Copying GC

AKA the scavenger

Copying garbage collection algorithm

- Divides the heap into two equal parts
  - *to-space* & *from-space*
  - Use one part at a time (*to-space*)
- When *to-space* fills up, flip the roles
  - Old *to-space* becomes *from-space*
  - Old *from-space* becomes *to-space*
- Copy live objects from *from-space* to *to-space*
  - Begin by following pointer from the root set

Copying garbage collection

- Also known by the following names
  - Stop-and-copy garbage collection
  - Scavenger
    - Garbage objects are simply abandoned in old space
    - Picks out worthwhile objects amidst garbage & take them away

Advantages of Copying Collection

- Live data structures are compacted in *to-space*
  - No fragmentation
- Allocate object fast and efficiently
  - No free list
  - Out-of-space check is a simple pointer comparison
  - New memory allocated by simply incrementing free space pointer

Advantages of Copying Collection

- Collects in time proportional to live data
- Avoids stack and/or pointer reversal
- Imposes no overhead on mutator operations
  - *e.g.* pointer updates
- Advantages over RCGC and MSGC have lead to its widespread adoption

Disadvantages of copying collection

- Wastes half your memory
- Copying takes time

Allocation in copying collector

```
init() {
    to_space  = Heap_bottom
    space_size = Heap_size / 2
    top_of_space = to_space + space_size
    from_space = top_of_space + 1
    free = to_space
}
new(n){
    if (free + n > top_of_space) {flip()}
     if (free + n > top_of_space) { abort “Memory exhausted”}
    new_cell = free                              // allocate()
    free = free + n
    return new_cell
}
```

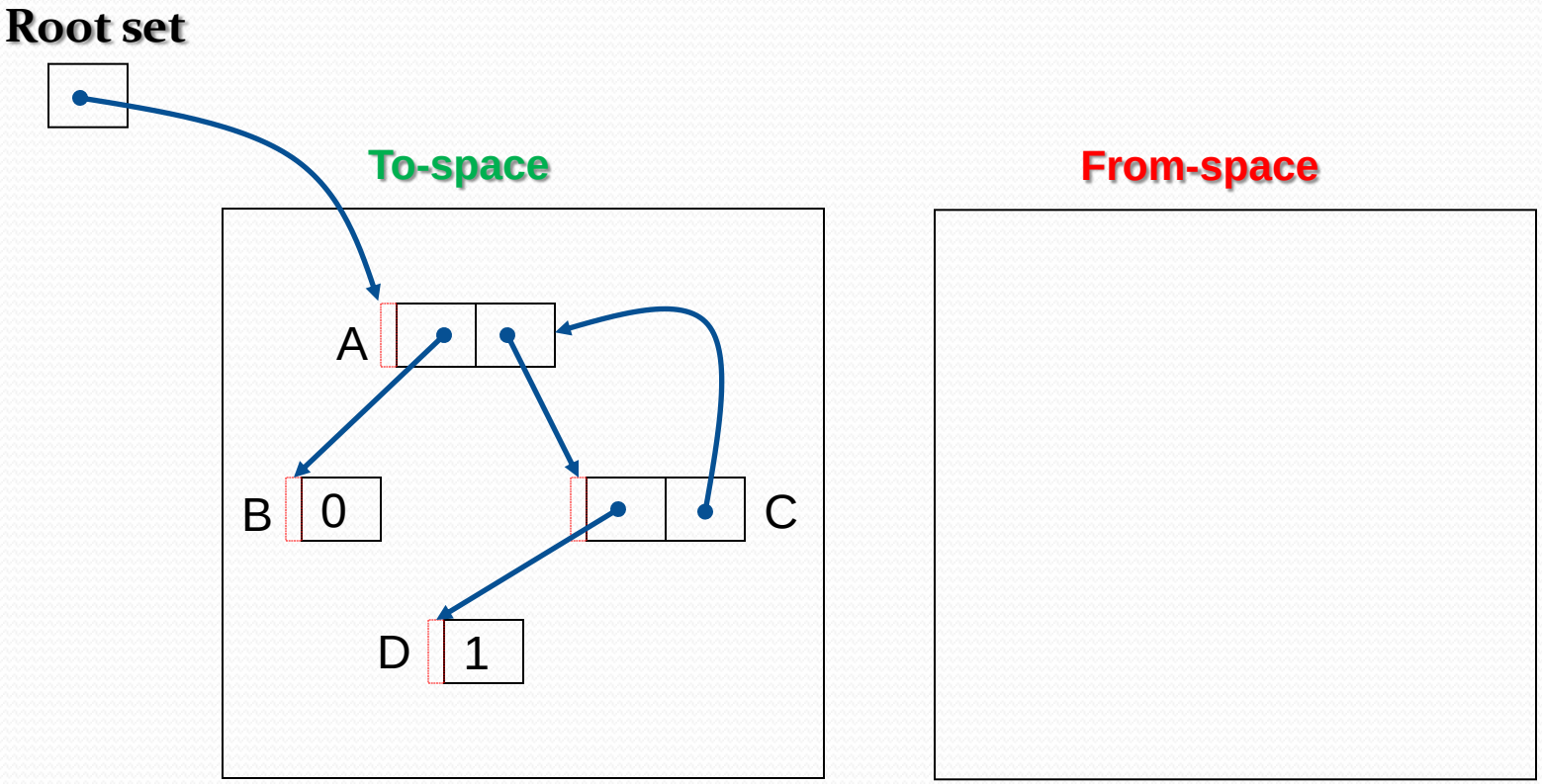
Flipping the spaces

```
flip() {
    to_space, from_space  = from_space, to_space
    top_of_space = to_space + space_size
    free = to_space
    for R in Roots
            R = copy(R)                    // Root pointer now points to copy of R
}
```

