Garbage Collection

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Reference Counting

- Counts number of pointers to an object
- Object deleted when the count hits zero
- Eager — object deleted as soon as it is finished with
- Problem: Circular references

Reference Counting

- Saw how we can graft reference counting support onto C++
- Programmer must manually retain and release the object
- Can lead to errors
- Isn’t there an automatic method?

Garbage Collection

- Automatically reclaim memory from ‘garbage’ (unused objects)
- Several techniques out there
- Not without its own issues
- Consider the basic techniques

Reference Counting

- Common technique — ActionScript, Python
- Language hides the calls to retain/release object
- Still suffers from circular references and thus memory leaks
- Python tries to find cycles to avoid this

Reference Counting

- Lightweight
- Minimal code required to implement
- Minimal execution time
- Important advantages in real-time environments

Tracing Collectors

- Trace-based Garbage Collector
- 'Trace over every object'
- Look at two types:
  - Mark-sweep collectors
  - Copying collectors

Tracing Collectors

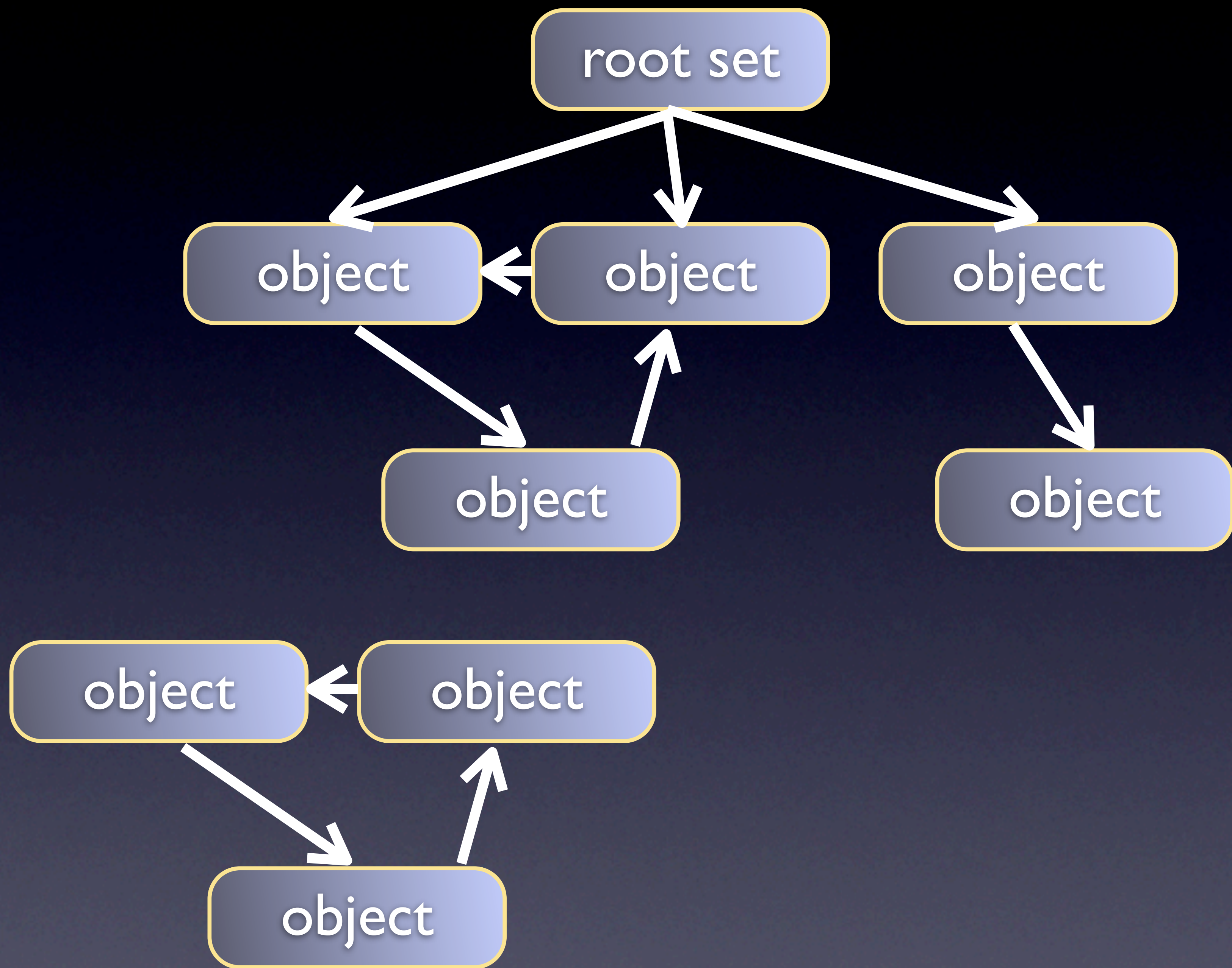
- Stop-the-world
- Check to see which objects are in use
- And, by corollary, those which are not
- Delete the unused ones
- Restart-the-world

Big Problem

- How do we know:
  - Which objects are in use? (or *reachable*)
  - How many objects there are?
- In fact, isn't this the problem Garbage Collection is meant to solve
- Key is in the name — Trace-based

