GC and Performance Tips

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Agenda

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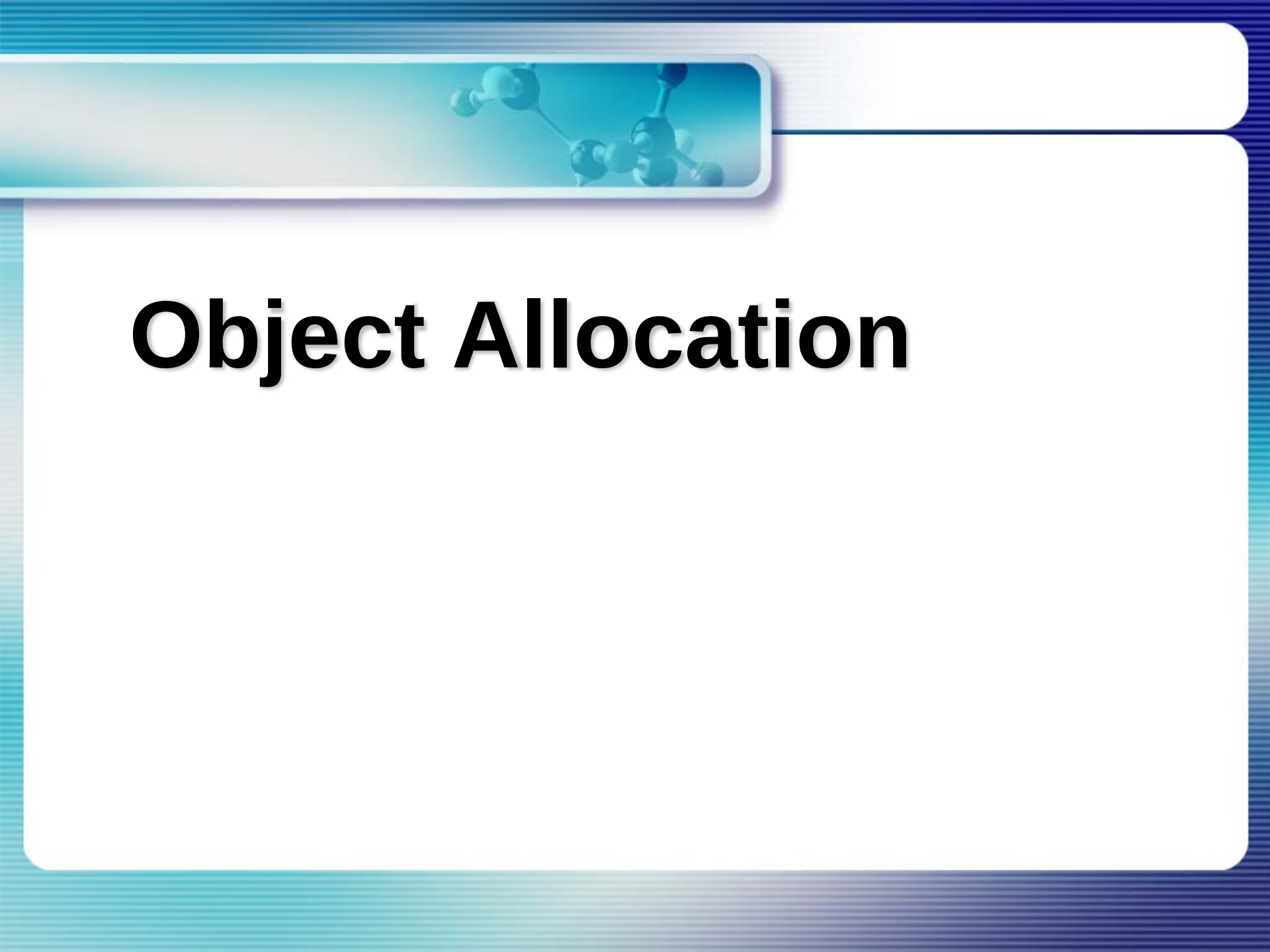

Object Allocation

Creating Work for the GC

- Allocation
  - But, typically, **super** fast
    - Maybe more expensive for non-compacting GCs
  - Higher allocation rate implies more frequent GCs
- Live data size
  - More work for the GC to find what is live
- Reference field updates
  - More overhead on the application, …
  - And it also creates more work for the GC
    - Especially on generational/incremental GCs