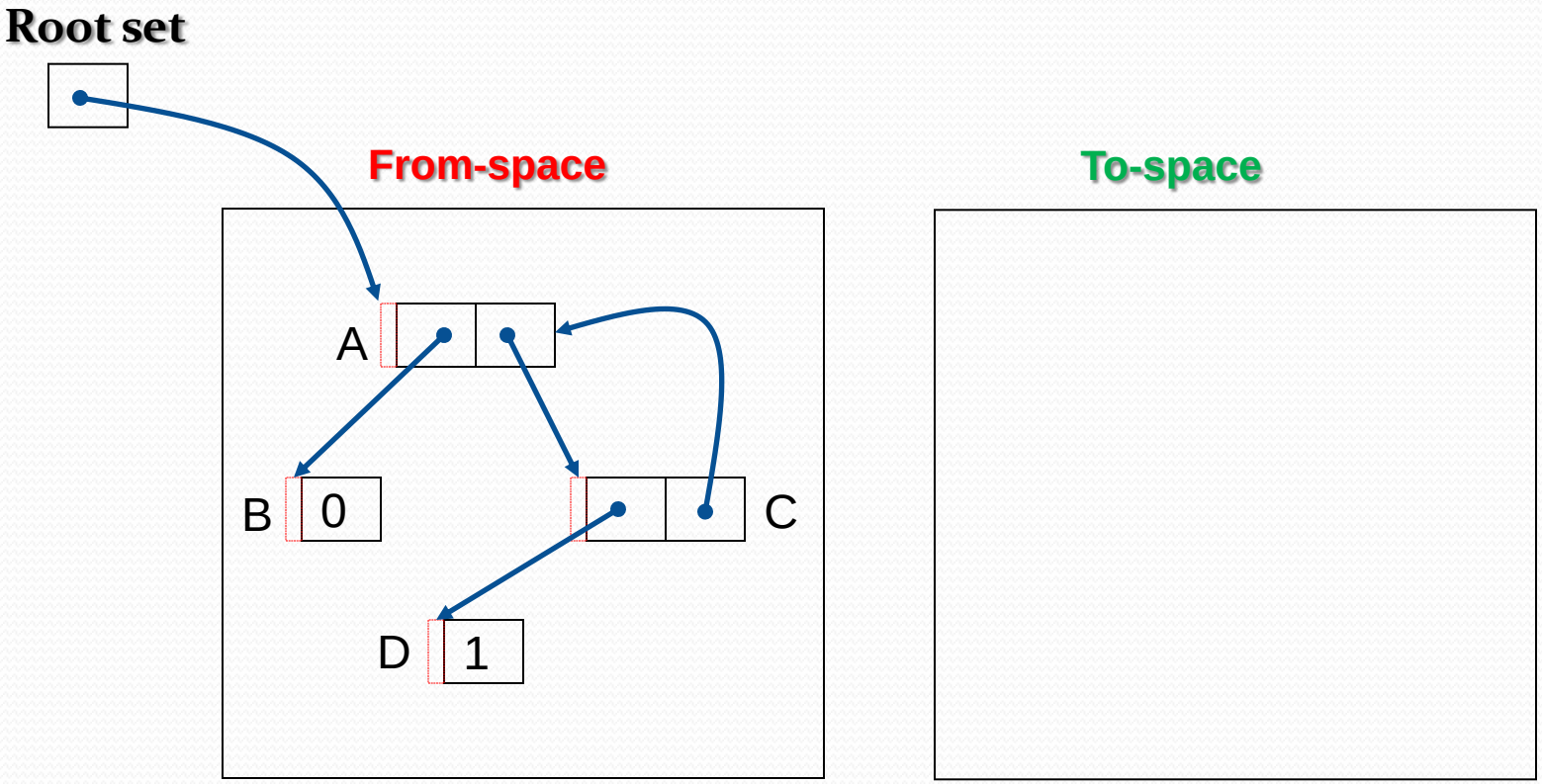
Copying for variable-sized objects

```
// P points to memory location, not an address
copy(P) {
    if (atomic(P) or P == nil) return P  // P is not a pointer
    if not forwarded(P)                  // P stores a forwarding address after copied
            n = size(P)
            P′ = free                    // reserve space in to_space for copy of P
            free = free + n
            temp = P[0]                  // P[0] holds forwarding address
            forwarding_address(P) = P′
             P′[0] = copy(temp)          // Restore P[0]
            for i = 1 to i = n – 1       // Copy each field of P to P′
                        P′[i] = copy(P[i])
    return forwarding_address(P)         // Stored in P[0]
}
```

