) (young), 0.2584864 secs]

[Parallel Time: 253.2 ms, GC Workers: 8]

[GC Worker Start (ms): Min: 154431.3, Avg: 154431.4, Max: 154431.5, Diff: 0.1]

[Ext Root Scanning (ms): Min: 0.1, Avg: 0.2, Max: 0.3, Diff: 0.1, Sum: 1.4]

[Update RS (ms): Min: 3.3, Avg: 3.5, Max: 3.8, Diff: 0.6, Sum: 28.2]

[Processed Buffers: Min: 3, Avg: 3.5, Max: 5, Diff: 2, Sum: 28]

[Scan RS (ms): Min: 46.1, Avg: 46.4, Max: 46.7, Diff: 0.6, Sum: 371.2]

[Code Root Scanning (ms): Min: 0.0, Avg: 0.1, Max: 0.1, Diff: 0.1, Sum: 0.5]

[Object Copy (ms): Min: 202.7, Avg: 202.8, Max: 202.9, Diff: 0.3, Sum: 1622.4]

[Termination (ms): Min: 0.0, Avg: 0.1, Max: 0.1, Diff: 0.1, Sum: 0.5]

[GC Worker Other (ms): Min: 0.0, Avg: 0.1, Max: 0.1, Diff: 0.1, Sum: 0.6]

[GC Worker Total (ms): Min: 253.0, Avg: 253.1, Max: 253.1, Diff: 0.1, Sum: 2024.7]

[GC Worker End (ms): Min: 154684.5, Avg: 154684.5, Max: 154684.5, Diff: 0.1]

[Code Root Fixup: 0.1 ms]

[Code Root Purge: 0.0 ms]

[Clear CT: 0.7 ms]

[Other: 4.4 ms]

[Choose CSet: 0.0 ms]

[Ref Proc: 0.3 ms]

[Ref Enq: 0.0 ms]

[Redirty Cards: 0.3 ms]

[Humongous Reclaim: 0.0 ms]

[Free CSet: 3.2 ms]

[Eden: 4972.0M(4972.0M)->0.0B(4916.0M) Survivors: 148.0M->204.0M Heap: 5295.8M(10.0G)->379.4M(10.0G)]

[Times: user=1.72 sys=0.14, real=0.26 secs]

# Young Collection

```
154.431: [GC pause (G1 Evacuation Pause) (young), 0.2584864 secs]
  [Parallel Time: 253.2 ms, GC Workers: 8]
    [GC Worker Start (ms): Min: 154431.3, Avg: 154431.4, Max: 154431.5, Diff: 0.1]
    [Ext Root Scanning (ms): Min: 0.1, Avg: 0.2, Max: 0.3, Diff: 0.1, Sum: 1.4]
    [Update RS (ms): Min: 3.3, Avg: 3.5, Max: 3.8, Diff: 0.6, Sum: 28.2]
      [Processed Buffers: Min: 3, Avg: 3.5, Max: 5, Diff: 2, Sum: 28]
    [Scan RS (ms): Min: 46.1, Avg: 46.4, Max: 46.7, Diff: 0.6, Sum: 371.2]
    [Code Root Scanning (ms): Min: 0.0, Avg: 0.1, Max: 0.1, Diff: 0.1, Sum: 0.5]
    [Object Copy (ms): Min: 202.7, Avg: 202.8, Max: 202.9, Diff: 0.3, Sum: 1622.4]
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    [GC Worker Other (ms): Min: 0.0, Avg: 0.1, Max: 0.1, Diff: 0.1, Sum: 0.6]
    [GC Worker Total (ms): Min: 253.0, Avg: 253.1, Max: 253.1, Diff: 0.1, Sum: 2024.7]
    [GC Worker End (ms): Min: 154684.5, Avg: 154684.5, Max: 154684.5, Diff: 0.1]
  [Code Root Fixup: 0.1 ms]
  [Code Root Purge: 0.0 ms]
  [Clear CT: 0.7 ms]
  [Other: 4.4 ms]
    [Choose CSet: 0.0 ms]
    [Ref Proc: 0.3 ms]
    [Ref Enq: 0.0 ms]
    [Redirty Cards: 0.3 ms]
    [Humongous Reclaim: 0.0 ms]
    [Free CSet: 3.2 ms]
  [Eden: 4972.0M(4972.0M)->0.0B(4916.0M) Survivors: 148.0M->204.0M Heap: 5295.8M(10.0G)->379.4M(10.0G)]
  [Times: user=1.72 sys=0.14, real=0.26 secs]
```

# Young Collection

154.431: [GC pause (G1 Evacuation Pause) (young), 0.2584864 secs]

[Parallel Time: 253.2 ms, GC Workers: 8]

[GC Worker Start (ms): Min: 154431.3, Avg: 154431.4, Max: 154431.5, Diff: 0.1]

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[Update RS (ms): Min: 3.3, Avg: 3.5, Max: 3.8, Diff: 0.6, Sum: 28.2]

[Processed Buffers: Min: 3, Avg: 3.5, Max: 5, Diff: 2, Sum: 28]

[Scan RS (ms): Min: 46.1, Avg: 46.4, Max: 46.7, Diff: 0.6, Sum: 371.2]

[Code Root Scanning (ms): Min: 0.0, Avg: 0.1, Max: 0.1, Diff: 0.1, Sum: 0.5]

[Object Copy (ms): Min: 202.7, Avg: 202.8, Max: 202.9, Diff: 0.3, Sum: 1622.4]

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[GC Worker Other (ms): Min: 0.0, Avg: 0.1, Max: 0.1, Diff: 0.1, Sum: 0.6]

[GC Worker Total (ms): Min: 253.0, Avg: 253.1, Max: 253.1, Diff: 0.1, Sum: 2024.7]

[GC Worker End (ms): Min: 154684.5, Avg: 154684.5, Max: 154684.5, Diff: 0.1]

[Code Root Fixup: 0.1 ms]

[Code Root Purge: 0.0 ms]

[Clear CT: 0.7 ms]

[Other: 4.4 ms]

[Choose CSet: 0.0 ms]

[Ref Proc: 0.3 ms]

[Ref Enq: 0.0 ms]

[Redirty Cards: 0.3 ms]

[Humongous Reclaim: 0.0 ms]

[Free CSet: 3.2 ms]

[Eden: 4972.0M(4972.0M)->0.0B(4916.0M) Survivors: 148.0M->204.0M Heap: 5295.8M(10.0G)->379.4M(10.0G)]

[Times: user=1.72 sys=0.14, real=0.26 secs]



# Young Collection

```
154.431: [GC pause (G1 Evacuation Pause) (young), 0.2584864 secs]
  [Parallel Time: 253.2 ms, GC Workers: 8]
    [GC Worker Start (ms): Min: 154431.3, Avg: 154431.4, Max: 154431.5, Diff: 0.1]
    [Ext Root Scanning (ms): Min: 0.1, Avg: 0.2, Max: 0.3, Diff: 0.1, Sum: 1.4]
    [Update RS (ms): Min: 3.3, Avg: 3.5, Max: 3.8, Diff: 0.6, Sum: 28.2]
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    [Object Copy (ms): Min: 202.7, Avg: 202.8, Max: 202.9, Diff: 0.3, Sum: 1622.4]
    [Termination (ms): Min: 0.0, Avg: 0.1, Max: 0.1, Diff: 0.1, Sum: 0.5]
    [GC Worker Other (ms): Min: 0.0, Avg: 0.1, Max: 0.1, Diff: 0.1, Sum: 0.6]
    [GC Worker Total (ms): Min: 253.0, Avg: 253.1, Max: 253.1, Diff: 0.1, Sum: 2024.7]
    [GC Worker End (ms): Min: 154684.5, Avg: 154684.5, Max: 154684.5, Diff: 0.1]
  [Code Root Fixup: 0.1 ms]
  [Code Root Purge: 0.0 ms]
  [Clear CT: 0.7 ms]
  [Other: 4.4 ms]
    [Choose CSet: 0.0 ms]
    [Ref Proc: 0.3 ms]
    [Ref Enq: 0.0 ms]
    [Redirty Cards: 0.3 ms]
    [Humongous Reclaim: 0.0 ms]
    [Free CSet: 3.2 ms]
  [Eden: 4972.0M(4972.0M)->0.0B(4916.0M) Survivors: 148.0M->204.0M Heap: 5295.8M(10.0G)->379.4M(10.0G)]
  [Times: user=1.72 sys=0.14, real=0.26 secs]
```



