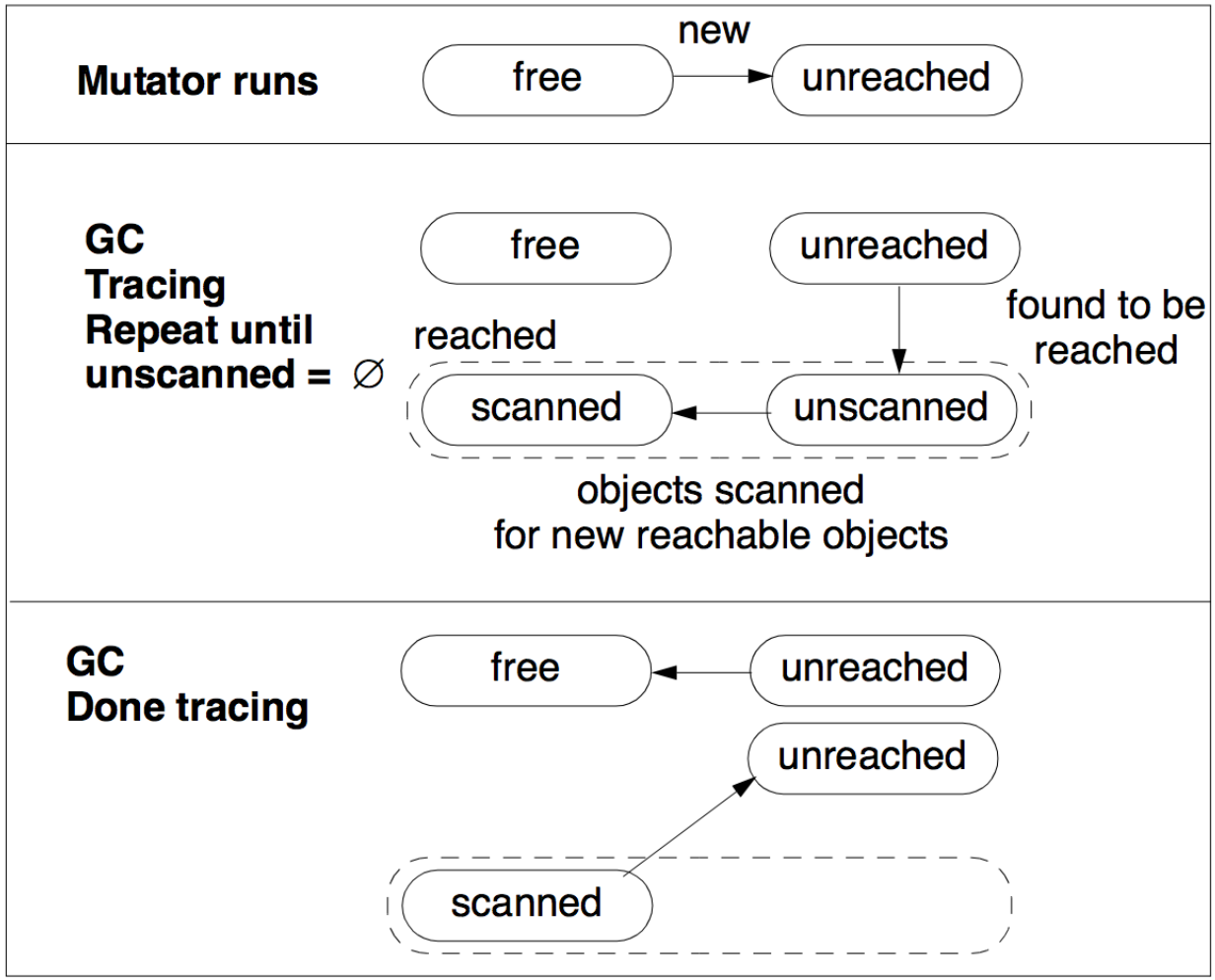
Lecture 18

Advanced Garbage Collection

I. Break Up GC in Time (Incremental)
II. Break Up GC in Space (Partial)

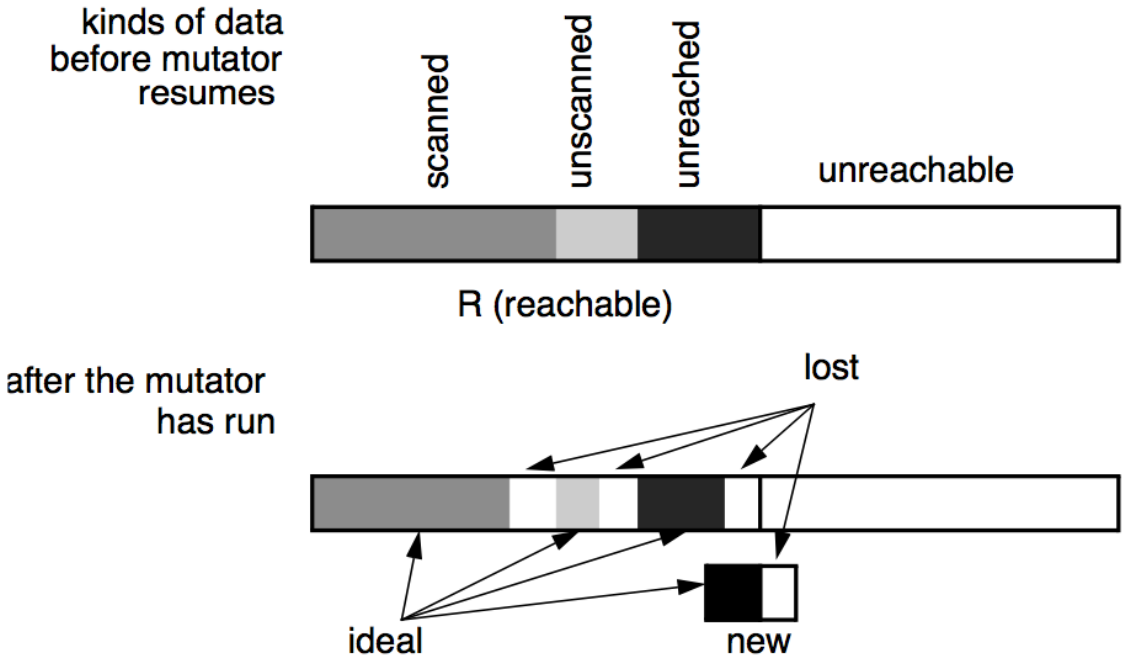
Readings: Ch. 7.6.4 - 7.7.4

Trace-Based GC: Memory Life-Cycle



Incremental GC

- **Interleaves GC with mutator action to reduce pause time**



Ideal = (R ∪ New) - Lost

(R ∪ New) - Lost ⊆ Answer ⊆ (R ∪ New)

Effects of Mutation

- **Reachable set changes as mutator runs**
  - R: set of reachable objects before the mutator runs
  - Ideal: set of reachable objects at the end of the GC cycle
  - New: set of newly created objects
  - Lost: set of objects that become unreachable in the interim
  - Ideal = (R ∪ New) - Lost
- **Ideal: Very expensive**
- **Conservative Incremental GC:**
  May misclassify some unreachable as reachable
  - should not include objects unreachable before GC starts
  - guarantees that garbage will be eliminated in the next round