In-use objects

- Assume there is a *root set* of known objects
- Reachable object is the *root set* and any objects referenced by the *root set*
- And any objects referenced by objects referenced by the *root set*…
- Until there are no new objects to add to the set of reachable objects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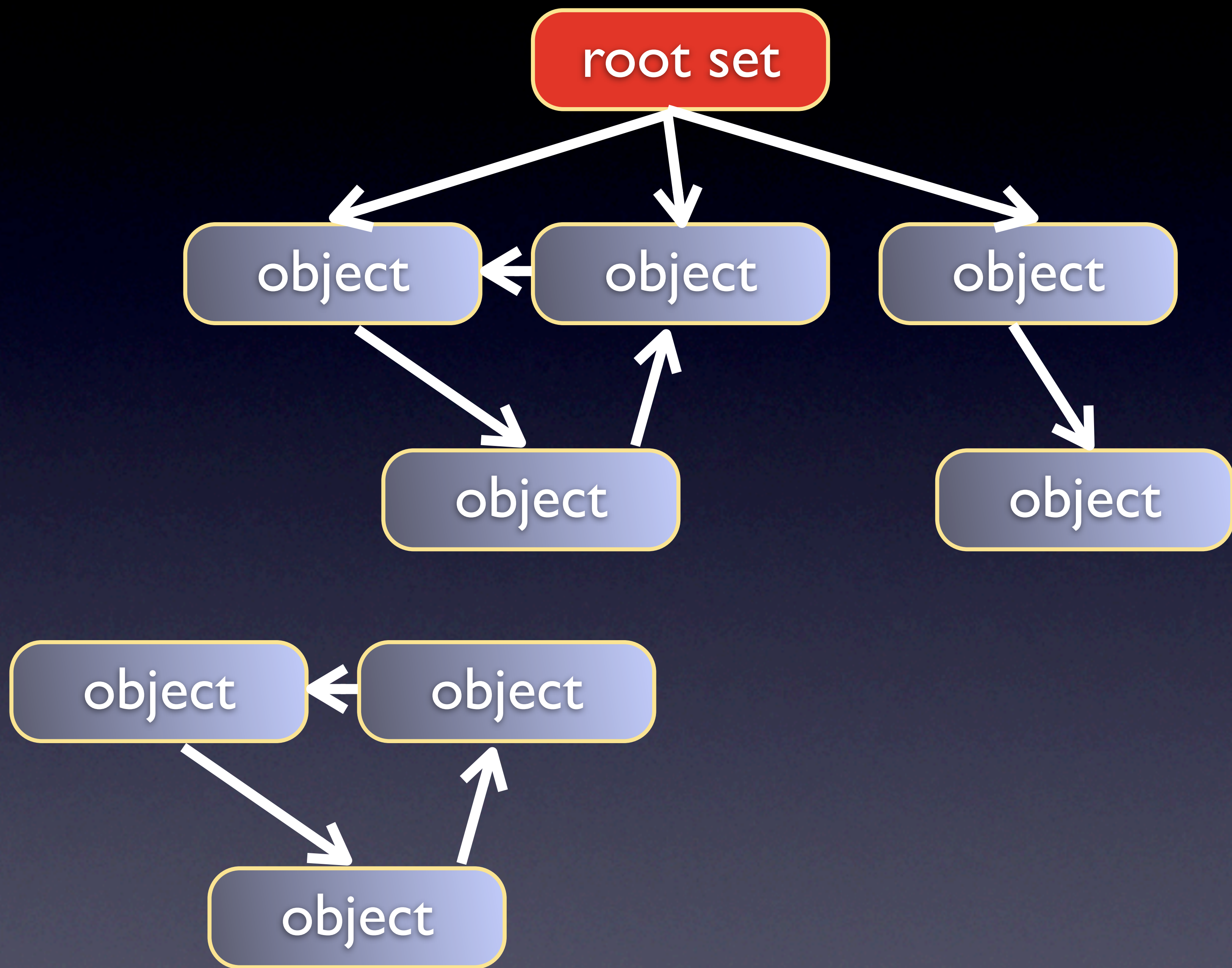