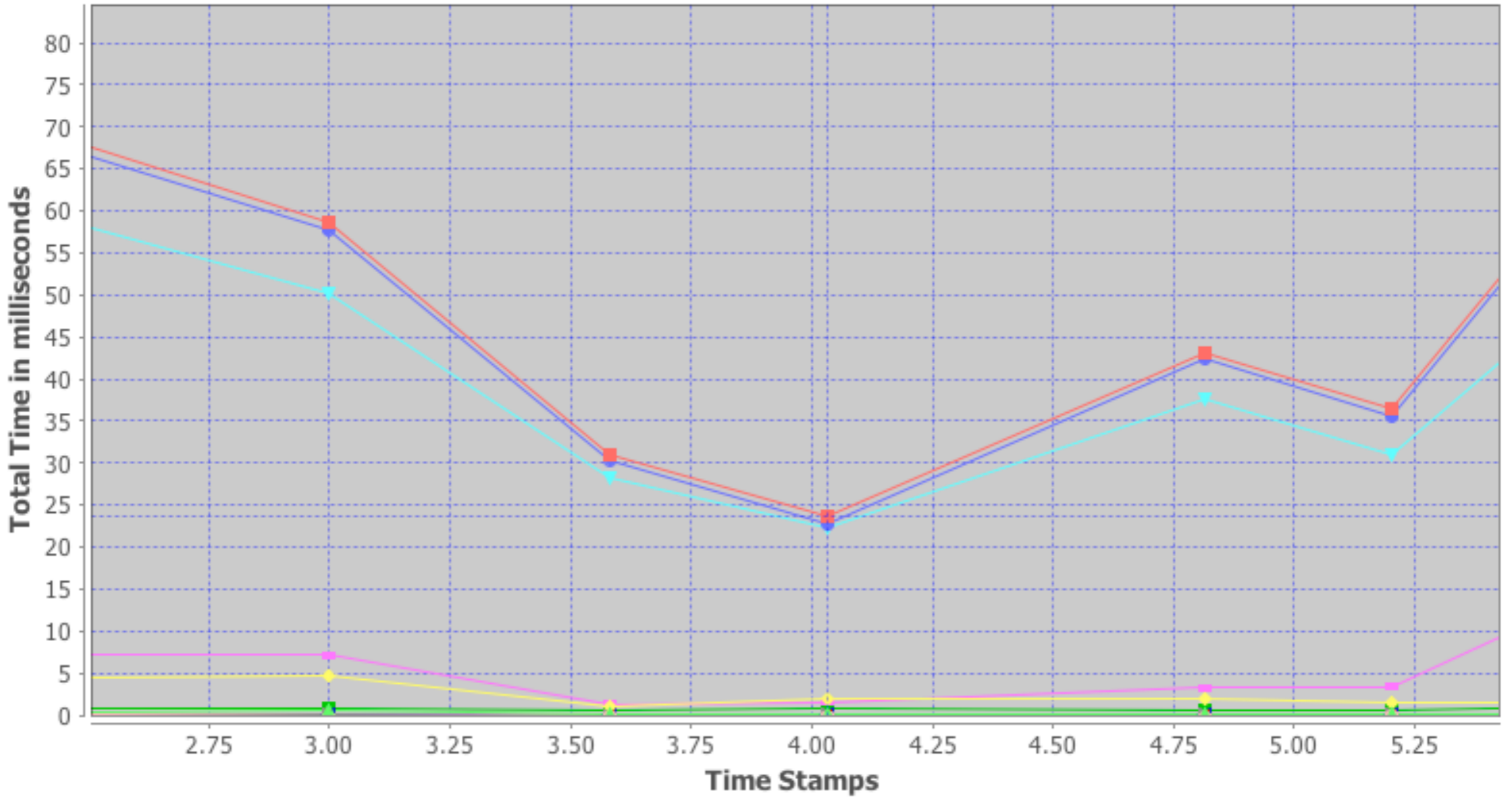
# Young Collection

```
154.431: [GC pause (G1 Evacuation Pause) (young), 0.2584864 secs]
  [Parallel Time: 253.2 ms, GC Workers: 8]
    [GC Worker Start (ms): Min: 154431.3, Avg: 154431.4, Max: 154431.5, Diff: 0.1]
    [Ext Root Scanning (ms): Min: 0.1, Avg: 0.2, Max: 0.3, Diff: 0.1, Sum: 1.4]
    [Update RS (ms): Min: 3.3, Avg: 3.5, Max: 3.8, Diff: 0.6, Sum: 28.2]
      [Processed Buffers: Min: 3, Avg: 3.5, Max: 5, Diff: 2, Sum: 28]
    [Scan RS (ms): Min: 46.1, Avg: 46.4, Max: 46.7, Diff: 0.6, Sum: 371.2]
    [Code Root Scanning (ms): Min: 0.0, Avg: 0.1, Max: 0.1, Diff: 0.1, Sum: 0.5]
    [Object Copy (ms): Min: 202.7, Avg: 202.8, Max: 202.9, Diff: 0.3, Sum: 1622.4]
    [Termination (ms): Min: 0.0, Avg: 0.1, Max: 0.1, Diff: 0.1, Sum: 0.5]
    [GC Worker Other (ms): Min: 0.0, Avg: 0.1, Max: 0.1, Diff: 0.1, Sum: 0.6]
    [GC Worker Total (ms): Min: 253.0, Avg: 253.1, Max: 253.1, Diff: 0.1, Sum: 2024.7]
    [GC Worker End (ms): Min: 154684.5, Avg: 154684.5, Max: 154684.5, Diff: 0.1]
  [Code Root Fixup: 0.1 ms]
  [Code Root Purge: 0.0 ms]
  [Clear CT: 0.7 ms]
  [Other: 4.4 ms]
    [Choose CSet: 0.0 ms]
    [Ref Proc: 0.3 ms]
    [Ref Enq: 0.0 ms]
    [Redirty Cards: 0.3 ms]
  [Humongous Reclaim: 0.0 ms]
    [Free CSet: 3.2 ms]
  [Eden: 4972.0M(4972.0M)->0.0B(4916.0M) Survivors: 148.0M->204.0M Heap: 5295.8M(10.0G)->379.4M(10.0G)]
  [Times: user=1.72 sys=0.14, real=0.26 secs]
```

# Young Collection

```
154.431: [GC pause (G1 Evacuation Pause) (young), 0.2584864 secs]
  [Parallel Time: 253.2 ms, GC Workers: 8]
    [GC Worker Start (ms): Min: 154431.3, Avg: 154431.4, Max: 154431.5, Diff: 0.1]
    [Ext Root Scanning (ms): Min: 0.1, Avg: 0.2, Max: 0.3, Diff: 0.1, Sum: 1.4]
    [Update RS (ms): Min: 3.3, Avg: 3.5, Max: 3.8, Diff: 0.6, Sum: 28.2]
      [Processed Buffers: Min: 3, Avg: 3.5, Max: 5, Diff: 2, Sum: 28]
    [Scan RS (ms): Min: 46.1, Avg: 46.4, Max: 46.7, Diff: 0.6, Sum: 371.2]
    [Code Root Scanning (ms): Min: 0.0, Avg: 0.1, Max: 0.1, Diff: 0.1, Sum: 0.5]
    [Object Copy (ms): Min: 202.7, Avg: 202.8, Max: 202.9, Diff: 0.3, Sum: 1622.4]
    [Termination (ms): Min: 0.0, Avg: 0.1, Max: 0.1, Diff: 0.1, Sum: 0.5]
    [GC Worker Other (ms): Min: 0.0, Avg: 0.1, Max: 0.1, Diff: 0.1, Sum: 0.6]
    [GC Worker Total (ms): Min: 253.0, Avg: 253.1, Max: 253.1, Diff: 0.1, Sum: 2024.7]
    [GC Worker End (ms): Min: 154684.5, Avg: 154684.5, Max: 154684.5, Diff: 0.1]
  [Code Root Fixup: 0.1 ms]
  [Code Root Purge: 0.0 ms]
  [Clear CT: 0.7 ms]
  [Other: 4.4 ms]
    [Choose CSet: 0.0 ms]
    [Ref Proc: 0.3 ms]
    [Ref Enq: 0.0 ms]
    [Redirty Cards: 0.3 ms]
    [Humongous Reclaim: 0.0 ms]
    [Free CSet: 3.2 ms]
  [Eden: 4972.0M(4972.0M)->0.0B(4916.0M) Survivors: 148.0M->204.0M Heap: 5295.8M(10.0G)->379.4M(10.0G)]
  [Times: user=1.72 sys=0.14, real=0.26 secs]
```

# G1 GC Sub-component Plot



■ Pause Times ● Parallel Times ▲ Ext. Root Scan Times ◆ Update RS Times ■ Scan RS Times ▼ Object Copy Times ○ Termination Times  
▲ Worker Other Times ■ Code Root Fixup Times ▲ Clear CT Times ■ Other Times

# Marking Threshold



# Initiating Heap Occupancy Percent

- Threshold to start the concurrent marking cycle to identify candidate old regions.
- When old generation occupancy crosses this adaptive threshold.
- Based on the total heap size.