Object Allocation

- Typically, object allocation is very cheap!
  - 10 native instructions in the fast common case
  - No remembered set overhead on new objects
  - C/C++ has faster allocation? Not!
- Reclamation of new objects is very cheap too!
  - Young GCs in generational systems
- So
  - Do not be afraid to allocate small objects for intermediate results
  - GCs **love** small, immutable objects
  - Generational GCs **love** small, short-lived objects

Object Allocation

- This is NOT advising needless allocation
  - More allocation means more GC
- What this does mean is
  - Try to use short-lived immutable objects instead of long-lived mutable objects
  - Use clearer, simpler code with more allocations instead of more obscure code with fewer allocations

Large Objects

Large Objects

- Very large objects are:
  - Expensive to allocate (maybe not through the fast path)
  - Expensive to initialize (zeroing)
  - Can cause performance issues
- Large objects of different sizes can cause fragmentation
  - For non-compacting or partially-compacting GCs
- Avoid if you can
  - And, yes, this is not always possible or desirable

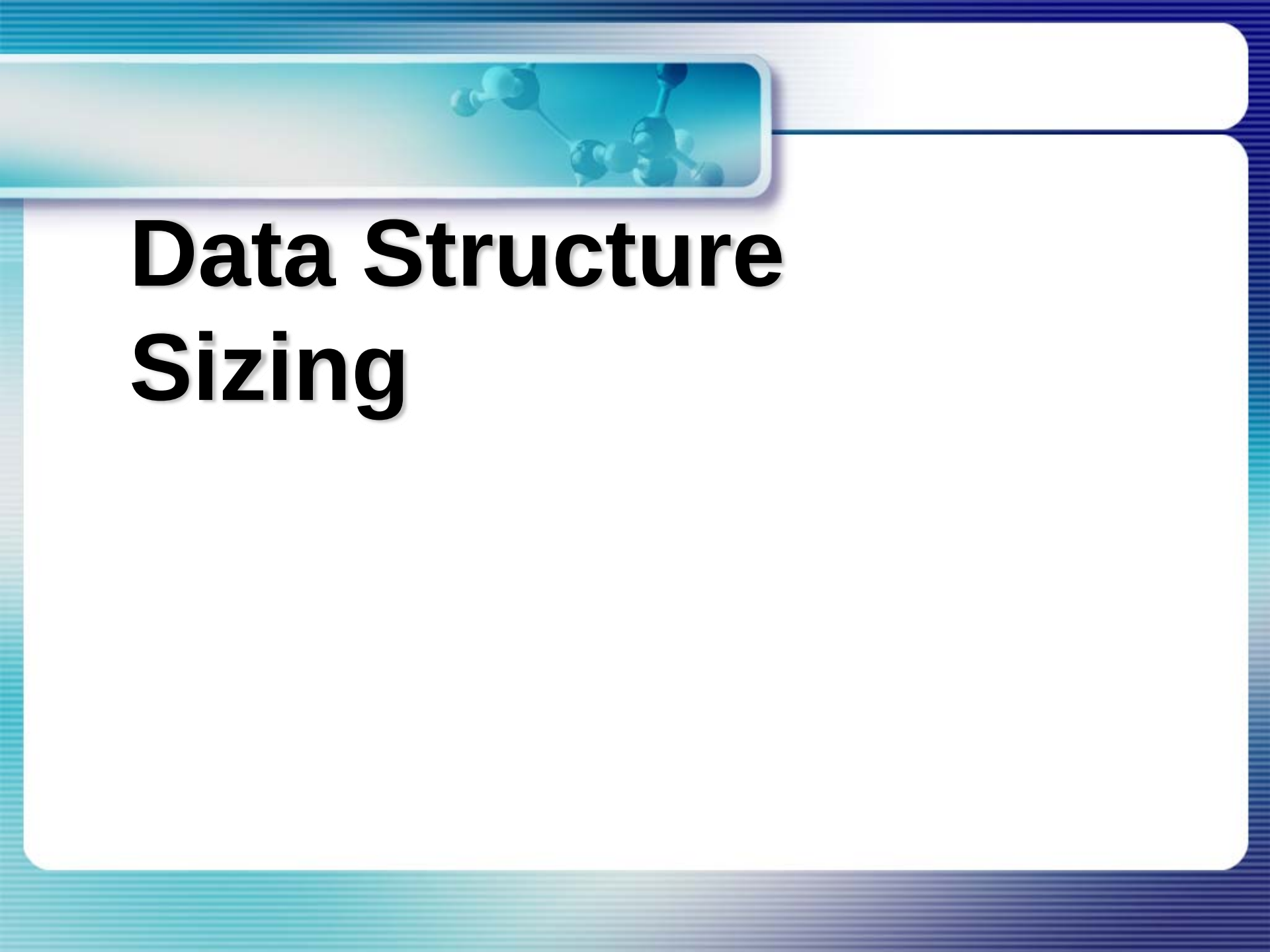
Explicit GCs

Explicit GCs

- DO NOT DO IT!
  - Applications do not have enough information
  - GC does (knows allocation/promotion rate, etc.)
  - System.gc() at the wrong time
    - Hurts performance with no benefit
- Exceptions
  - Between well-defined application phases (maybe)
  - When performance does not matter (e.g., late at night)
- Java HotSpot™ virtual machine
  - System.gc() does a stop-the-world full GC
  - Use -XX:+DisableExplicitGC to ignore System.gc()

Explicit GCs

- Incremental GCs
  - Designed to avoid full GCs…
  - But System.gc() does exactly that!
- In the Java HotSpot virtual machine (CMS)
  - -XX:+ExplicitGCInvokesConcurrent
- Beware
  - Libraries that call System.gc()
    - Run FindBugs over your libraries to check for that
  - Java™ RMI calls System.gc() for its distributed GC algorithm
    - Decrease its frequency, or invoke concurrent, or both!


Data Structure
Sizing

Data Structure Sizing

- Array-based data structures
  - Avoid frequent re-sizing
- e.g., this will allocate the associated array twice

```
  ArrayList<String> list = new ArrayList<String>();
list.ensureCapacity(1024);
```

- The preferred version
  - (Part of periodic audits of the Java Platform, Standard Edition (Java SE) libraries)

```
ArrayList<String> list = new
ArrayList<String>(1024);
```

Data Structure Sizing

- Additionally, try to size data structures as realistically as possible