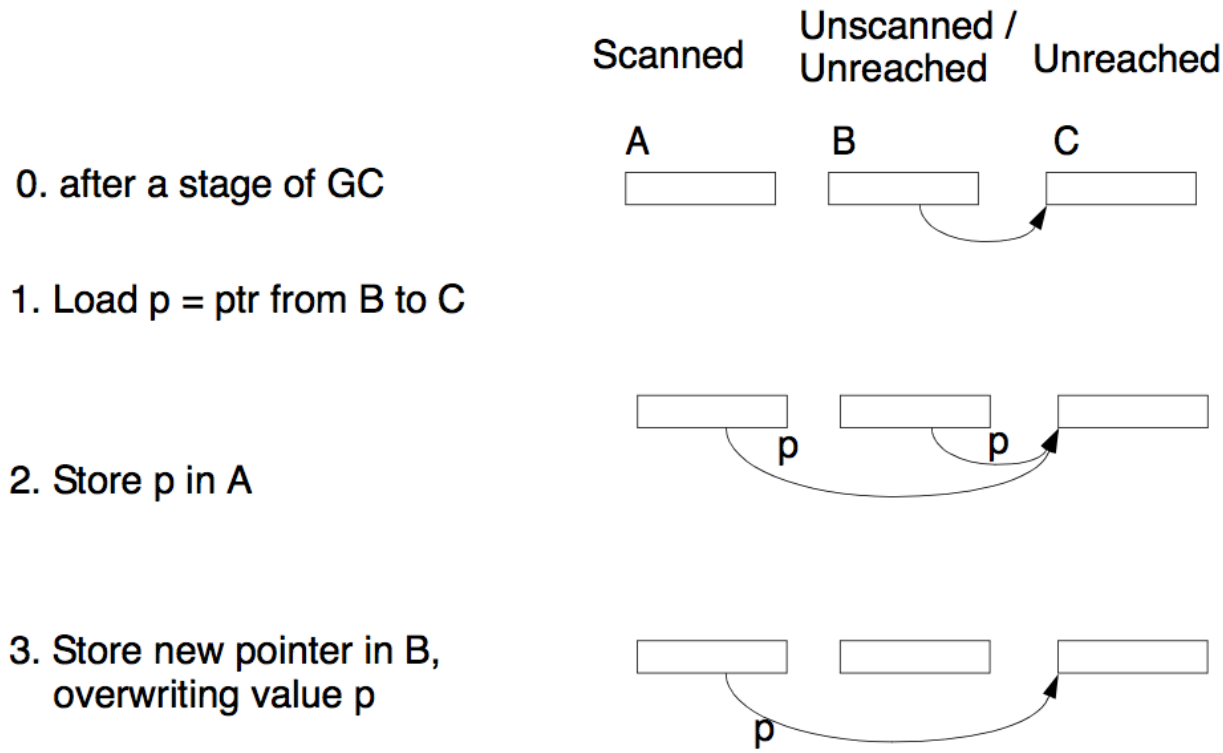
$$\textbf{Ideal} = (\textbf{R} \cup \textbf{New}) - \textbf{Lost} \subseteq \textbf{Answer} \subseteq (\textbf{R} \cup \textbf{New})$$

Algorithm Proposal 1

- **Initial condition**
  - Scanned, Unscanned lists from before
- **To resume GC**
  - Find root sets
  - Place newly reached objects in "unscanned list"
  - Continue to trace reachability without redoing "scanned" objects
- **Did we find all reachable objects?**

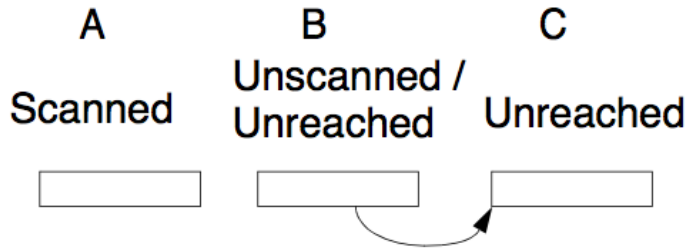
Missed Reachable Objects

- **All reaching pointers are found in "scanned objects"**
- **Requires the occurrence of a 3-step sequence in the mutator:**



Solution

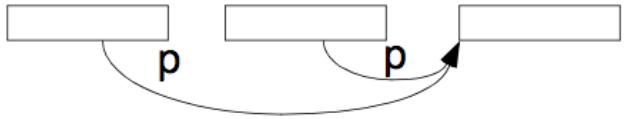
- **Intercept p in any of the three-step sequence**
- **Treat pointee of p as "unscanned"**



0. after a stage of GC

1. Load p = ptr from B to C

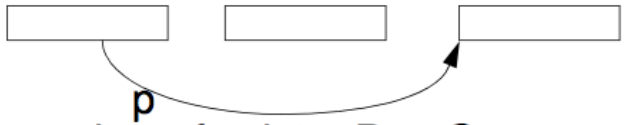
   Read barrier: remember all loads of pointers from B → C