# The Concurrent Marking Stages

# Concurrent Marking - Initial Mark Stage

- stop the world, piggy-backed on a young pause
- marks all root objects

# Concurrent Marking - Root Region Scanning Stage

- works concurrently with the mutators
- survivor regions are root regions
- must complete before the next GC pause

# Concurrent Marking - Concurrent Marking Stage

- works concurrently with the mutators
  - `-XX:ConcGCThreads`
- pre-write barrier needed
- live data accounting
- `XX:+ClassUnloadingWithConcurrentMark`

# Concurrent Marking - Final Mark Stage

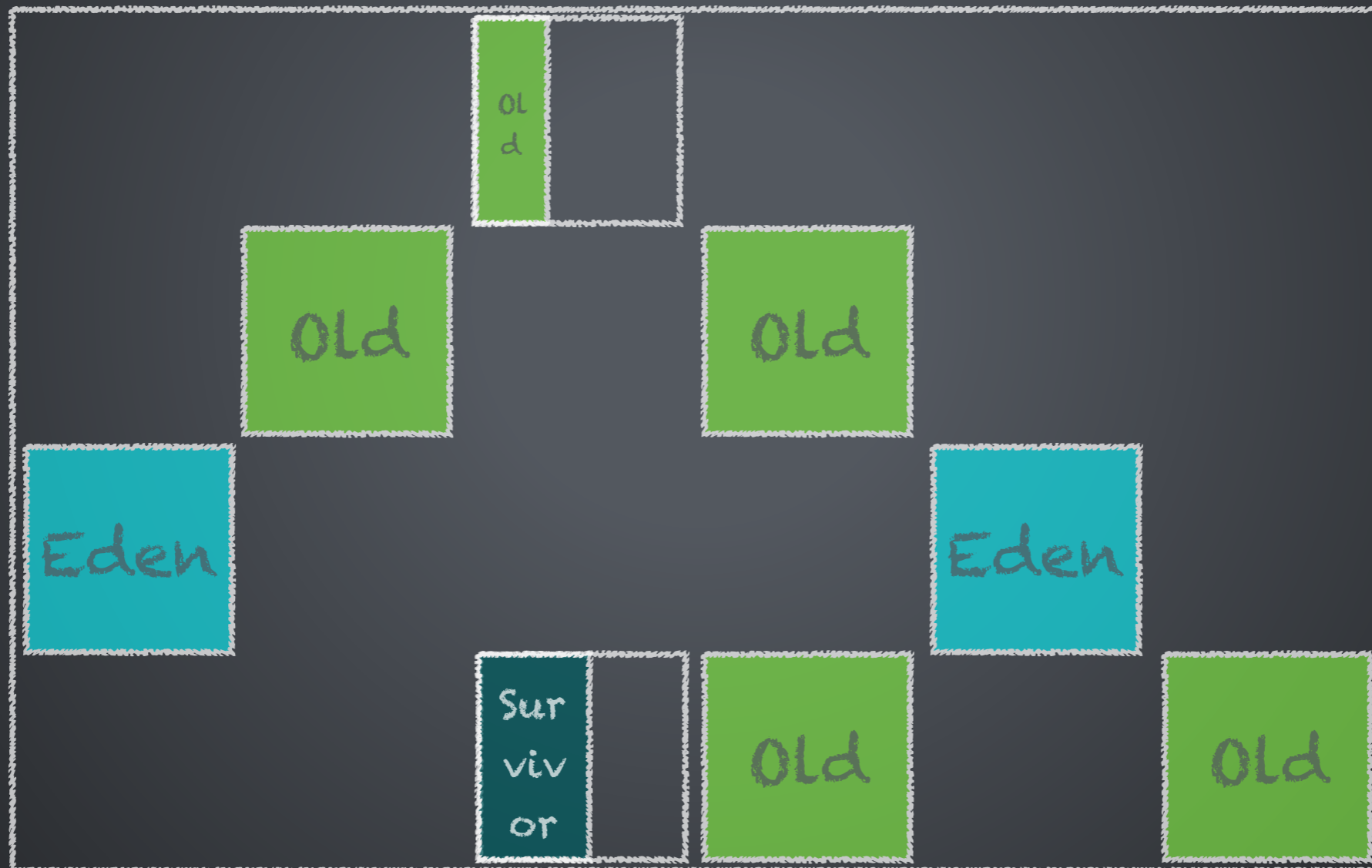
- stop the world
  - `XX:ParallelGCThreads`
- traverse any unvisited live objects.
- safely complete live data accounting.
- reference processing
  - `XX:+ParallelRefProcEnabled`



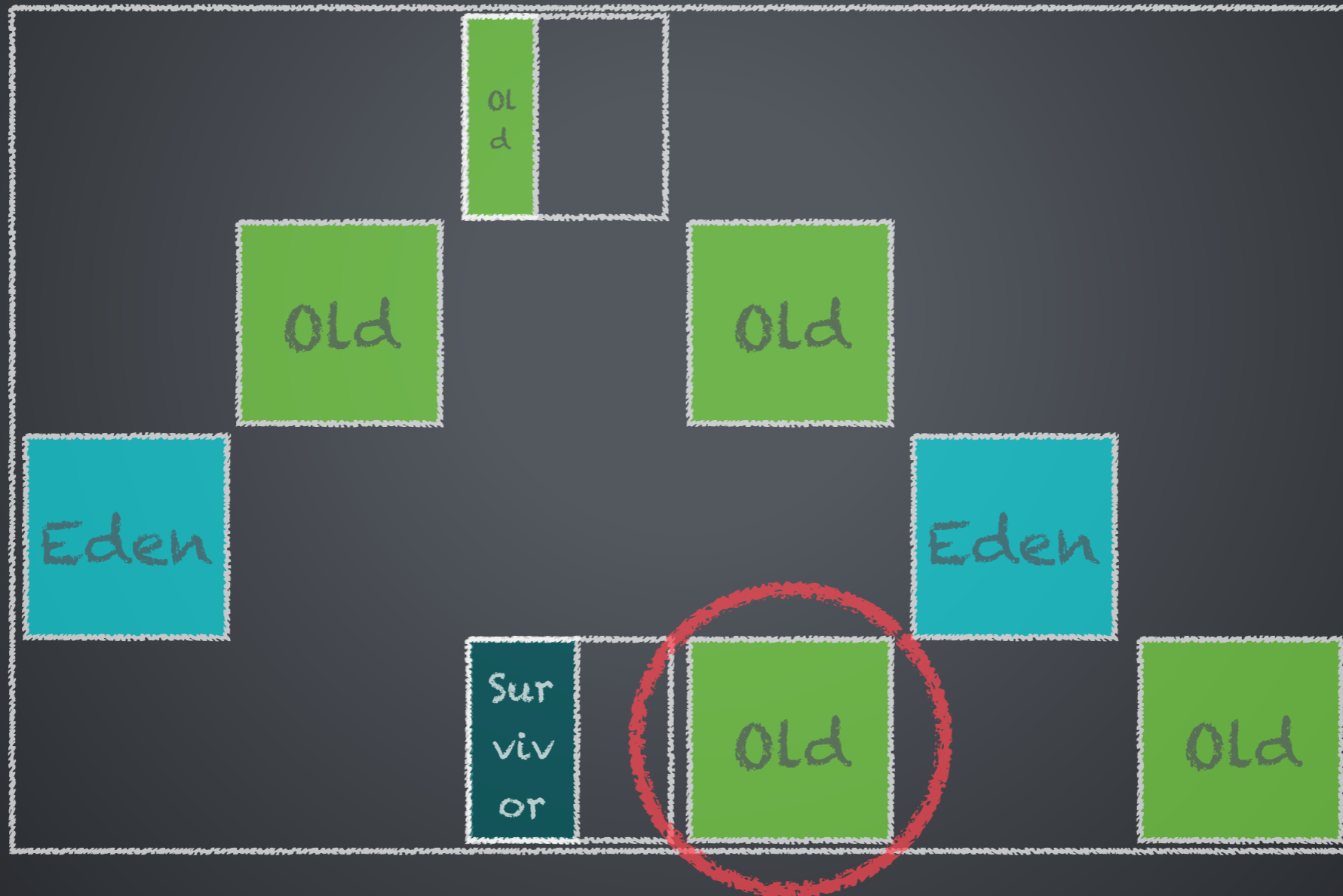
# Concurrent Marking - Cleanup Stage

- stop the world
  - identifying completely free regions
  - sorting regions based on “efficiency”
  - RSet scrubbing
- concurrent
  - reset and return empty region to the free list.