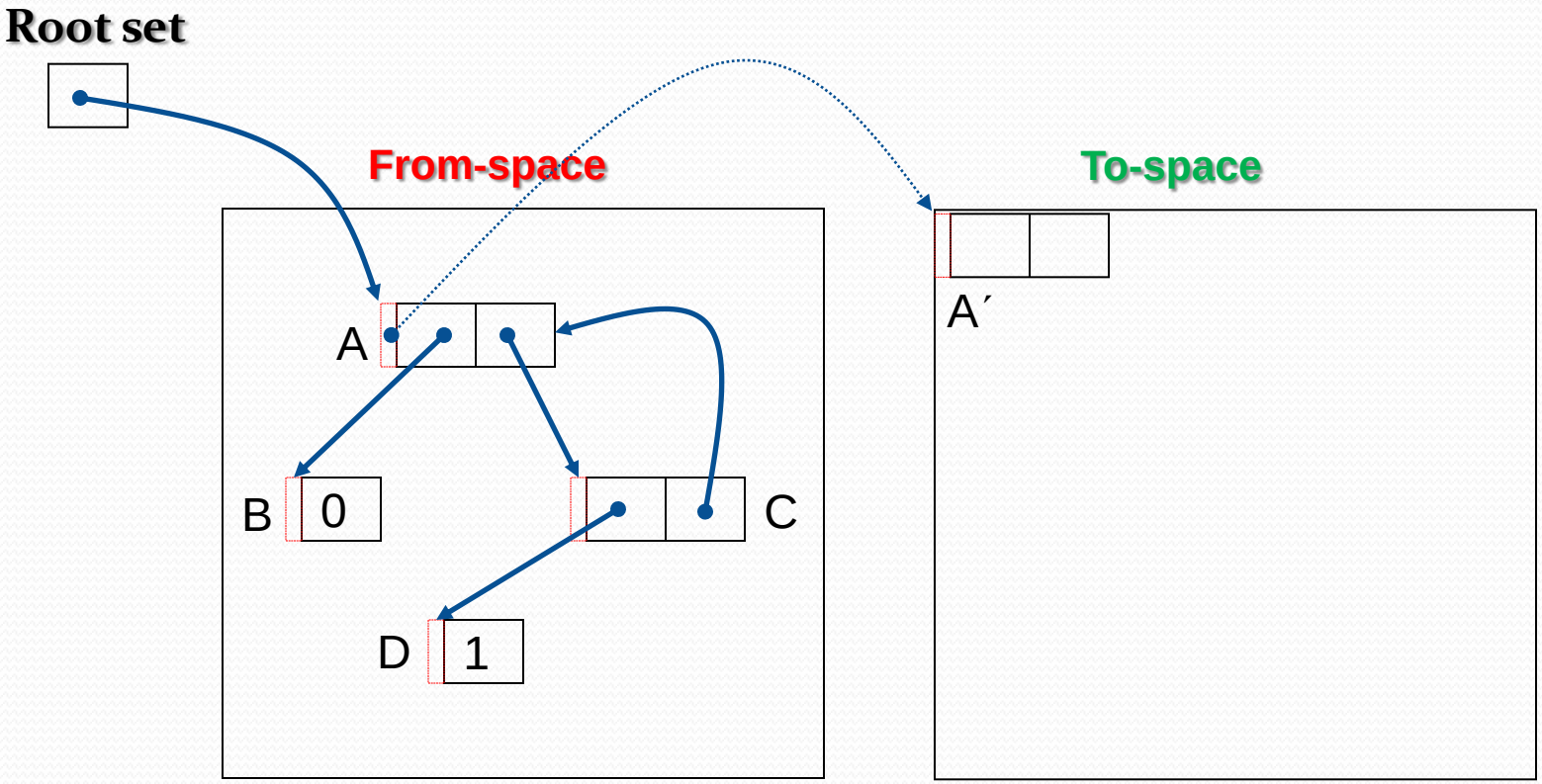
Example of how algorithm works



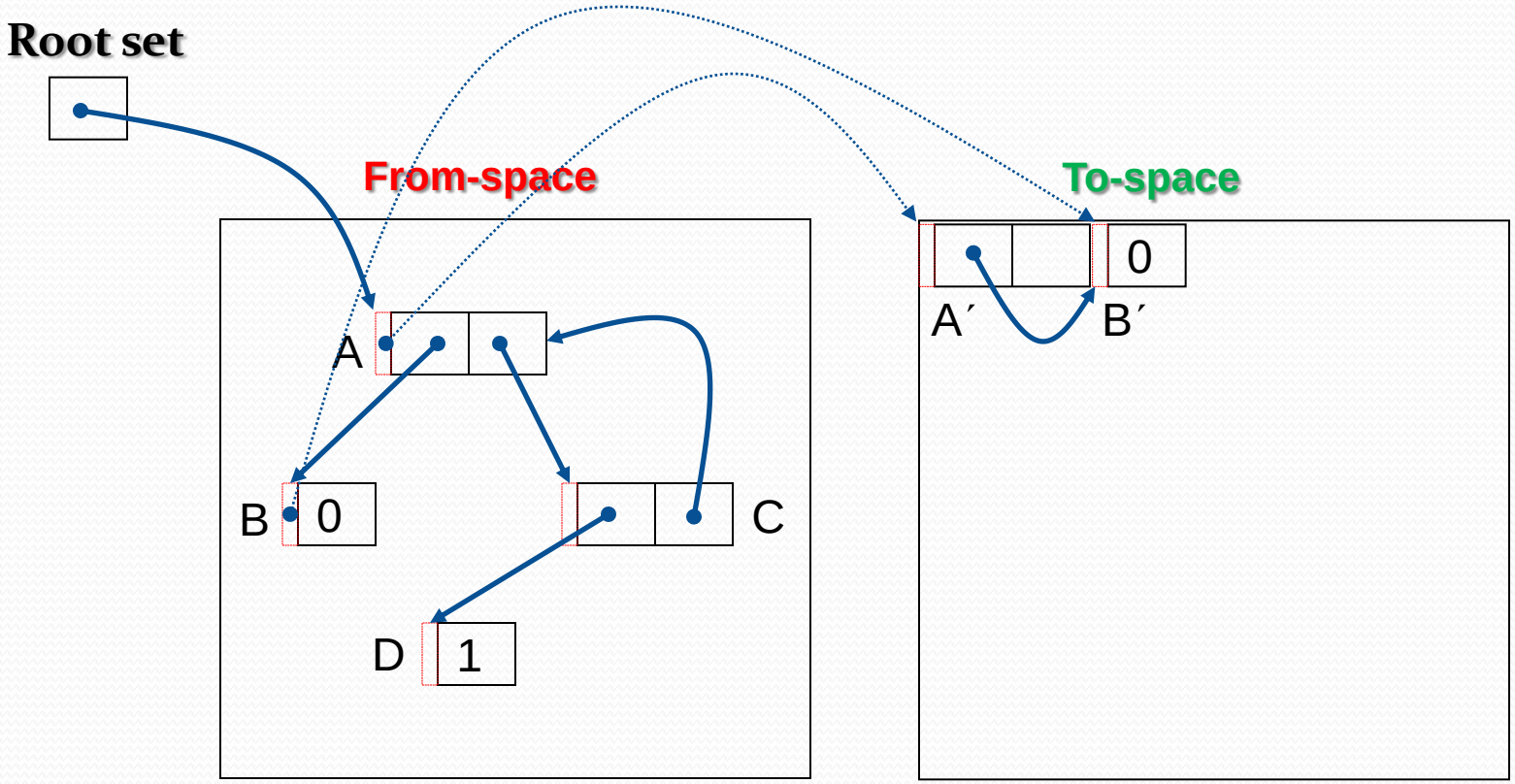
Flip the spaces