2. Store p in A

   Write barrier: remember all stores of pointers A → C

3. Store new pointer in B, overwriting value p



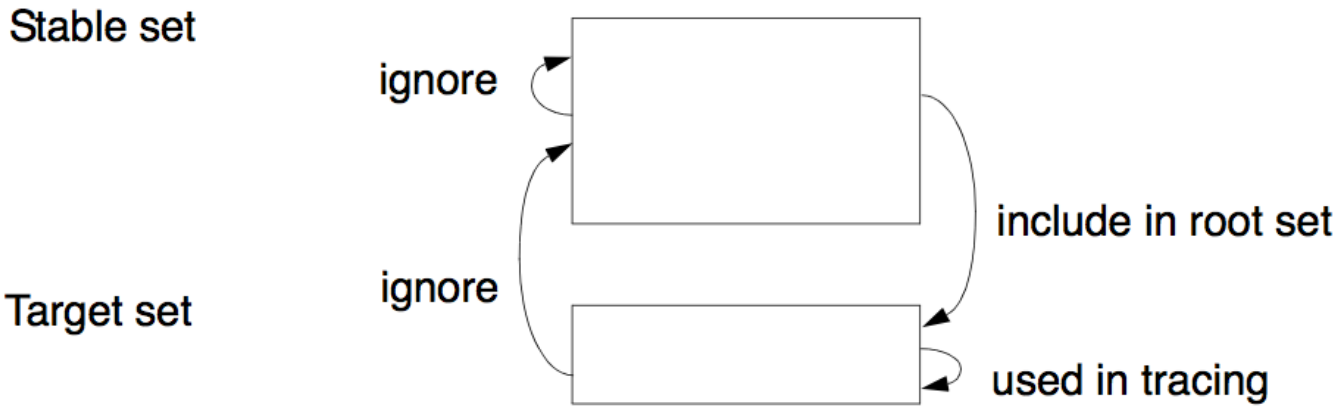
   Overwrite barrier: remember all overwrites of pointer B → C

Efficiency of Different Barriers

- **Most efficient: Write barrier**
  - less instances than read barrier
  - includes less unreachable objects than over-write barriers

II. Partial GC

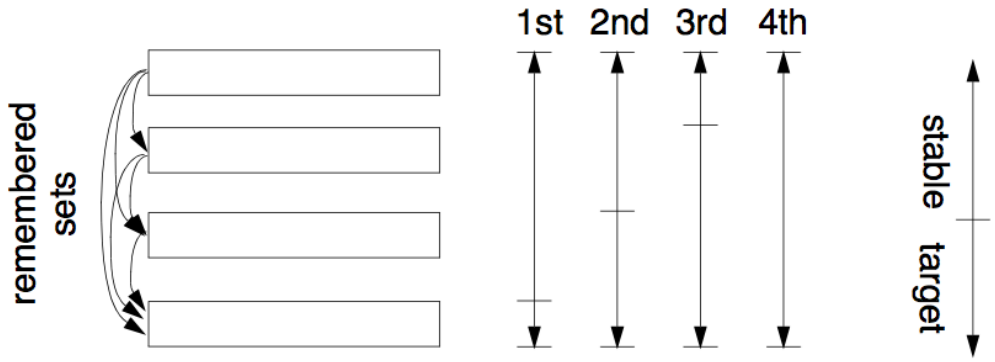
- **Reduces pause time by collecting only objects in the target area:**



- **Algorithm**
  - New "root set"
    = original root set + pointers from Stable to Target set
  - Change program to intercept all writes to Stable set
- **Never misclassify reachable as unreachable**
- **May misclassify unreachable as reachable**

Generational GC

- **Observation: objects die young**
  - 80-98% die within a few million instructions or before 1 MB has been allocated
- **Generational GC: collect newly allocated objects more often**



- **ith generation**
  - new root set
    = original root set + all pointers from generations j to i (j > i)
- **When 1st generation fills up**
  - GC copies reachable objects into 2nd generation, and so on.

Properties

- **Never misclassify reachable as unreachable**

- **Misclassify unreachable as reachable**
  - when pointers in earlier generations are overwritten
  - eventually collect all garbage as generations get larger

- **Effective: time spent on objects that are mostly garbage**

- **GC of mature objects takes longer**
  - Size of target set increases
  - Eventually a full GC is performed

Conclusions

- **Trace-based GC:**
  find all reachable objects, complement to get unreachable
  - 4 states: free, unreached, unscanned, scanned
  - break up reachability analysis
    - in time (incremental)
    - in space (partial: generational)