```
ArrayList<String> list = new
ArrayList<String>(1024);
```

- If 1M strings are added to it:
  - Several array-resizing operations will take place
  - They will allocate several large-ish arrays
  - They will cause a lot of array copying
  - They might cause fragmentation issues on non-compacting GCs

Object Pooling

Object Pooling

- Legacy of older VMs with terrible allocation performance
- Remember
  - Generational GCs **love** short-lived, immutable objects…
  - Not long-lived, highly mutable objects
- Unused objects in pools
  - Are like a bad tax
  - Are live; the GC must process them
  - Provide no benefit; the application does not use them

Object Pooling

- Exceptions
  - Objects that are expensive to allocate and/or initialize
  - Objects that represent scarce resources
  - Examples
    - Threads pools
    - Database connection pools
- Caveats to the exceptions
  - Use existing libraries wherever possible
  - Can you write a better thread pool than Doug Lea?

Problems with Finalization

Finalization Description

- Finalization
  - Essentially, a postmortem hook
  - Allows cleanup when GC finds an object unreachable
  - Typically used to reclaim native resources
- Finalizable objects
  - Have a non-trivial finalize() method

Allocation/Reclamation

- Finalizable object allocation
  - Much slower
  - The VM must track finalizable objects
- Finalizable object reclamation
  - It takes at least two GC cycles
    - The GC cycles are slower too
  - First cycle identifies object as garbage
    - Enqueues object on finalization queue
  - Second cycle reclaims space after finalize() completes
    - Unless finalize() resurrects the object!

Finalizers vs. Destructors

- Beware
  - Finalizers are not like C++ destructors!
- No guarantees
  - When they will be called
  - Whether they will be called
  - The order in which they will be called
- The closest concept to a destructor
  - Finally clause

Finalizers and Memory Retention

- Finalizable objects
  - Are retained longer
  - Along with everything reachable from them
  - finalize() is an application-defined method
    - It may access any field
- More pressure on the GC

“Sneaky” Memory Retention

- You do not have to explicitly use finalizers
  - To be affected by finalization-induced heap pressure
  - Library classes you extend might define finalizers
- Below, buffer will survive at least two GC cycles
  - In Java Development Kit (JDK™) 1.5 and earlier

```
class MyFrame extends JFrame {
   private byte[] buffer = new byte[16 * 1024 * 1024];
   ...
}
```