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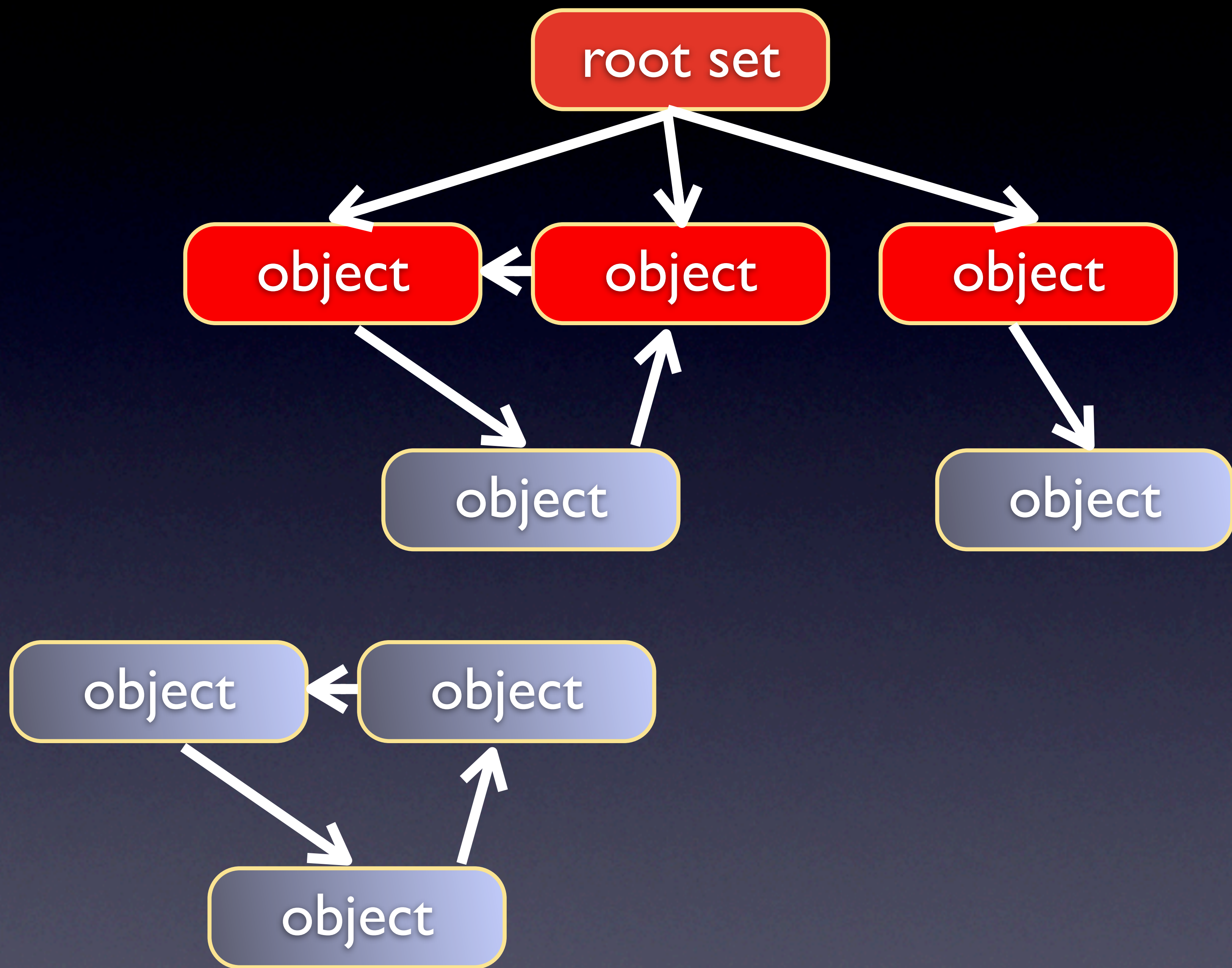
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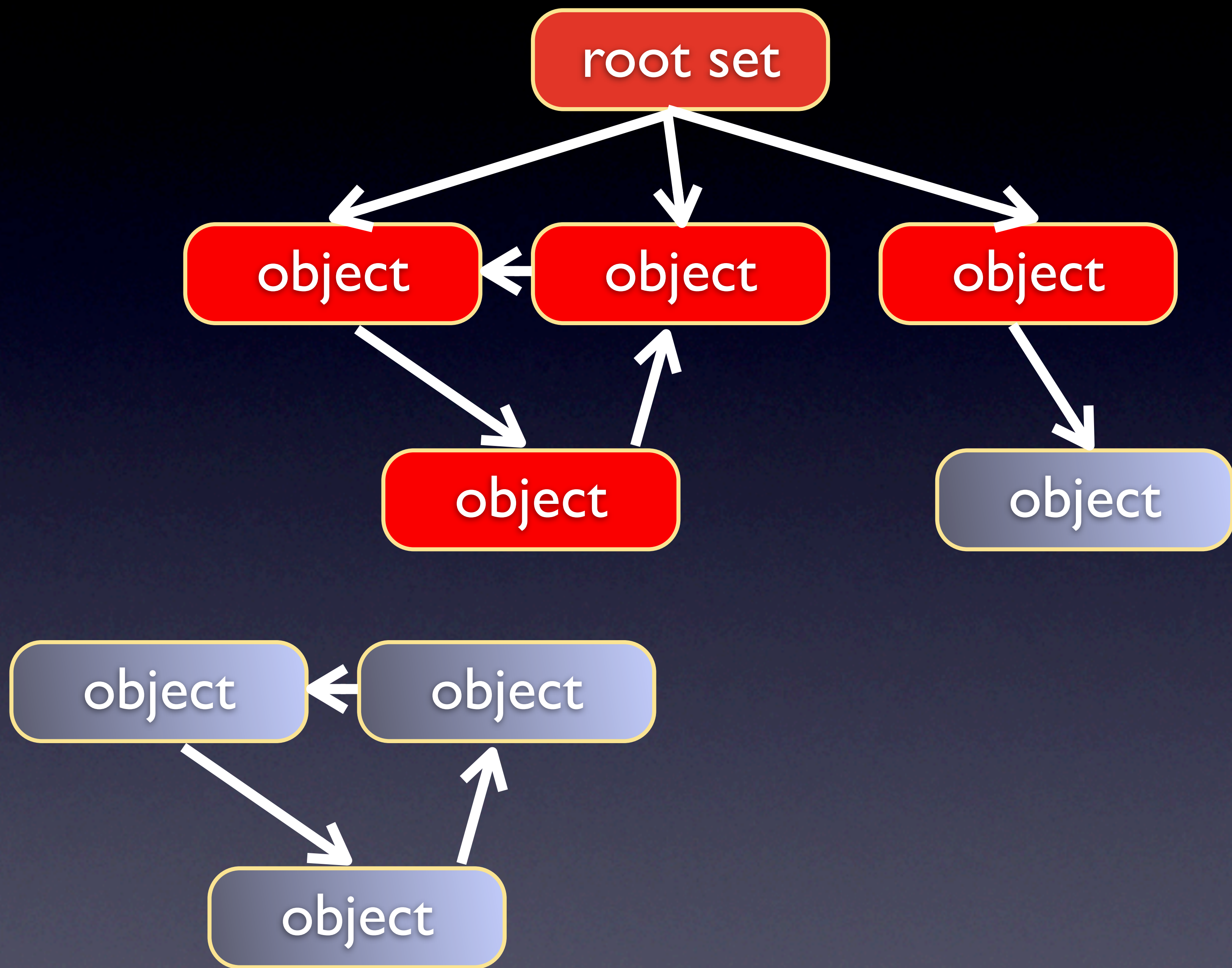
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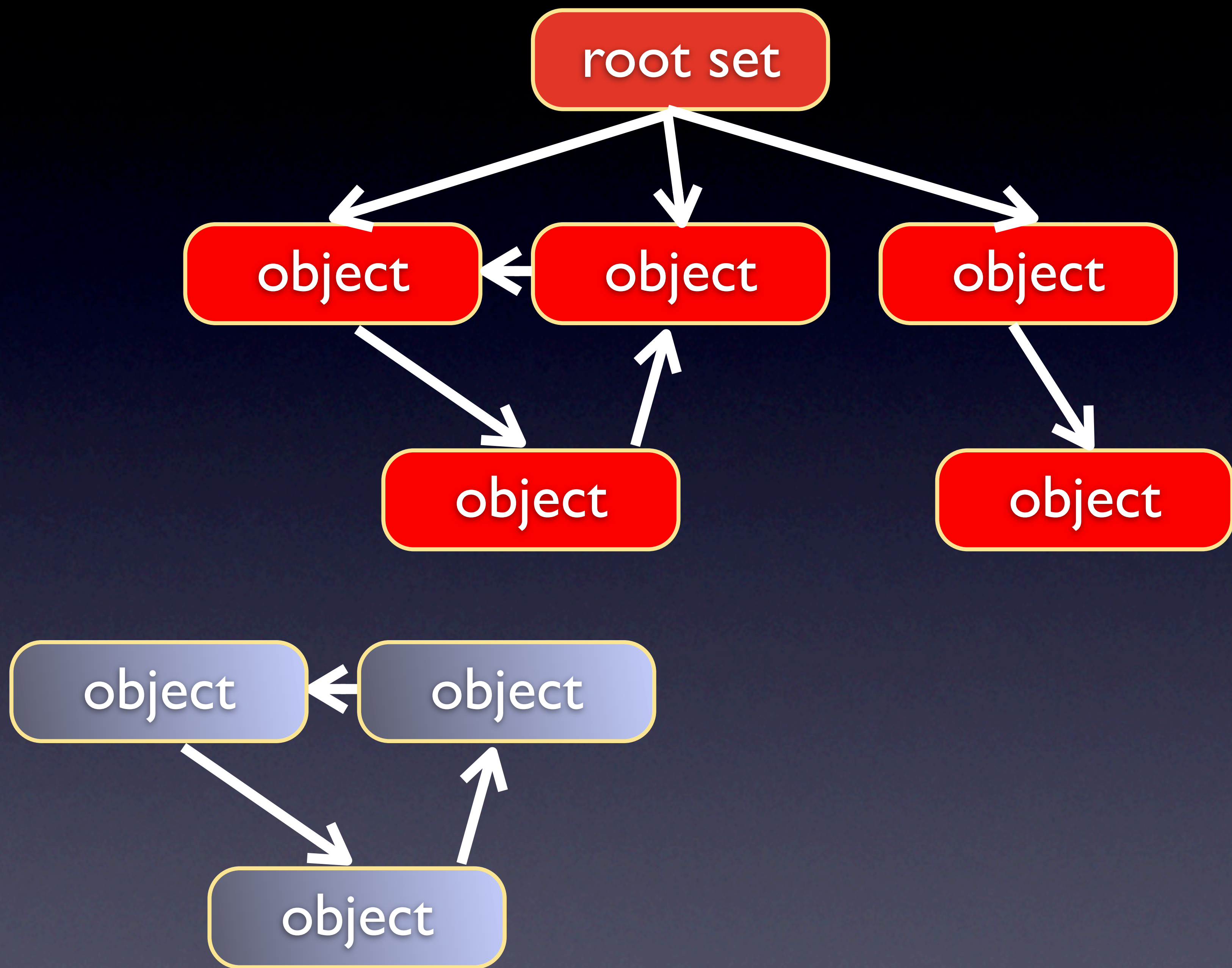
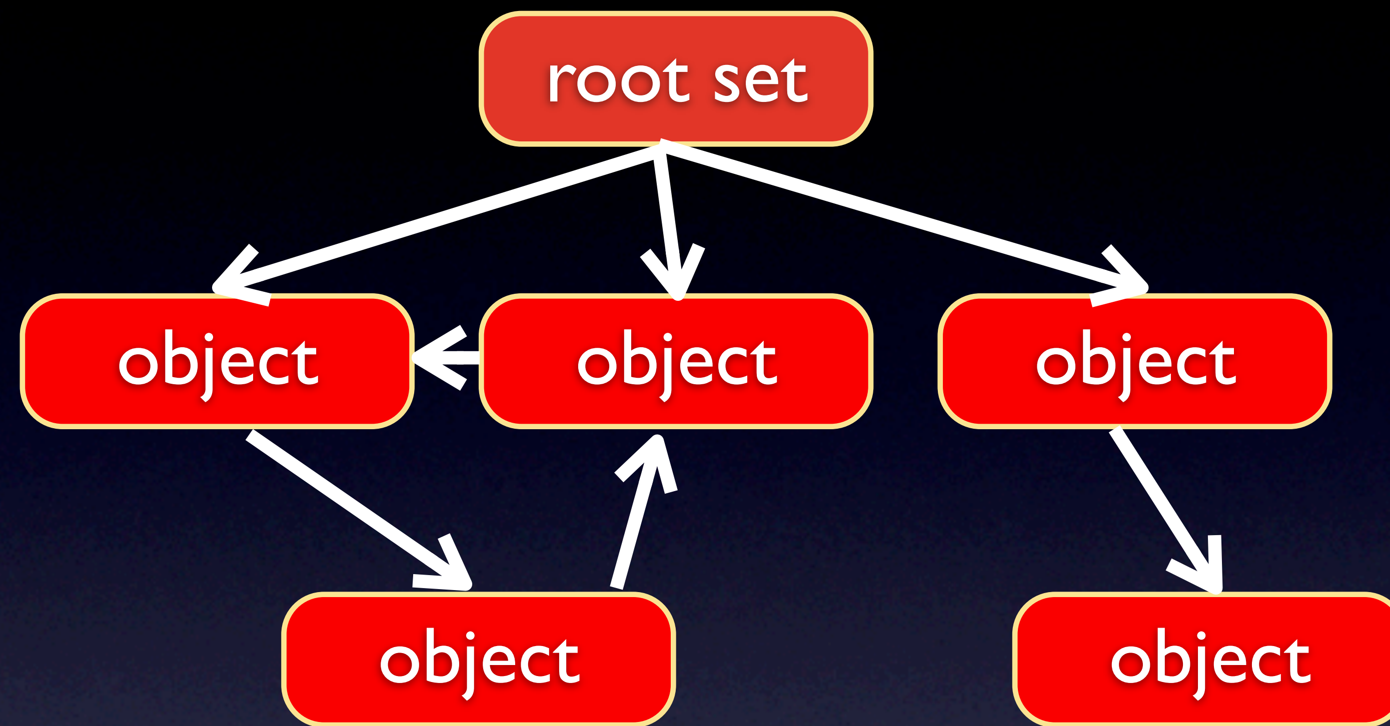


