Copying Garbage Collection

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1 The idea of *Copying GC*

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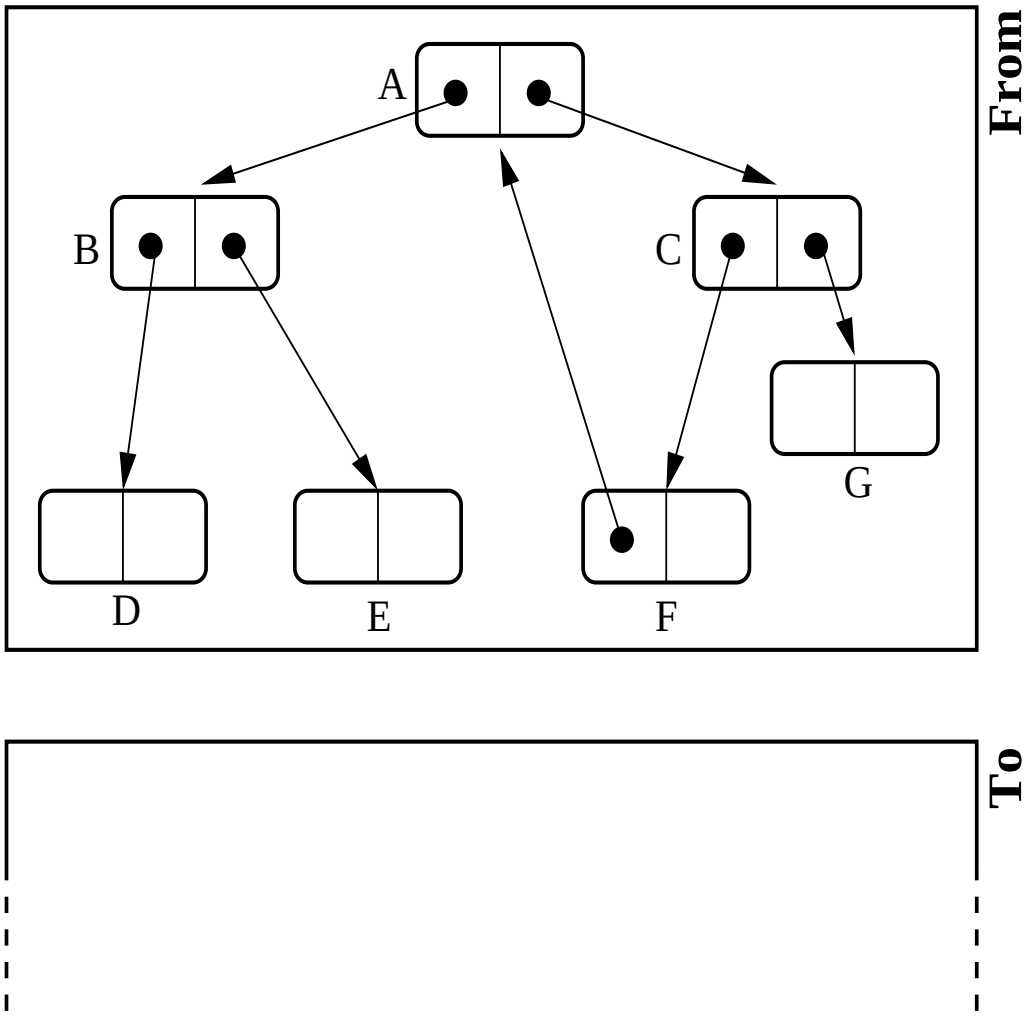
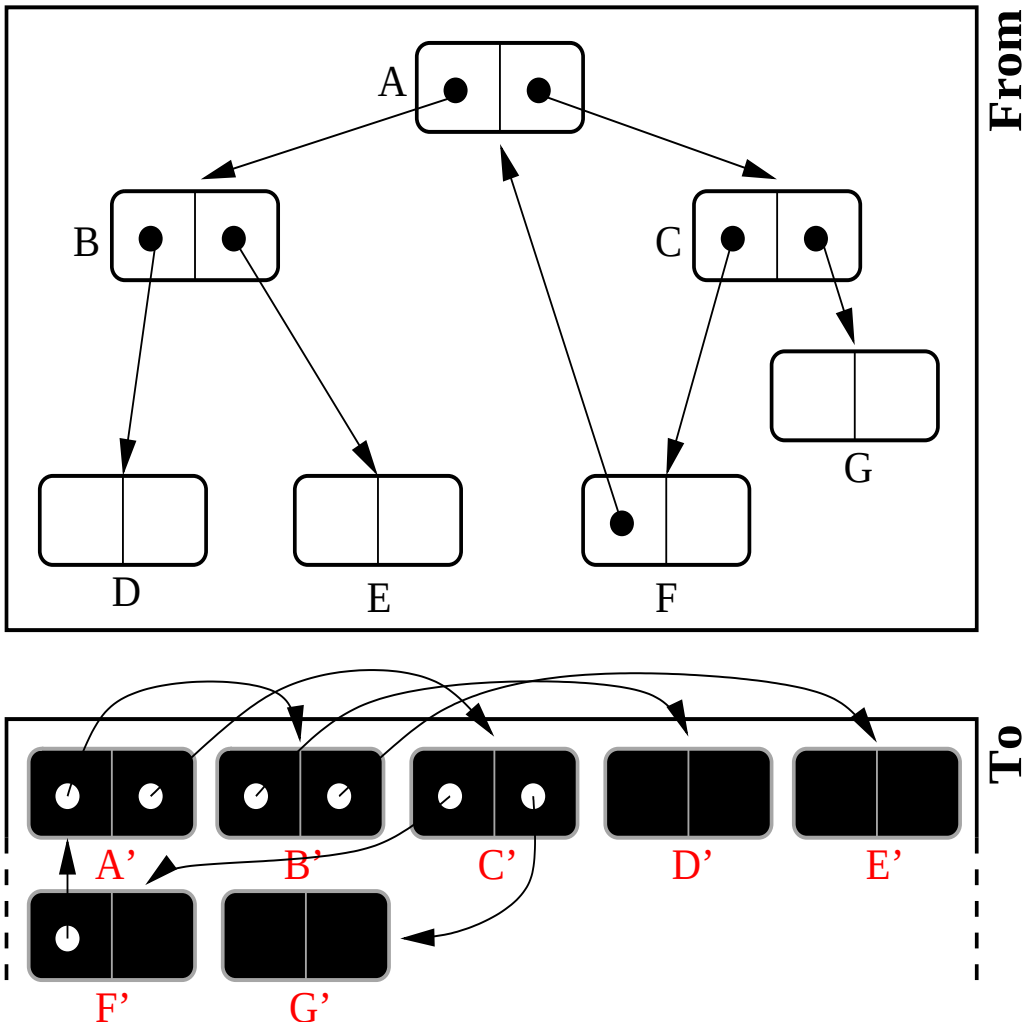
- Two "semi-spaces" (*From*-space and *To*-space)
- Only From-space "active"
- At GC time, copy the live nodes from From-Space to To-Space
- Then "flip" the spaces