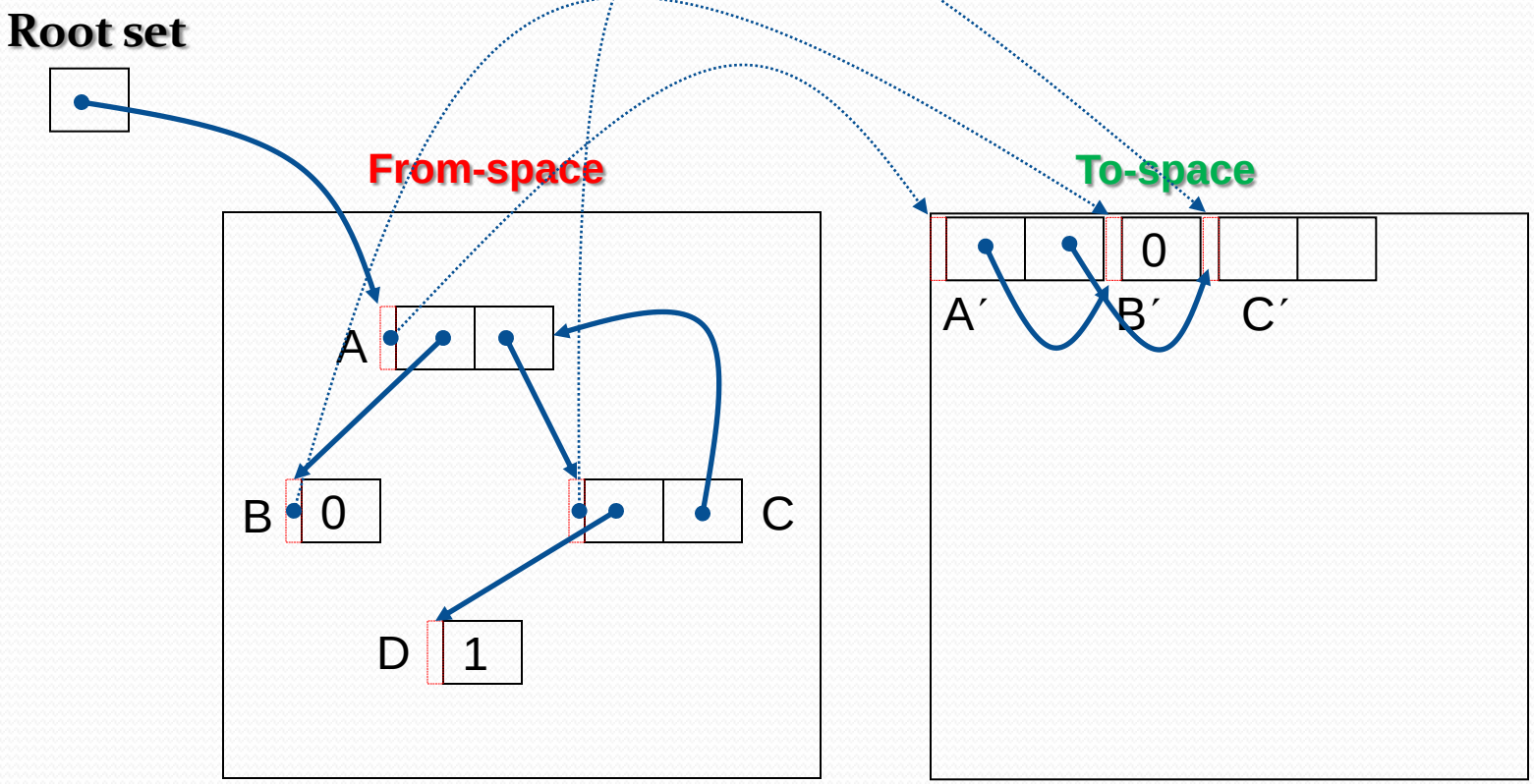
Copy root object first



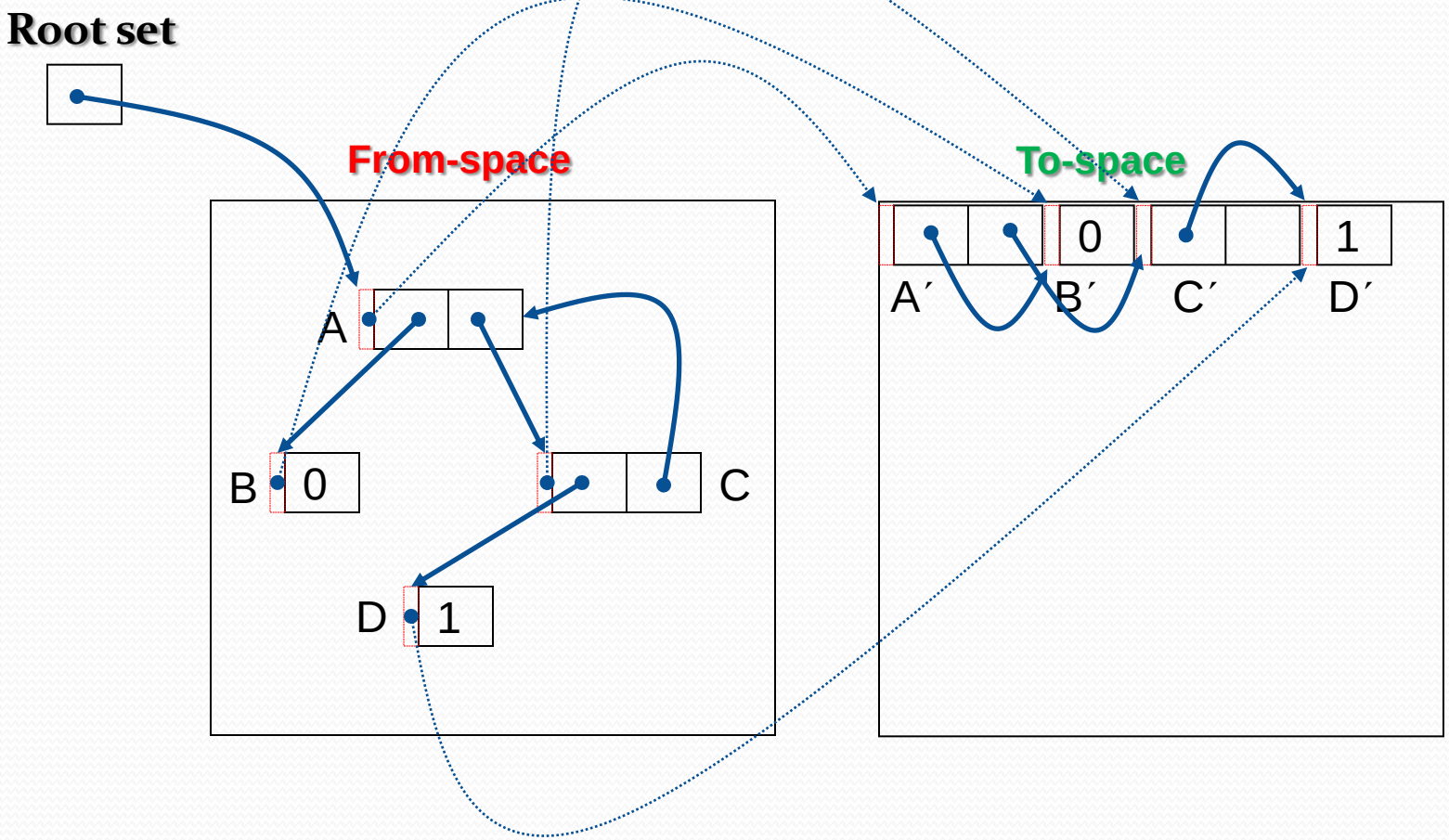
Then copy B: left child of A