Objects in bottom-left unreachable from root set



Objects in bottom-left unreachable from root set

Root Set

- All objects pointed to by global variables
- All objects pointed to by static class variables
- All objects pointed to by local variables
- All objects pointed to by CPU registers

Local variables of this method and all methods up the call stack

All objects

- Can find the objects still in use
- Objects not in use = All object minus in use objects
- How do we find all objects?
- Think about how objects are created…
- Every object created by calling `new`

All objects…

- Could store pointers returned from `new`
- But there is a simpler way
- Memory Allocator maintains a list of allocated memory blocks and of free memory
- Garbage Collector can just use the allocator’s list

Allocated memory blocks will be the objects

Garbage Collector is part of the memory allocator anyway so this is not a problem

Stop The World

- Important to stop execution of the program
- If not, program will change state as collector runs
- Objects may by marked as in-use when they are no longer used

Stop the world

- Suppose the GC builds the root set
- Program then moves an object pointer from an object (a) into a local variable
- GC traces over reachable objects
- Object (a) never reached and so freed
- Program accesses (a) and crashes

Mark-Sweep collector

- Mark-Sweep is a basic form of garbage collector
- First pass, marks every object that is accessible as 'in-use' (by visiting every reachable object)
- Second pass, visit every object allocated and destroy those not marked as in-use

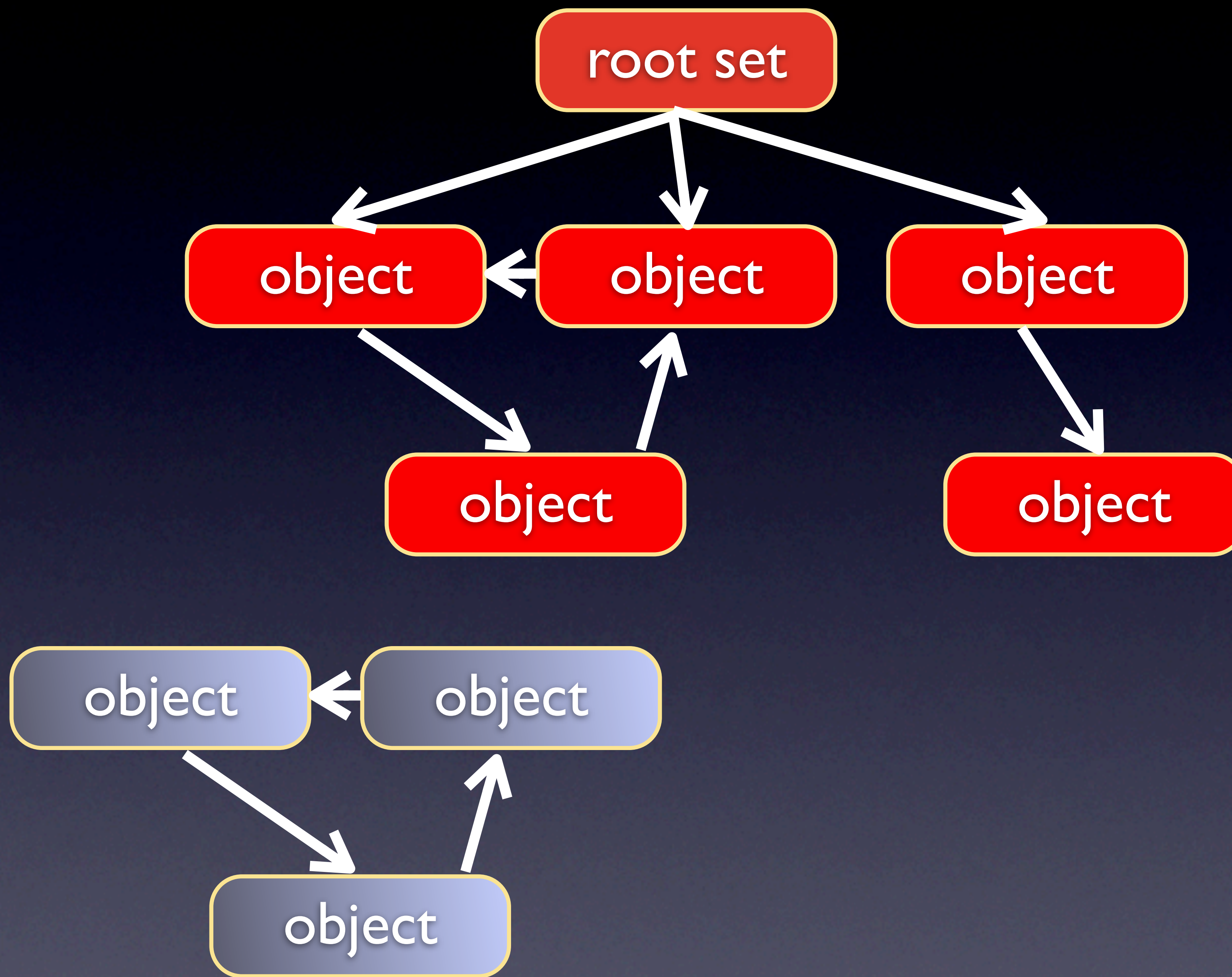
Pass 1 – Marking

- Marks all objects that are ‘in-use’
- Already seen how this can be done
- Start off with objects in the root-set and recursively follow pointers to other objects
- Mark object as ‘in-use’ as you visit it

Pass 2 – Sweep

- Stepping through the allocator’s list of allocated memory blocks
- If the object is not marked ‘in-use’ it is destroyed
- The ‘in-use’ flag is cleared