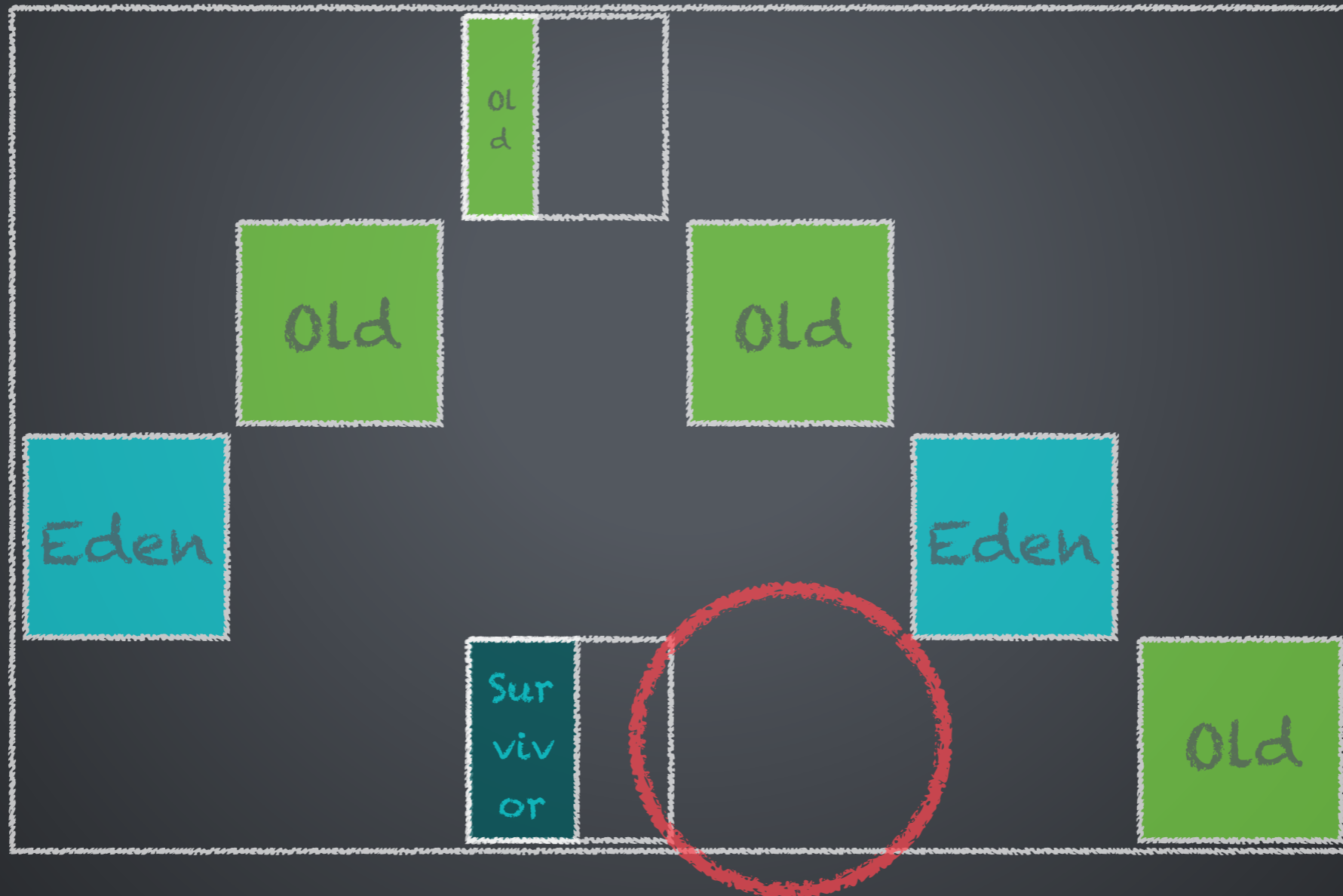
# G1 GC Heap



# Cleanup Phase



# Cleanup Phase



Concurrent Marking  
Stages Log Snippet with -  
Xlog:gc\*,ergo\*

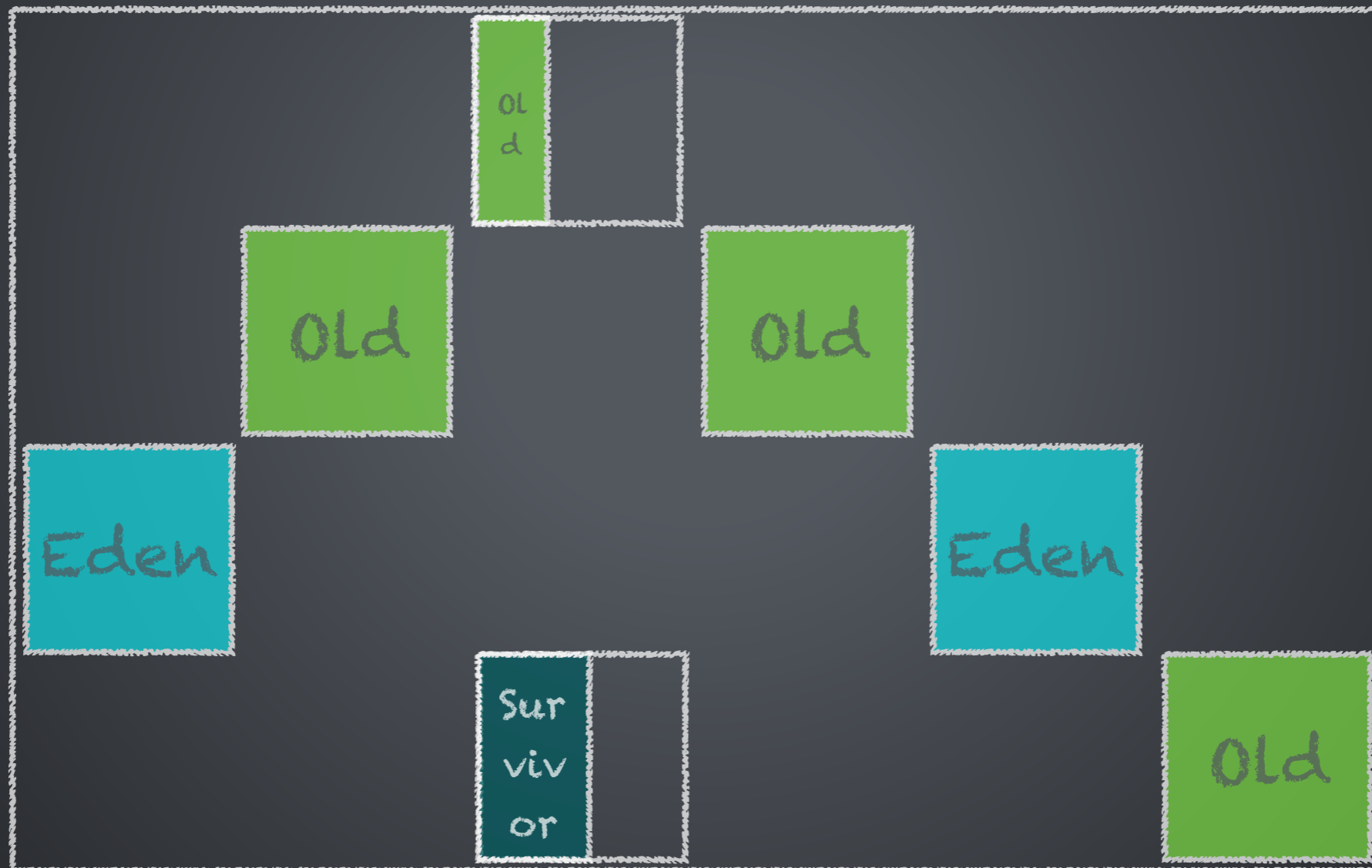


# Concurrent Marking Stages

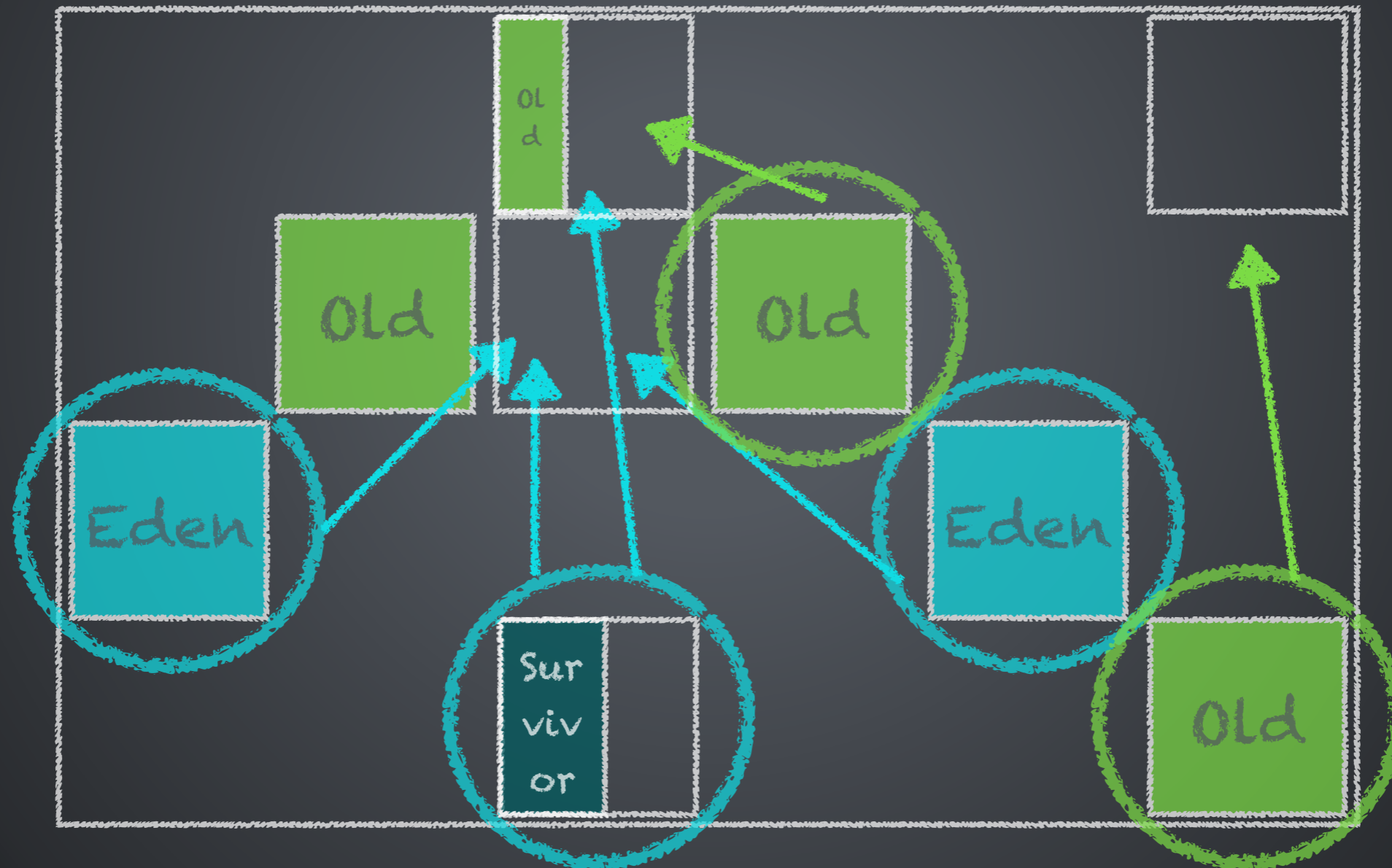
```
[9.474s][info][gc,start    ] GC(17) Pause Initial Mark (G1 Evacuation Pause) (9.474s)
[9.507s][info][gc,heap      ] GC(17) Eden regions: 142->0(143)
[9.507s][info][gc,heap      ] GC(17) Survivor regions: 6->11(19)
[9.507s][info][gc,heap      ] GC(17) Old regions: 218->218
[9.507s][info][gc,heap      ] GC(17) Humongous regions: 30->30
[9.507s][info][gc,metaspace] GC(17) Metaspace: 9976K->9976K(1058816K)
[9.507s][info][gc           ] GC(17) Pause Initial Mark (G1 Evacuation Pause) 395M-
>258M(500M) (9.474s, 9.507s) 33.170ms
[9.507s][info][gc,cpu       ] GC(17) User=0.20s Sys=0.00s Real=0.03s
[9.507s][info][gc           ] GC(18) Concurrent Root Region Scan (9.507s)
[9.534s][info][gc           ] GC(18) Concurrent Root Region Scan (9.507s, 9.534s) 26.740ms
[9.534s][info][gc           ] GC(18) Concurrent Mark (9.534s)
[9.791s][info][gc           ] GC(18) Concurrent Mark (9.534s, 9.791s) 256.961ms
[9.791s][info][gc,start     ] GC(18) Pause Remark (9.791s)
[9.794s][info][gc           ] GC(18) Pause Remark 269M->269M(500M) (9.791s, 9.794s) 3.008ms
[9.794s][info][gc,cpu       ] GC(18) User=0.01s Sys=0.00s Real=0.01s
[9.794s][info][gc,start     ] GC(18) Pause Cleanup (9.794s)
[9.795s][info][gc           ] GC(18) Pause Cleanup 269M->223M(500M) (9.794s, 9.795s)
1.219ms
[9.795s][info][gc,cpu       ] GC(18) User=0.01s Sys=0.00s Real=0.00s
[9.795s][info][gc           ] GC(18) Concurrent Cleanup (9.795s)
[9.795s][info][gc           ] GC(18) Concurrent Cleanup (9.795s, 9.795s) 0.115ms
```