Memory Leak Types

- “Traditional” memory leaks
  - Heap keeps growing, and growing, and growing…
  - OutOfMemoryError
- “Temporary” memory leaks
  - Heap usage is temporarily very high, then it decreases
  - Bursts of frequent GCs
- Both finalizers and reference objects
  - Can delay the reclamation of objects…
  - As well as everything reachable from them
  - Temporary heap usage spikes

Memory Leak Detection Tools

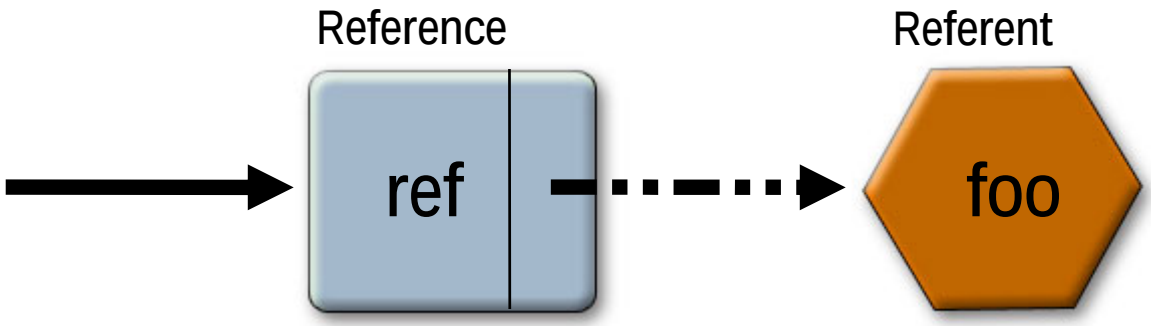
- Many tools to choose from
- ***"Is there a memory leak"?***
  - Monitor VM's heap usage with jconsole and jstat
- ***"Which objects are filling up the heap?"***
  - *Get a class histogram with* jmap or
  - -XX:+PrintClassHistogram and Ctrl-Break
- ***"Why are these objects still reachable?"***
  - Get reachability analysis with jhat

Using Reference Objects

Reference Objects

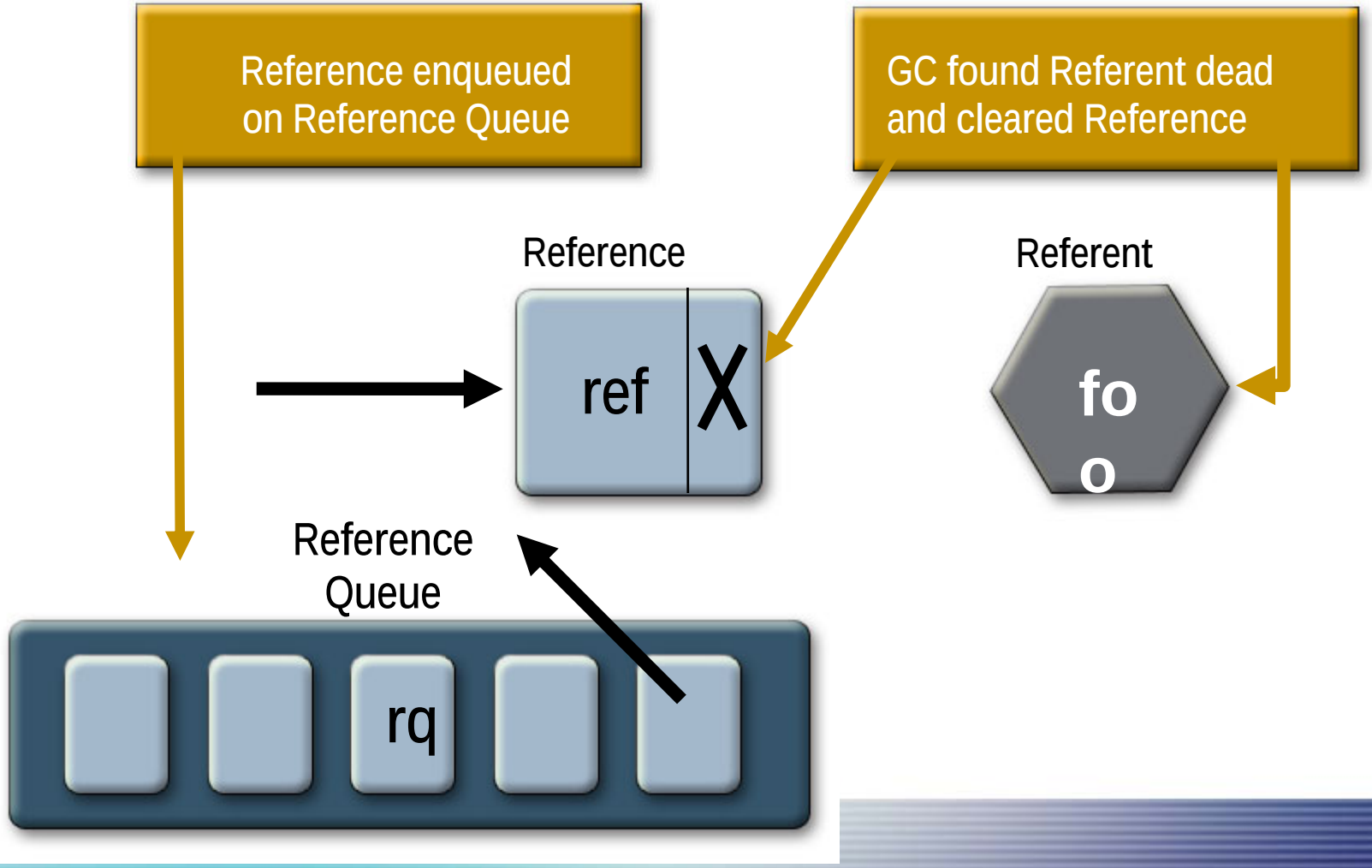
- Purpose
  - Postmortem hooks, more flexible than finalization
- Three types of reference objects
  - Weak references
  - Soft references
  - Phantom references
- All three
  - Can enqueue the reference object…
  - On a designated reference Queue…
  - When the GC finds its referent to be unreachable