if it wasn’t cleared we’d never know if an object went out-of-scope



Illustrate with laser pointer how objects are reached

Mark/Sweep

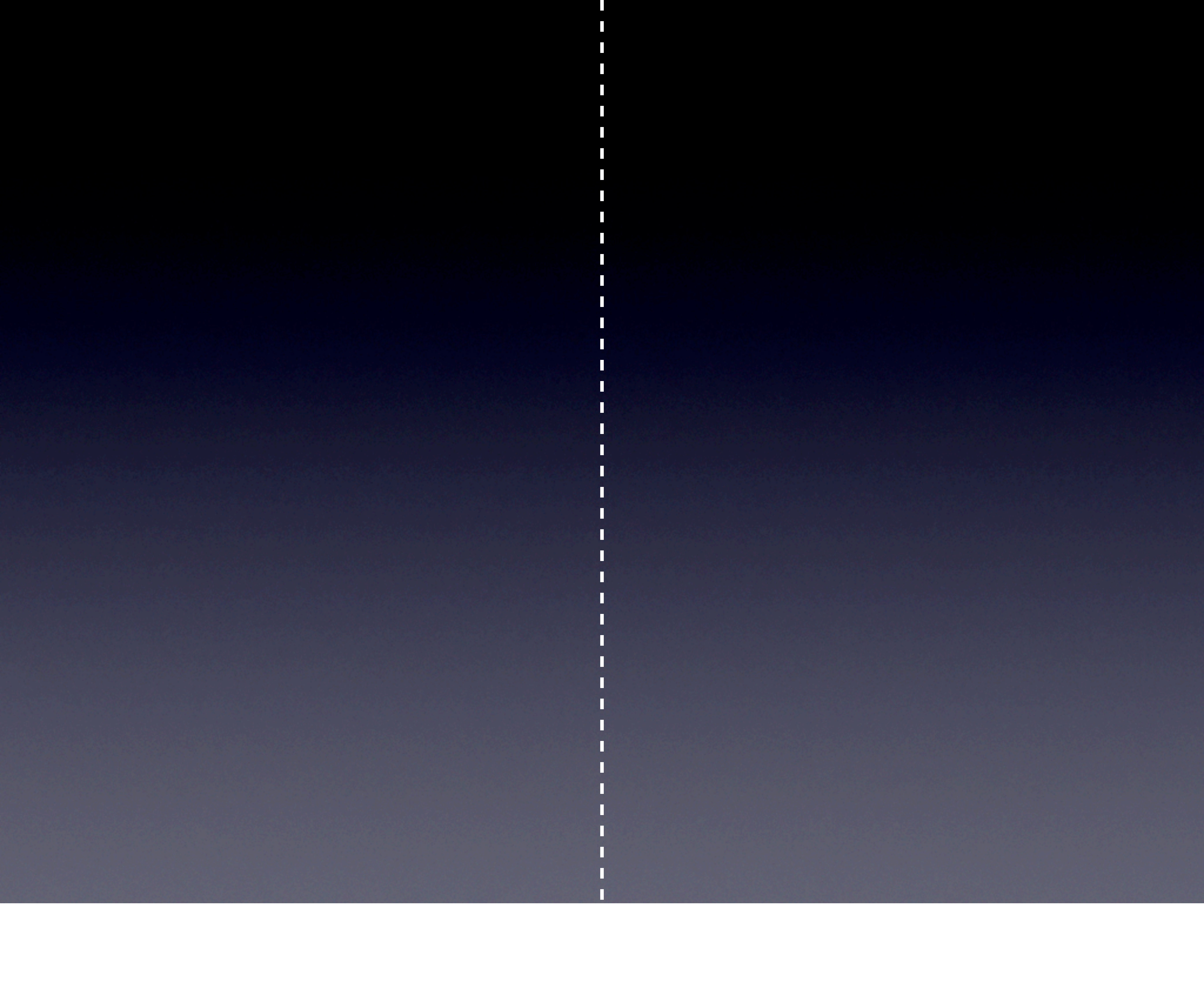
- Visits every allocated object — potentially twice
- Garbage collection time is proportional to number of objects created

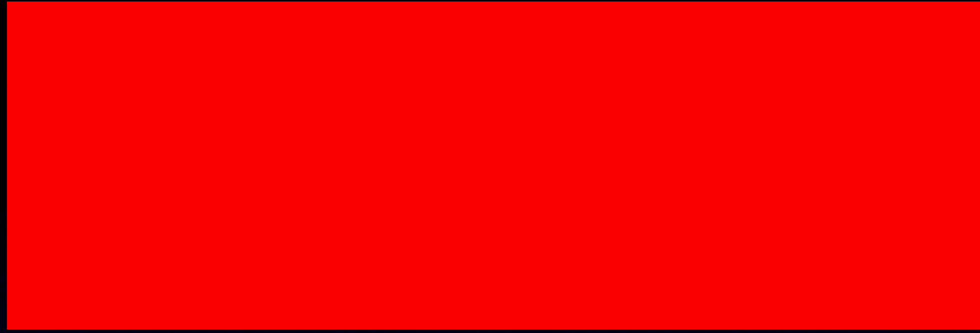
Copy Collector

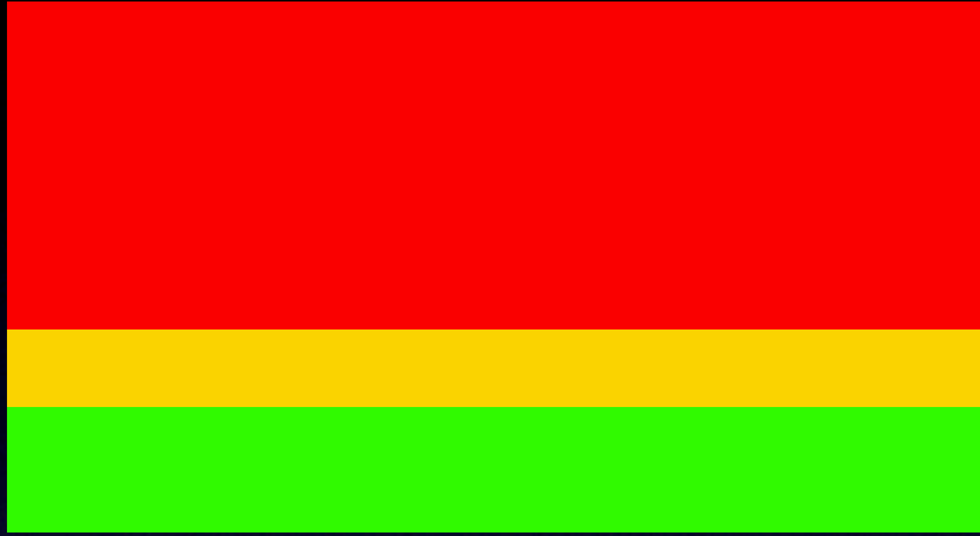
- Very different approach
- Splits the memory into two halves or banks
- All memory allocations occur from one of the banks, the other half is unused

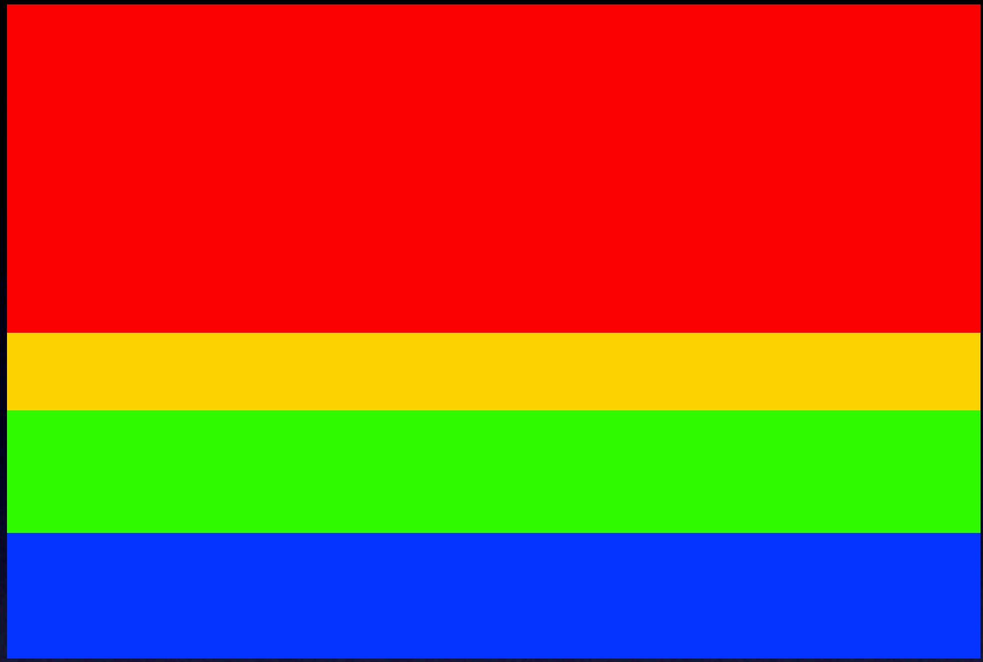
Copy Collector

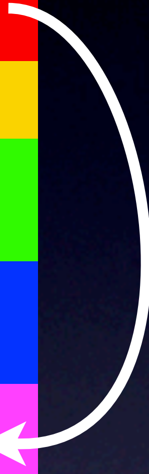
- Collector traces from the root set as per usual
- Rather than marking as ‘in-use’, it copies reachable objects from one bank of memory to the other
- Result is that all reachable objects are now in the new bank