# Incremental Compaction aka Mixed Collection

# G1 GC Heap

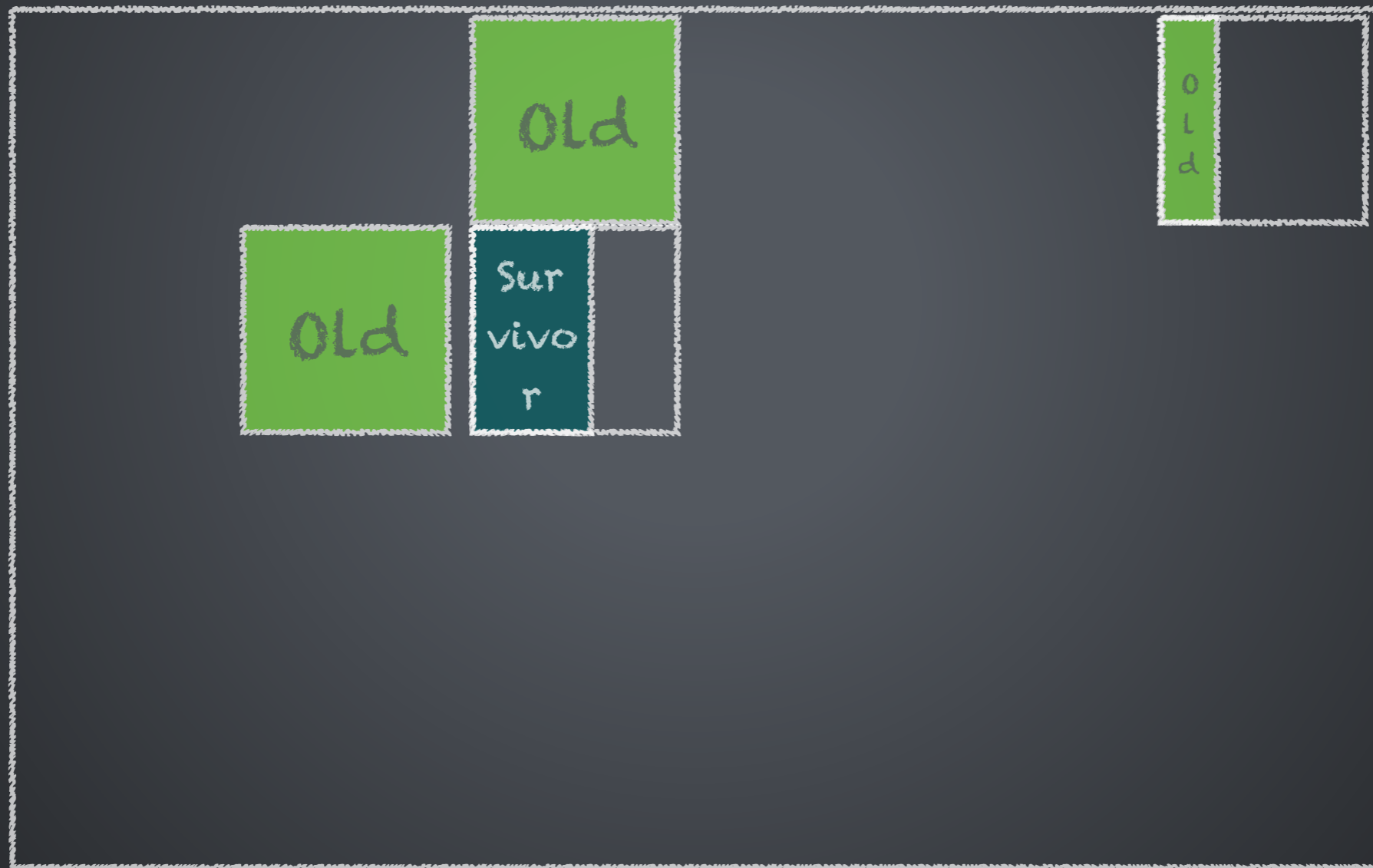


# During a Mixed Collection





# After a Mixed Collection





A Mixed Collection Log  
Snippet with -  
`Xlog:gc*,ergo*=trace`

# Mixed GC

```
[98.879s][info ][gc,start    ] GC(40) Pause Mixed (G1 Evacuation Pause) (98.879s)
[98.879s][trace][gc,ergo,cset] GC(40) Start choosing CSet. pending cards: 9847 predicted
base time: 9.51ms remaining time: 40.49ms target pause time: 50.00ms
[98.879s][trace][gc,ergo,cset] GC(40) Add young regions to CSet. eden: 179 regions,
survivors: 21 regions, predicted young region time: 76.52ms, target pause time: 50.00ms
[98.880s][debug][gc,ergo,cset] GC(40) Finish adding old regions to CSet (predicted time is
too high). predicted time: 0.77ms, remaining time: 0.00ms old 22 regions, min 22 regions
[98.880s][debug][gc,ergo,cset] GC(40) Added expensive regions to CSet (old CSet region num
not reached min).old: 22 regions, expensive: 22 regions, min: 22 regions, remaining time:
0.00ms
[98.880s][debug][gc,ergo,cset] GC(40) Finish choosing CSet. old: 22 regions, predicted old
region time: 14.78ms, time remaining: 0.00
[98.927s][debug][gc,ergo    ] GC(40) continue mixed GCs (candidate old regions
available). candidate old regions: 148 reclaimable: 91013912 (8.48) threshold: 5
[98.927s][info ][gc,heap    ] GC(40) Eden regions: 179->0(193)
[98.927s][info ][gc,heap    ] GC(40) Survivor regions: 21->7(25)
[98.927s][info ][gc,heap    ] GC(40) Old regions: 291->289
[98.927s][info ][gc,heap    ] GC(40) Humongous regions: 14->14
[98.927s][info ][gc,metaspace] GC(40) Metaspace: 10418K->10418K(1058816K)
[98.927s][info ][gc        ] GC(40) Pause Mixed (G1 Evacuation Pause) 503M->309M(1024M)
(98.879s, 98.927s) 47.529ms
[98.927s][info ][gc,cpu     ] GC(40) User=0.36s Sys=0.01s Real=0.05s
```