Reference Objects: Illustration (1/2)




```
ref  = new WeakReference(foo, rq);
```

Reference Objects: Illustration



Weak References

Weak References

- Uses
  - ***Tell me if the object has been reclaimed by the GC"***
  - ***Do not retain this object because of this reference"***
- get() returns
  - The referent, if not reclaimed
  - null, otherwise
- Referent is cleared by the GC

Weak References

- Using weak references you can implement a flexible version of finalization that allows you to…
  - Prioritize object “finalization,”
  - Decide when to run object “finalization,”
  - Stop objects from being considered for “finalization,”
  - Be unaffected by the VM’s finalization queue,
  - Etc.
- See link below for a code sketch
  - http://www.devx.com/Java/Article/30192

Soft References

- Uses
  - ***Only reclaim this object if there is memory pressure”***
- get() returns
  - The referent, if not reclaimed
  - null, otherwise
- *Referent is cleared by the GC*

Soft References

- Implementing soft reference policy is tricky
  - Hard to make informed decisions
    - How much data reachable from each reference?
      - Prohibitively expensive to calculate
    - How expensive to recreate?
- OK for quick and simple caches
  - Remember: create strong references to data you want to keep

Phantom References

- Uses
  - ***Keep some data around after the object becomes unreachable so that I can use that data to clean up after the object”***
- *get() returns*
  - *null, always*
- *Referent is **not** cleared by the GC automatically*
  - *It is cleared when the reference object becomes unreachable*

Conclusions

- We covered a series of tips on how to write
  - Simpler
  - More readable
  - More GC-friendly code
- GC Tuning
  - You **will** improve your application performance if you tune GC for your application

More Information

- Memory management white paper
  - http://java.sun.com/j2se/reference/whitepapers/
- Destructors, Finalizers, and Synchronization
  - http://portal.acm.org/citation.cfm?id=604153
- Finalization, Threads, and the Java Technology Memory Model
  - http://developers.sun.com/learning/javaoneonline/2005/coreplatform/TS-3281.html
- Memory-retention due to finalization article
  - http://www.devx.com/Java/Article/30192

More Information

- Heap analysis tools
  - Monitoring and Management in 6.0
    - http://java.sun.com/developer/technicalArticles/J2SE/monitoring/
  - Troubleshooting guide
    - http://java.sun.com/javase/6/webnotes/trouble/
  - JConsole
    - http://java.sun.com/developer/technicalArticles/J2SE/jconsole.html

Thank You !

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