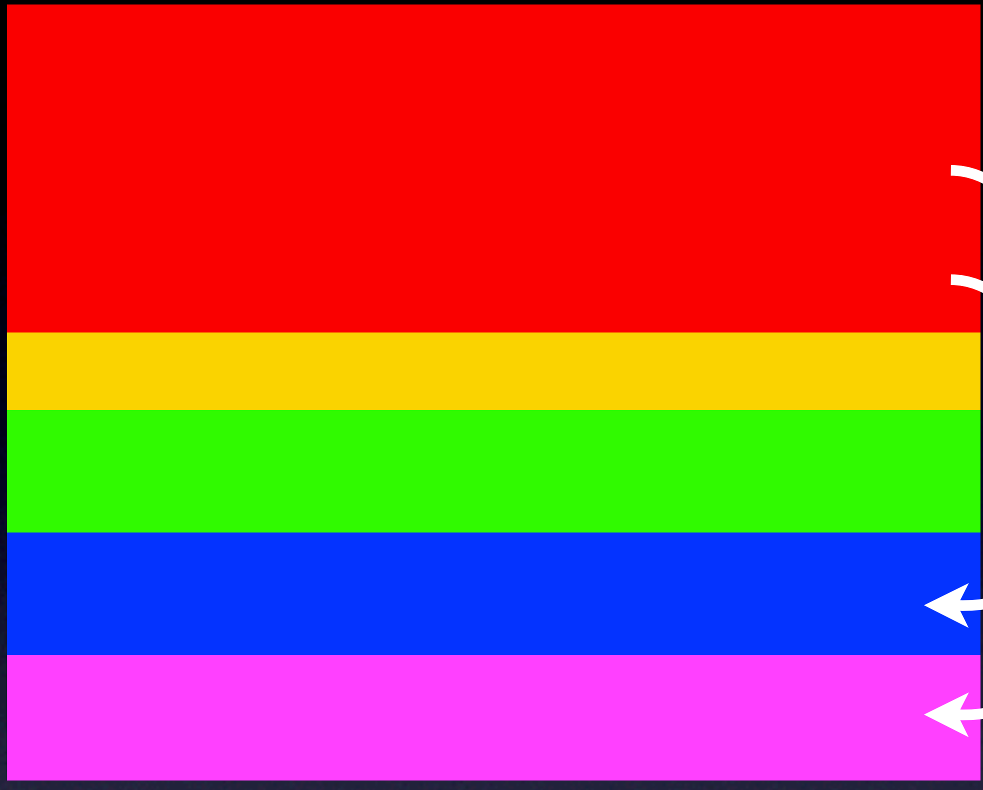


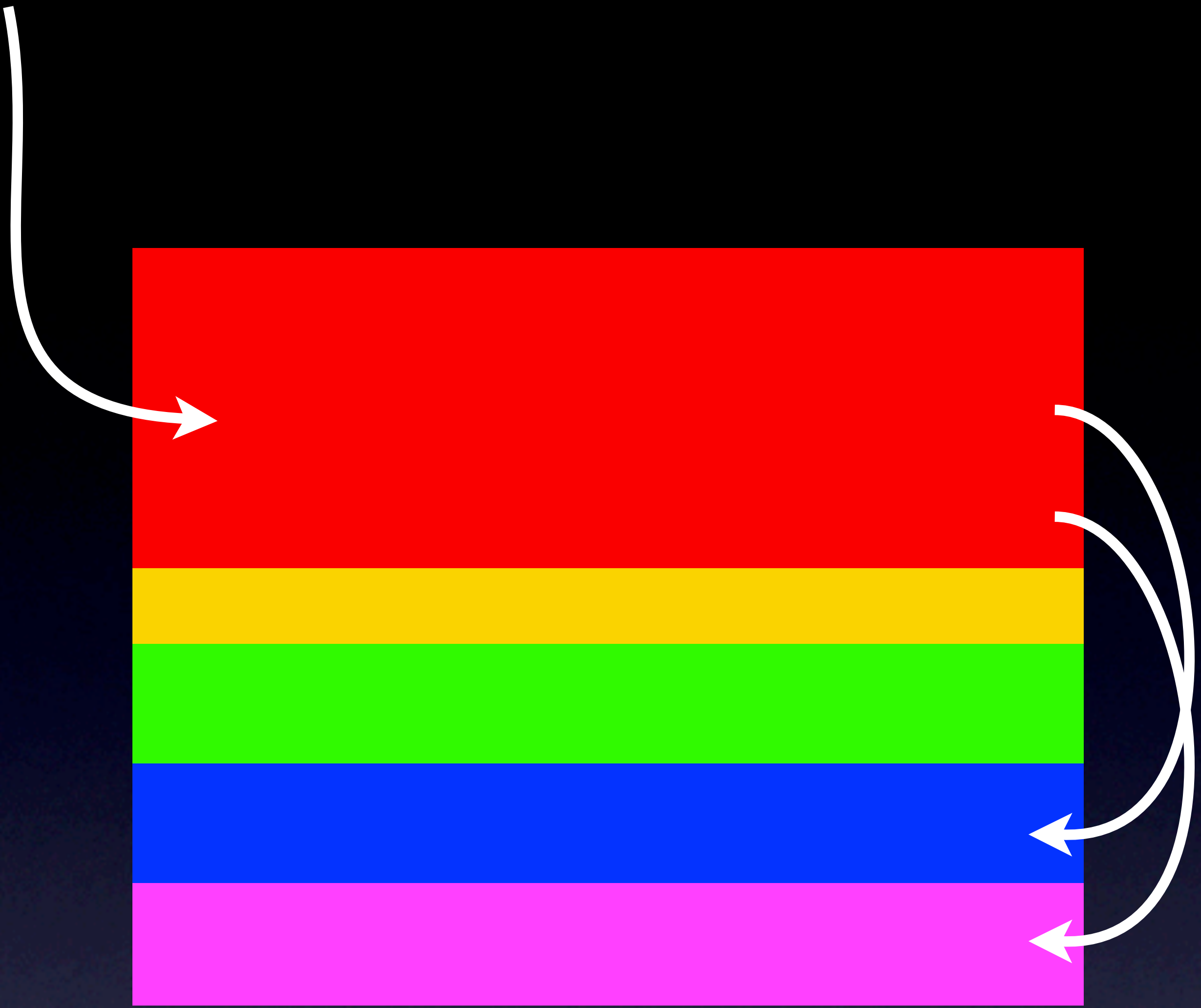


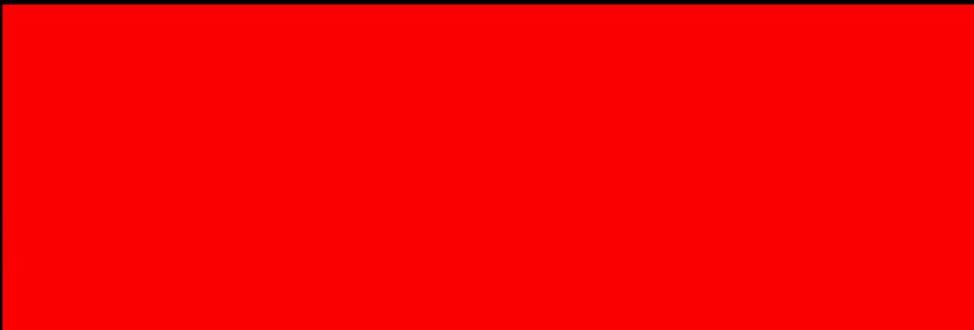


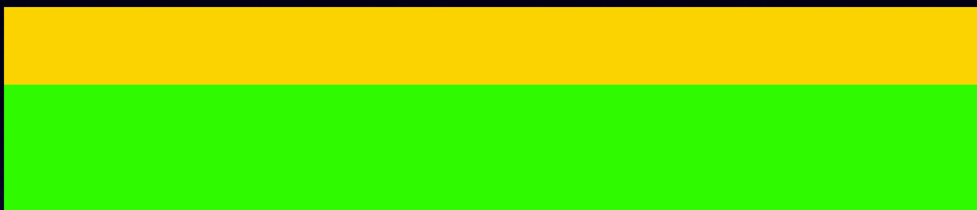


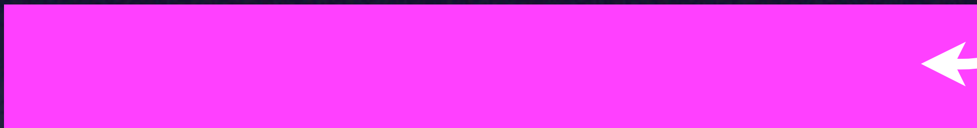


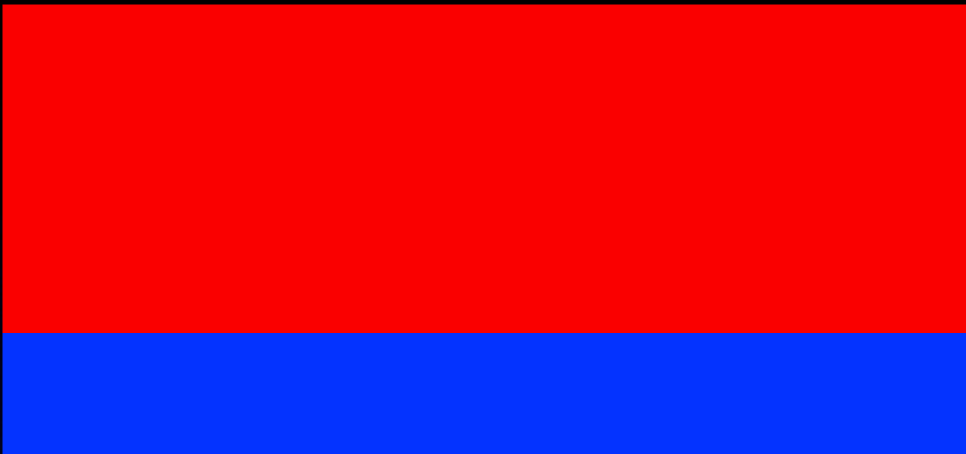


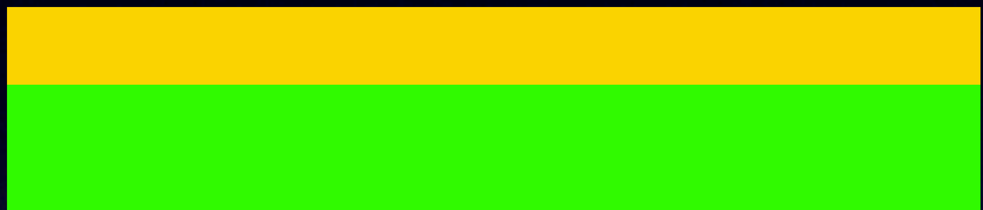


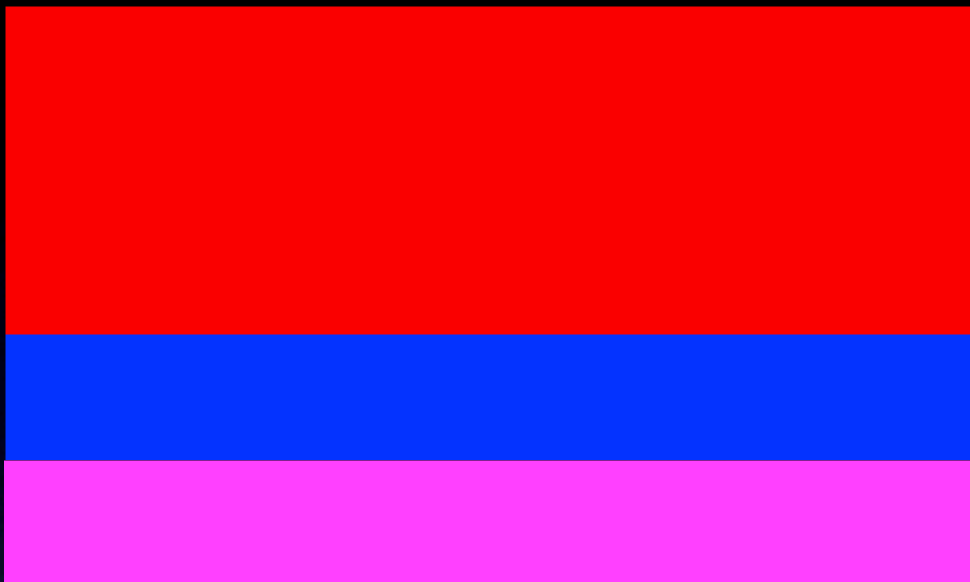


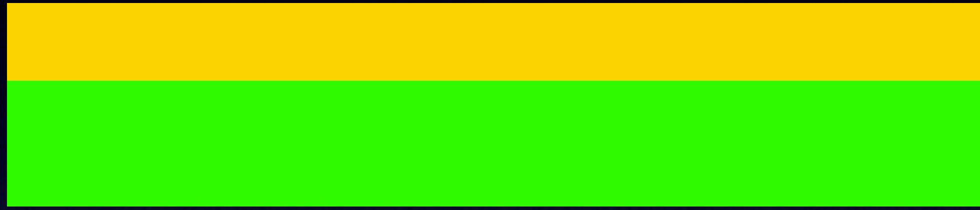


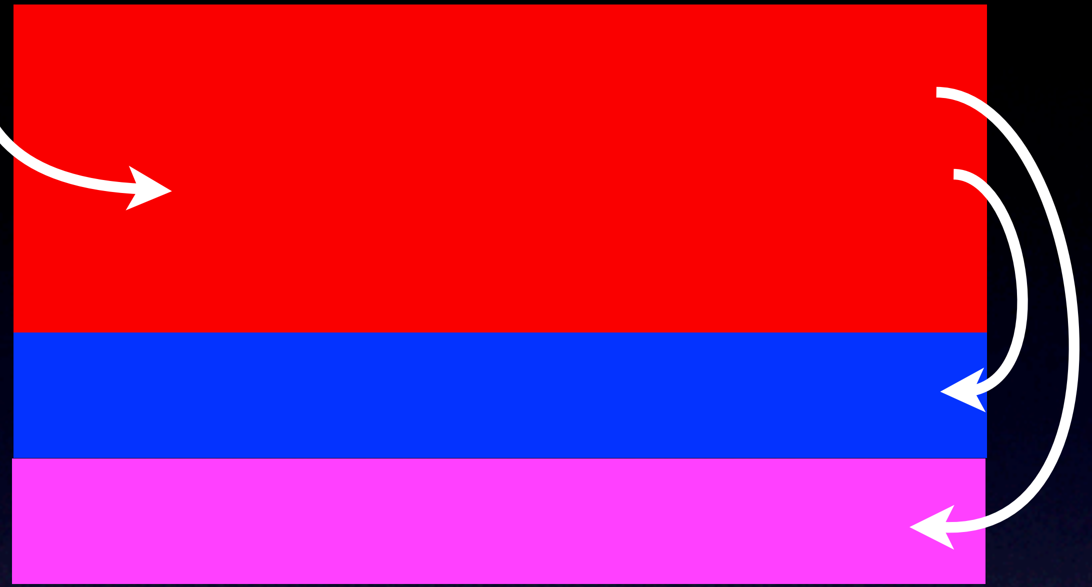


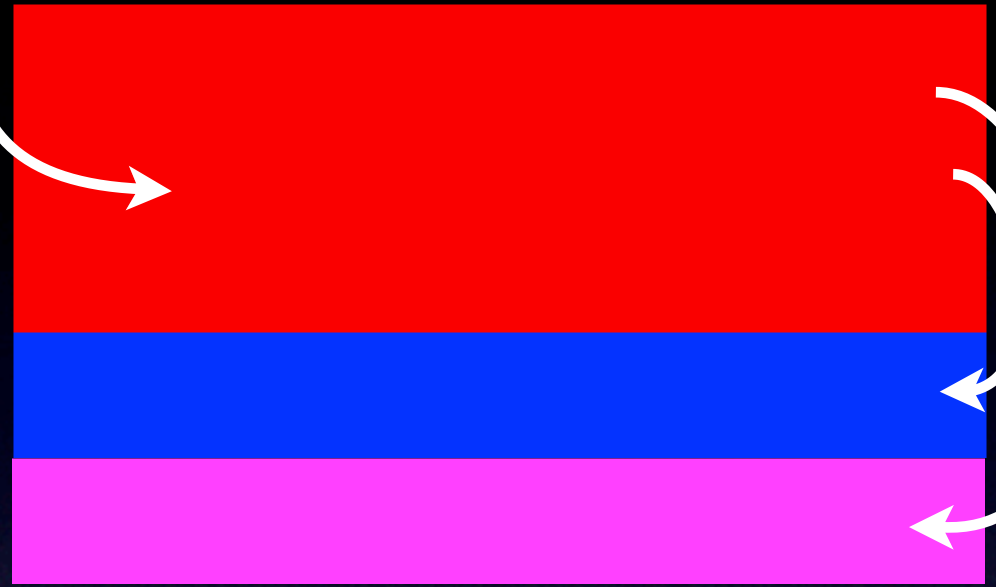


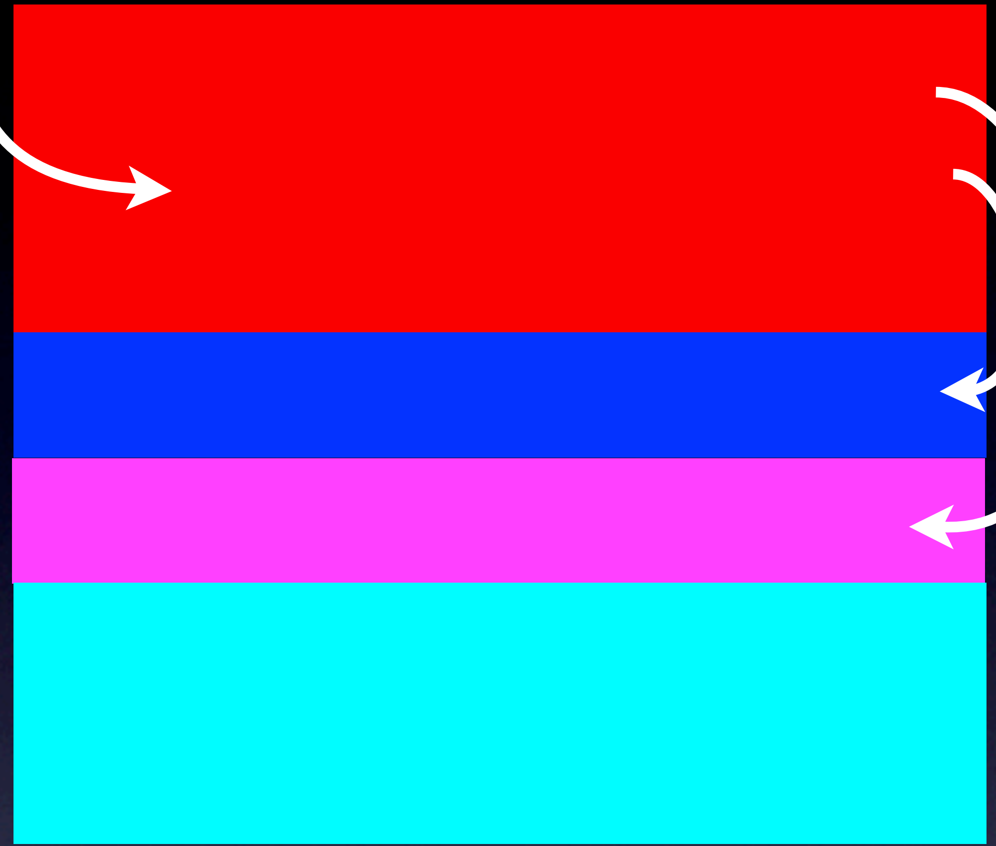












Copy Collector

- Collector fixes up object pointers to point to new location in memory
- Allocation is switched to happen from the new bank
- Next time GC happens it switches back to the previous bank

1st point definitely requires the world stopped or it'll go horrible wrong!

Copy Collector