# Mixed GC

```
[98.879s][info ][gc,start      ] GC(40) Pause Mixed (G1 Evacuation Pause) (98.879s)
[98.879s][trace][gc,ergo,cset] GC(40) Start choosing CSet. pending cards: 9847 predicted base time: 9.51ms
remaining time: 40.49ms target pause time: 50.00ms
[98.879s][trace][gc,ergo,cset] GC(40) Add young regions to CSet. eden: 179 regions, survivors: 21 regions,
predicted young region time: 76.52ms, target pause time: 50.00ms
[98.880s][debug][gc,ergo,cset] GC(40) Finish adding old regions to CSet (predicted time is too high).
predicted time: 0.77ms, remaining time: 0.00ms old 22 regions, min 22 regions
[98.880s][debug][gc,ergo,cset] GC(40) Added expensive regions to CSet (old CSet region num not reached
min).old: 22 regions, expensive: 22 regions, min: 22 regions, remaining time: 0.00ms
[98.880s][debug][gc,ergo,cset] GC(40) Finish choosing CSet. old: 22 regions, predicted old region time:
14.78ms, time remaining: 0.00
[98.927s][debug][gc,ergo      ] GC(40) continue mixed GCs (candidate old regions available). candidate old
regions: 148 reclaimable: 91013912 (8.48) threshold: 5
[98.927s][info ][gc,heap      ] GC(40) Eden regions: 179->0(193)
[98.927s][info ][gc,heap      ] GC(40) Survivor regions: 21->7(25)
[98.927s][info ][gc,heap      ] GC(40) Old regions: 291->289
[98.927s][info ][gc,heap      ] GC(40) Humongous regions: 14->14
[98.927s][info ][gc,metaspace] GC(40) Metaspace: 10418K->10418K(1058816K)
[98.927s][info ][gc          ] GC(40) Pause Mixed (G1 Evacuation Pause) 503M-
>309M(1024M) (98.879s, 98.927s) 47.529ms
[98.927s][info ][gc,cpu       ] GC(40) User=0.36s Sys=0.01s Real=0.05s
```

# Mixed GC

```
[98.879s][info ][gc,start      ] GC(40) Pause Mixed (G1 Evacuation Pause) (98.879s)
[98.879s][trace][gc,ergo,cset] GC(40) Start choosing CSet. pending cards: 9847 predicted base time: 9.51ms
remaining time: 40.49ms target pause time: 50.00ms
[98.879s][trace][gc,ergo,cset] GC(40) Add young regions to CSet. eden: 179
regions, survivors: 21 regions, predicted young region time: 76.52ms, target
pause time: 50.00ms
[98.880s][debug][gc,ergo,cset] GC(40) Finish adding old regions to CSet (predicted time is too high).
predicted time: 0.77ms, remaining time: 0.00ms old 22 regions, min 22 regions
[98.880s][debug][gc,ergo,cset] GC(40) Added expensive regions to CSet (old CSet region num not reached
min).old: 22 regions, expensive: 22 regions, min: 22 regions, remaining time: 0.00ms
[98.880s][debug][gc,ergo,cset] GC(40) Finish choosing CSet. old: 22 regions, predicted old region time:
14.78ms, time remaining: 0.00
[98.927s][debug][gc,ergo      ] GC(40) continue mixed GCs (candidate old regions available). candidate old
regions: 148 reclaimable: 91013912 (8.48) threshold: 5
[98.927s][info ][gc,heap      ] GC(40) Eden regions: 179->0(193)
[98.927s][info ][gc,heap      ] GC(40) Survivor regions: 21->7(25)
[98.927s][info ][gc,heap      ] GC(40) Old regions: 291->289
[98.927s][info ][gc,heap      ] GC(40) Humongous regions: 14->14
[98.927s][info ][gc,metaspace] GC(40) Metaspace: 10418K->10418K(1058816K)
[98.927s][info ][gc          ] GC(40) Pause Mixed (G1 Evacuation Pause) 503M->309M(1024M) (98.879s, 98.927s)
47.529ms
[98.927s][info ][gc,cpu       ] GC(40) User=0.36s Sys=0.01s Real=0.05s
```



# Mixed GC

```
[98.879s][info ][gc,start    ] GC(40) Pause Mixed (G1 Evacuation Pause) (98.879s)
[98.879s][trace][gc,ergo,cset] GC(40) Start choosing CSet. pending cards: 9847 predicted base time: 9.51ms
remaining time: 40.49ms target pause time: 50.00ms
[98.879s][trace][gc,ergo,cset] GC(40) Add young regions to CSet. eden: 179 regions, survivors: 21 regions,
predicted young region time: 76.52ms, target pause time: 50.00ms
[98.880s][debug][gc,ergo,cset] GC(40) Finish adding old regions to CSet
(predicted time is too high). predicted time: 0.77ms, remaining time: 0.00ms old
22 regions, min 22 regions
[98.880s][debug][gc,ergo,cset] GC(40) Added expensive regions to CSet (old CSet
region num not reached min).old: 22 regions, expensive: 22 regions, min: 22
regions, remaining time: 0.00ms
[98.880s][debug][gc,ergo,cset] GC(40) Finish choosing CSet. old: 22 regions,
predicted old region time: 14.78ms, time remaining: 0.00
[98.927s][debug][gc,ergo    ] GC(40) continue mixed GCs (candidate old regions available). candidate old
regions: 148 reclaimable: 91013912 (8.48) threshold: 5
[98.927s][info ][gc,heap    ] GC(40) Eden regions: 179->0(193)
[98.927s][info ][gc,heap    ] GC(40) Survivor regions: 21->7(25)
[98.927s][info ][gc,heap    ] GC(40) Old regions: 291->289
[98.927s][info ][gc,heap    ] GC(40) Humongous regions: 14->14
[98.927s][info ][gc,metaspace] GC(40) Metaspace: 10418K->10418K(1058816K)
[98.927s][info ][gc        ] GC(40) Pause Mixed (G1 Evacuation Pause) 503M->309M(1024M) (98.879s, 98.927s)
47.529ms
[98.927s][info ][gc,cpu     ] GC(40) User=0.36s Sys=0.01s Real=0.05s
```



# Mixed GC

- `XX:G1MixedGCCountTarget`

# Mixed GC

```
[98.880s][debug][gc,ergo,cset] GC(40) Finish adding old regions to CSet (predicted time is too high). predicted time: 0.77ms, remaining time: 0.00ms old 22 regions, min 22 regions
```

```
[98.880s][debug][gc,ergo,cset] GC(40) Added expensive regions to CSet (old CSet region num not reached min).old: 22 regions, expensive: 22 regions, min: 22 regions, remaining time: 0.00ms
```

```
[98.880s][debug][gc,ergo,cset] GC(40) Finish choosing CSet. old: 22 regions, predicted old region time: 14.78ms, time remaining: 0.00
```

# Mixed GC

```
[239.335s][debug][gc,ergo,cset] GC(145) Finish adding old regions to CSet (predicted time is too high). predicted time: 1.23ms, remaining time: 0.83ms old 45 regions, min 16 regions
```

```
[239.335s][debug][gc,ergo,cset] GC(145) Finish choosing CSet. old: 45 regions, predicted old region time: 28.08ms, time remaining: 0.83
```