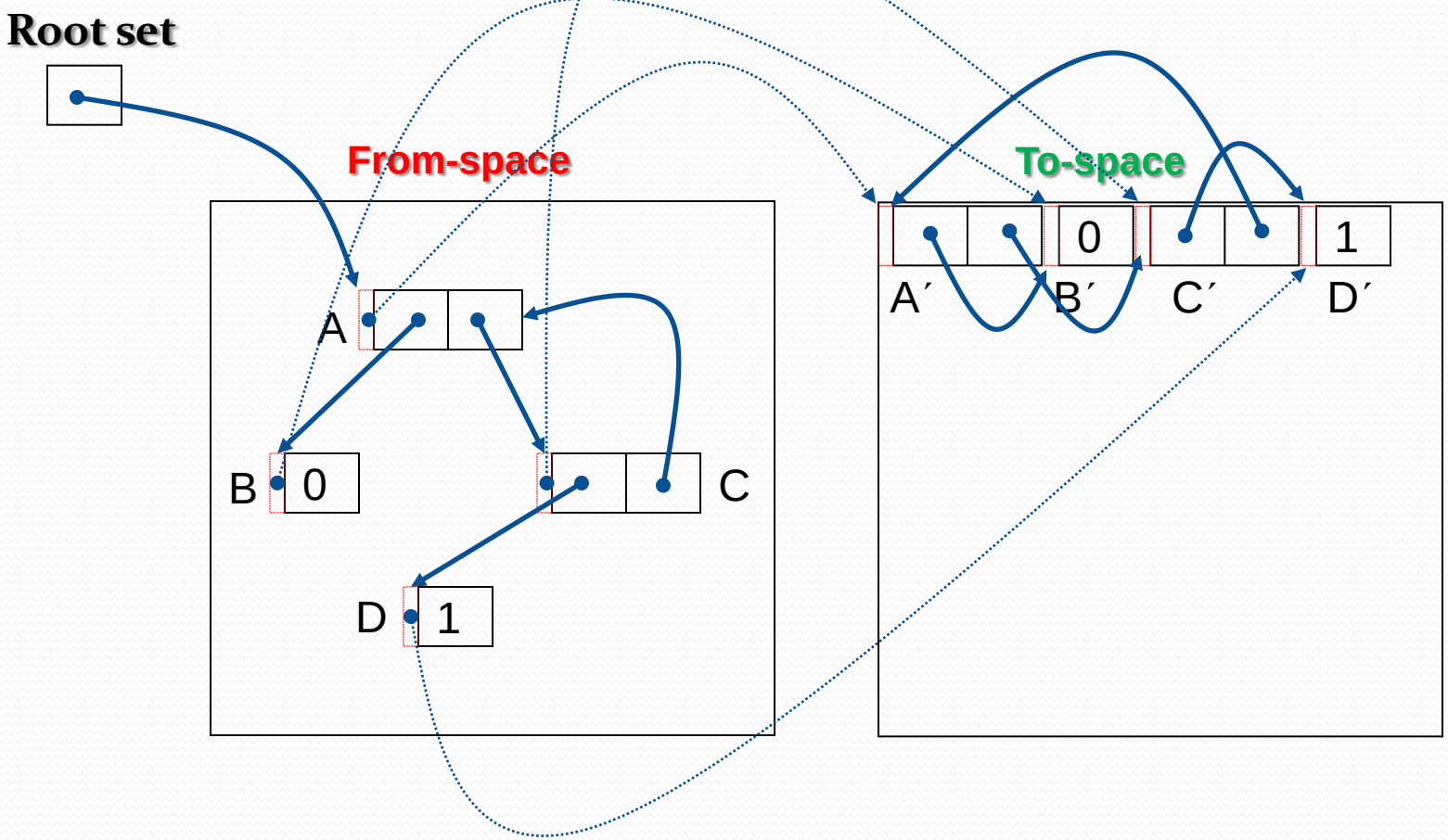
Now copy C: right child of A



Copy D: left child of C



Copy A: right child of C



Analysis of copying collection

- Assume there are L words of live data in heap of size H words
- Cost of GC is kL
  - Realistic value is 10L (k = 10)
- Cost per reclaimed word

$$\frac{kL}{\left(\frac{H}{2} - L\right)}$$

  - This has no lower bounds as H grows
  - If H = 4L then k ~ 10