- Copy Collector much faster than mark-sweep
- Only visits the reachable objects
- Memory allocation becomes trivial
- Java traditionally uses a Copy Collector
- Half of memory unused

Conservative GC

- GC relies on being able to find pointers to objects
- Easy when language designed for GC
  - Structure of object (i.e. what is a pointer and what isn't) is known by GC
  - GC can then find pointers in objects

Conservative GC

- Some languages (C++) don’t distinguish pointers from other bytes in memory
- GC then has to be conservative
- If these bytes could be an object pointer, then I’ll assume they are
- Means that objects may stay around longer than necessary

Is it an Object Pointer?

- Get potential pointer from memory
- Does it ‘point’ into a block of memory that has been allocated?
- If so, it is possibly a pointer so mark that block of memory (object) as ‘in-use’
- If not, not a valid pointer

GC Issues

- Stop-the-world
  - Program pauses periodically
  - What if something interesting happens during a pause?
- Modern GC algorithms that allow collection to happen in parallel with program execution

GC Issues

- Garbage Collection visits every object
- Research has shown that objects tend to have short lifetimes
- Some modern GC algorithms partition the heap into young and old objects

GC issues

- If an object exists for a predetermined period, it is moved from the young partition to the old partition
- Young partition is GC'd more regularly than the old partition
- Less objects to visit so quicker GC

Summary

- Garbage collection
- Tool for automatically destroying objects
- Two basic types: mark-sweep and Copy collectors
- Language support
- GC issues