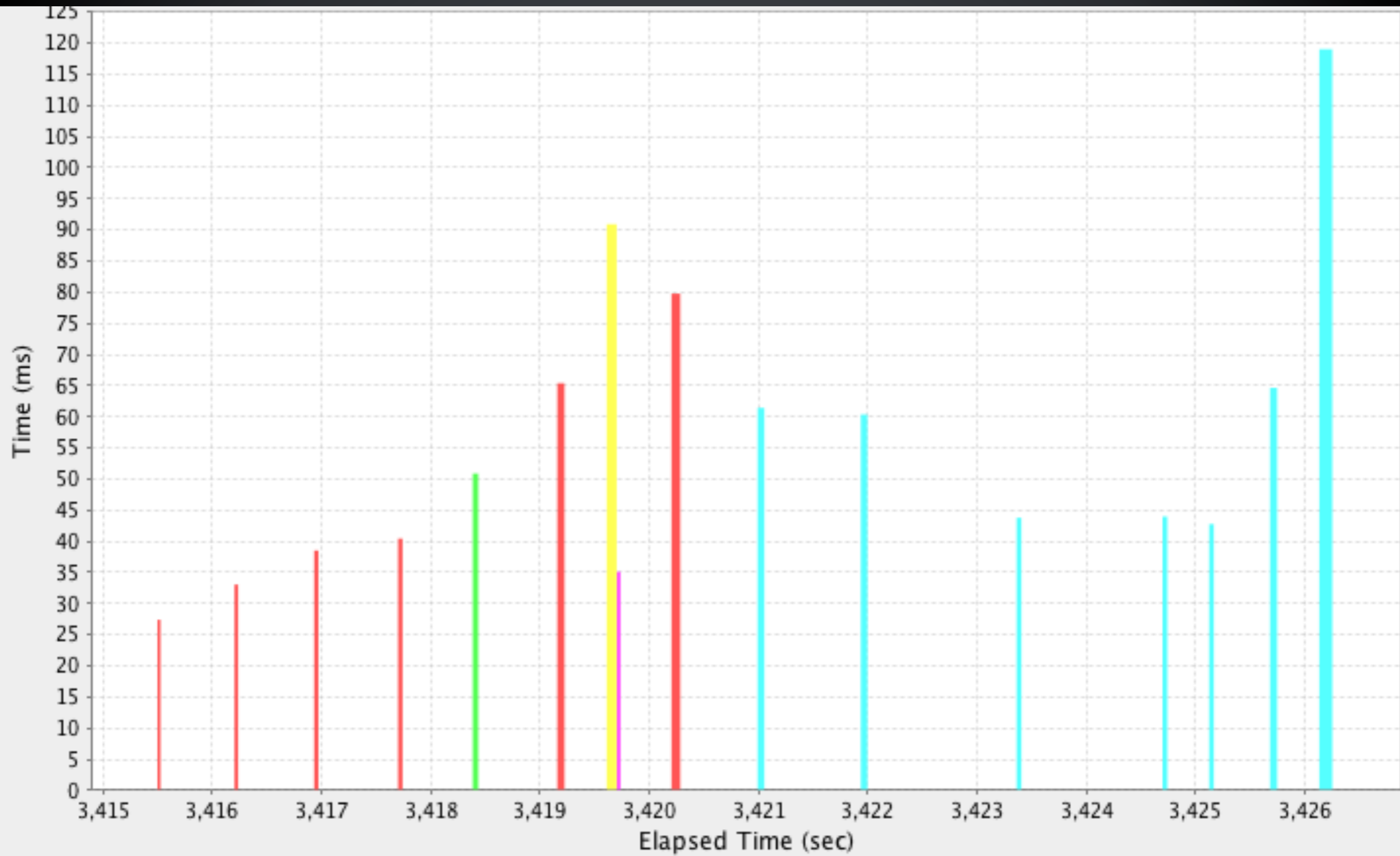
# Mixed GC

- `XX:G1HeapWastePercent`

# Mixed GC

```
[98.879s][info ][gc,start      ] GC(40) Pause Mixed (G1 Evacuation Pause) (98.879s)
[98.879s][trace][gc,ergo,cset] GC(40) Start choosing CSet. pending cards: 9847 predicted base time: 9.51ms
remaining time: 40.49ms target pause time: 50.00ms
[98.879s][trace][gc,ergo,cset] GC(40) Add young regions to CSet. eden: 179 regions, survivors: 21 regions,
predicted young region time: 76.52ms, target pause time: 50.00ms
[98.880s][debug][gc,ergo,cset] GC(40) Finish adding old regions to CSet (predicted time is too high).
predicted time: 0.77ms, remaining time: 0.00ms old 22 regions, min 22 regions
[98.880s][debug][gc,ergo,cset] GC(40) Added expensive regions to CSet (old CSet region num not reached
min).old: 22 regions, expensive: 22 regions, min: 22 regions, remaining time: 0.00ms
[98.880s][debug][gc,ergo,cset] GC(40) Finish choosing CSet. old: 22 regions, predicted old region time:
14.78ms, time remaining: 0.00
[98.927s][debug][gc,ergo      ] GC(40) continue mixed GCs (candidate old regions
available). candidate old regions: 148 reclaimable: 91013912 (8.48) threshold: 5
[98.927s][info ][gc,heap      ] GC(40) Eden regions: 179->0(193)
[98.927s][info ][gc,heap      ] GC(40) Survivor regions: 21->7(25)
[98.927s][info ][gc,heap      ] GC(40) Old regions: 291->289
[98.927s][info ][gc,heap      ] GC(40) Humongous regions: 14->14
[98.927s][info ][gc,metaspace] GC(40) Metaspace: 10418K->10418K(1058816K)
[98.927s][info ][gc          ] GC(40) Pause Mixed (G1 Evacuation Pause) 503M->309M(1024M) (98.879s, 98.927s)
47.529ms
[98.927s][info ][gc,cpu       ] GC(40) User=0.36s Sys=0.01s Real=0.05s
```





■ Young GC 
 ■ Full GC 
 ■ Initial Mark 
 ■ Remark 
 ■ Cleanup 
 ■ Mixed GC 
 ■ To Space Exhausted

# Promotion/Evacuation Failures In The G1 Collector

# Evacuation Failures

```
276.731: [GC pause (G1 Evacuation Pause) (young) (to-space exhausted),
0.8272932 secs]
  [Parallel Time: 387.0 ms, GC Workers: 8]
```

```
<snip>
```

```
  [Code Root Fixup: 0.1 ms]
  [Code Root Purge: 0.0 ms]
  [Clear CT: 0.2 ms]
[Other: 440.0 ms]
  [Evacuation Failure: 437.5 ms]
  [Choose CSet: 0.0 ms]
  [Ref Proc: 0.1 ms]
  [Ref Enq: 0.0 ms]
  [Redirty Cards: 0.9 ms]
  [Humongous Reclaim: 0.0 ms]
  [Free CSet: 0.9 ms]
  [Eden: 831.0M(900.0M)->0.0B(900.0M) Survivors: 0.0B->0.0B Heap: 1020.1M(1024.0M)-
>1020.1M(1024.0M)]
  [Times: user=3.64 sys=0.20, real=0.83 secs]
```

```
**
```

# Evacuation Failures

- When there are no more regions available for survivors or tenured objects, G1 GC encounters an evacuation failure.
- An evacuation failure is expensive and the usual pattern is that if you see a couple of evacuation failures; full GC could\* soon follow.

# Avoiding Evacuation Failures

A heavily tuned JVM command line may be restricting the G1 GC ergonomics and adaptability.

- ★ Start with just your heap sizes and a reasonable pause time goal



# Avoiding Evacuation Failures

Your live data set + long live transient data may be too large for the old generation

- ★ Check LDS+ and increase heap to accommodate everything in the old generation.

# Avoiding Evacuation Failures

Initiating Heap Occupancy Threshold could be the issue.

- ★ Check IHOP and make sure it accommodates the LDS+.
- ★ IHOP threshold too high -> Delayed marking -> Delayed incremental compaction -> Evacuation Failures!

# Avoiding Evacuation Failures

Marking Cycle could be taking too long to complete?

- ★ Increase concurrent marking threads
- ★ Reduce IHOP

# Avoiding Evacuation Failures

*to-space survivors are the problem?*

- ★ Increase the G1ReservePercent, if to-space survivors are triggering the evacuation failures!



# Avoiding Evacuation Failures

fragmentation an issue?



# Fragmentation In The G1 Collector

# G1 Heap Waste Percentage

- G1 GC is designed to “absorb” some fragmentation.
- Default is 5% of the total Java heap
- Tradeoff so that expensive regions are left out.

# G1 Mixed GC (Region) Liveness Threshold

- G1 GC's old regions are also designed to “absorb” some fragmentation.
- Default is 85% liveness in a G1 region.
- Tradeoff so that expensive regions are left out.

# Humongous Objects

# Humongous Objects



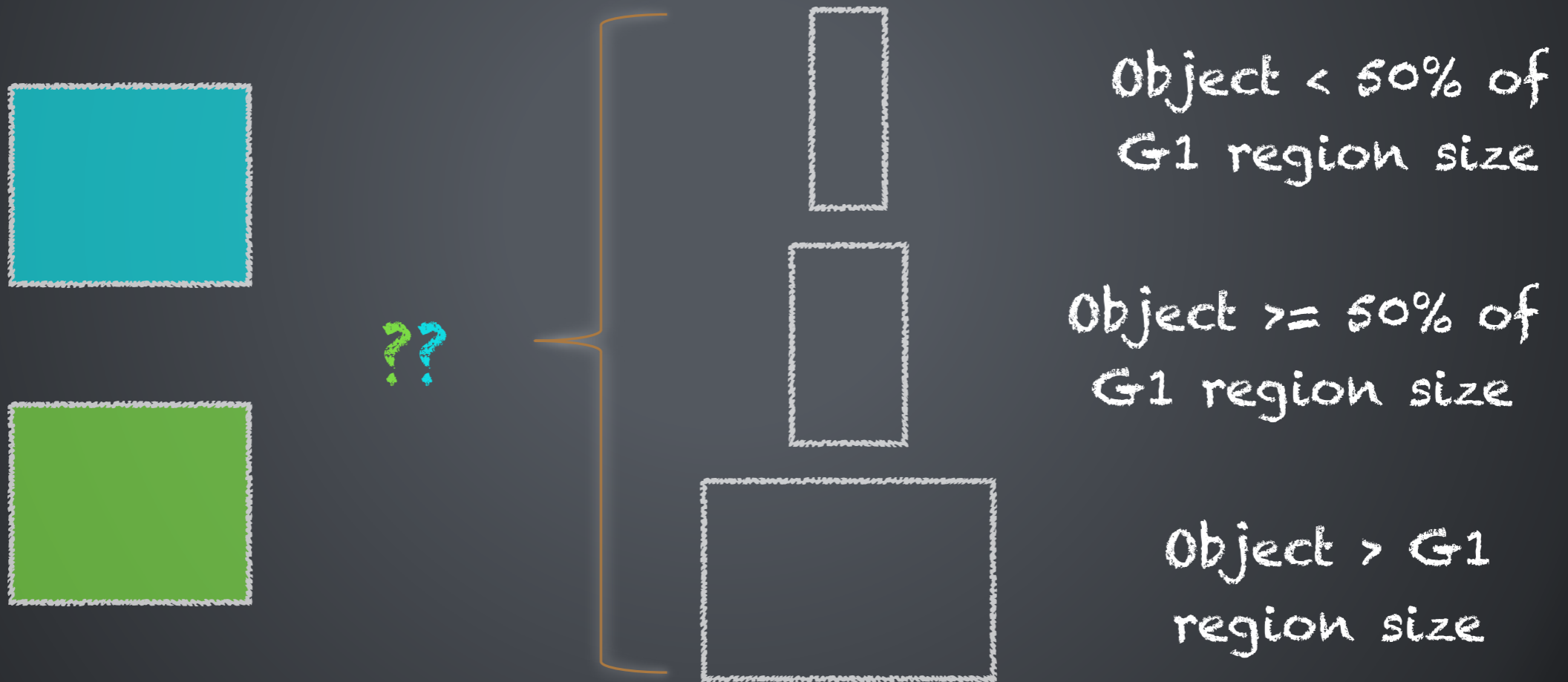
A young generation region



An old generation region



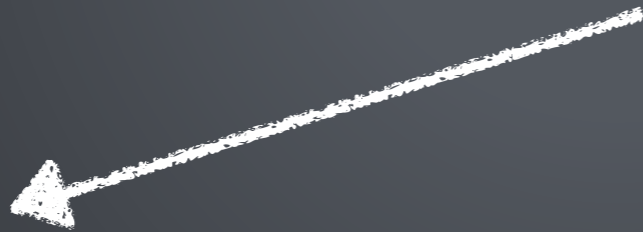
# Humongous Objects



# Humongous Objects

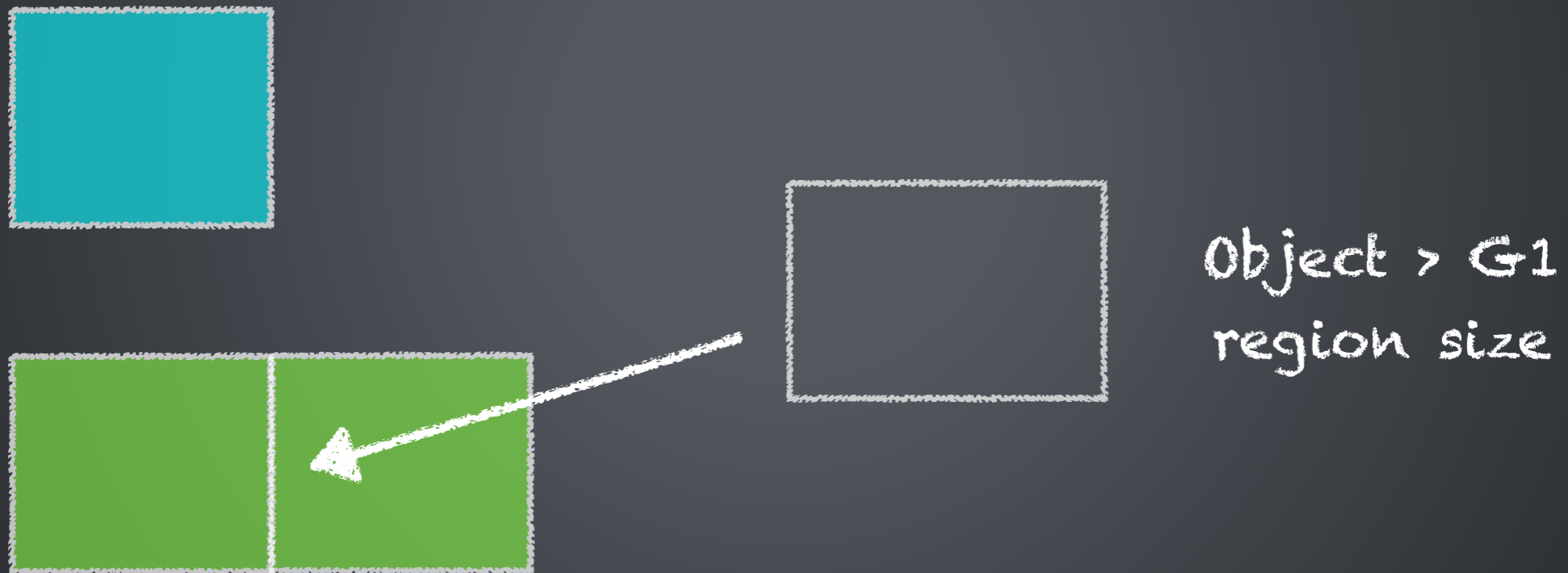


# Humongous Objects



Object  $\geq$  50% of  
G1 region size

# Humongous Objects



# Humongous Objects

Object NOT Humongous



Object Humongous



Wasted Space!

Object Humongous →  
Needs Contiguous Regions





# Humongous Objects

Ideally, humongous objects are few in number and are short lived.

- ★ A lot of long-lived humongous objects can cause evacuation failures since humongous regions add to the old generation occupancy.

Humongous Allocation  
Log Snippet with -  
Xlog:gc\*,ergo\*

# Humongous Allocations

```
[161.363s][info][gc,start    ] GC(110) Pause Initial Mark (G1
Humongous Allocation) (161.363s)
[161.388s][info][gc,heap      ] GC(110) Eden regions: 33-
>0(61)
[161.388s][info][gc,heap      ] GC(110) Survivor regions: 14-
>5(13)
[161.388s][info][gc,heap      ] GC(110) Old regions: 431->445
[161.388s][info][gc,heap      ] GC(110) Humongous regions: 32-
>32
[161.388s][info][gc,metaspace] GC(110) Metaspace: 10422K-
>10422K(1058816K)
[161.388s][info][gc          ] GC(110) Pause Initial Mark (G1
Humongous Allocation) 508M->481M(662M) (161.363s, 161.388s)
25.455ms
[161.388s][info][gc,cpu       ] GC(110) User=0.18s Sys=0.00s
Real=0.02s
```

# The Tuneables

# Tuneables

## Goal:

Get the GC ergonomics to work for you and know the defaults

## Tunables:

- Pause time goal, heap size, max and min nursery, concurrent and parallel threads
- The marking threshold, number of mixed GCs after marking, liveness threshold for the old regions, garbage toleration threshold, max old regions to be collected per mixed collection



# Tuneables

Things to remember -

- Know your defaults!
  - Understand your `G1HeapRegionSize` - It could be any factor of two from 1MB to 32MB. G1 strives for 2048 regions.
- Fixing the nursery size (using `Xmn`) will meddle with the GC ergonomics/adaptiveness.
- Don't set really aggressive pause time goals - this will increase the GC overhead.
- Spend time taming your mixed GCs - mixed GCs are incremental collections

# Tuneables

Things to remember -

- Taming mixed GCs:
  - Adjust the marking cycle according to you live data set.
  - Adjust you liveness threshold - this is the live occupancy threshold per region. Any region with liveness beyond this threshold will not be included in a mixed collection.
  - Adjust your garbage toleration threshold - helps G1 not get too aggressive with mixed collections
  - Distribute mixed GC pauses over a number of mixed collections - adjust your mixed GC count target and change your max old region threshold percent so that you can limit the old regions per collection

# Further Reading

<http://www.infoq.com/articles/G1-One-Garbage-Collector-To-Rule-Them-All>

<http://www.infoq.com/articles/tuning-tips-G1-GC>

<http://www.infoq.com/articles/Make-G1-Default-Garbage-Collector-in-Java-9>

Upcoming Book: Java Performance Companion, Chapters 1-3.

Unified GC Logging: <http://openjdk.java.net/jeps/271>

# Questions?

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