2 Before GC



3 After GC



4 Cheney's algorithm(1)

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- Interleaves copying and scanning

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- Two pointers needed: scan / free
- Forwarding pointers used to preserve sharing

5 Cheney's algorithm(2)

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Tricolour abstraction:

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Tricolour abstraction:

- Black nodes: GC finished, not to be considered again

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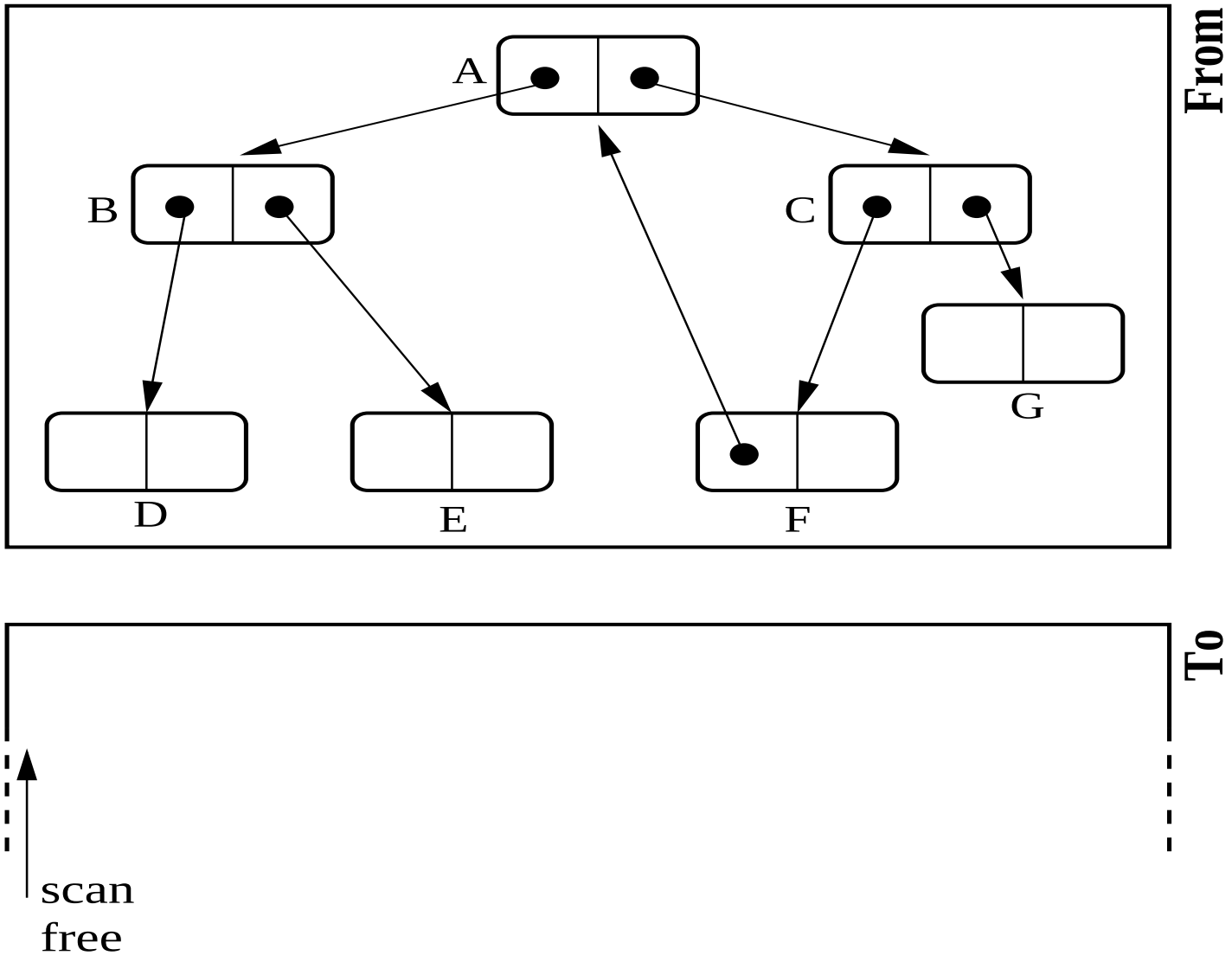
GC terminates when all reachable nodes are black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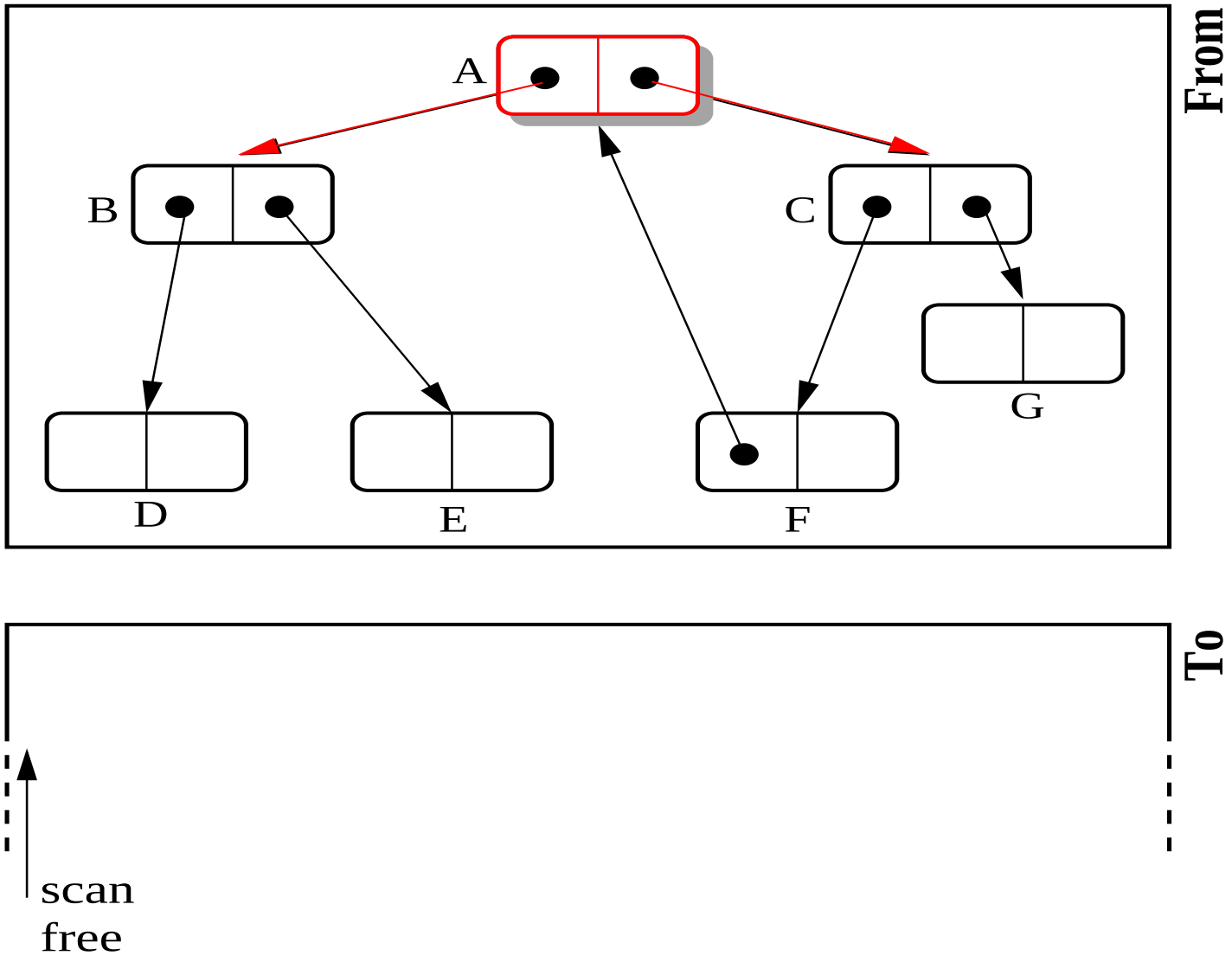
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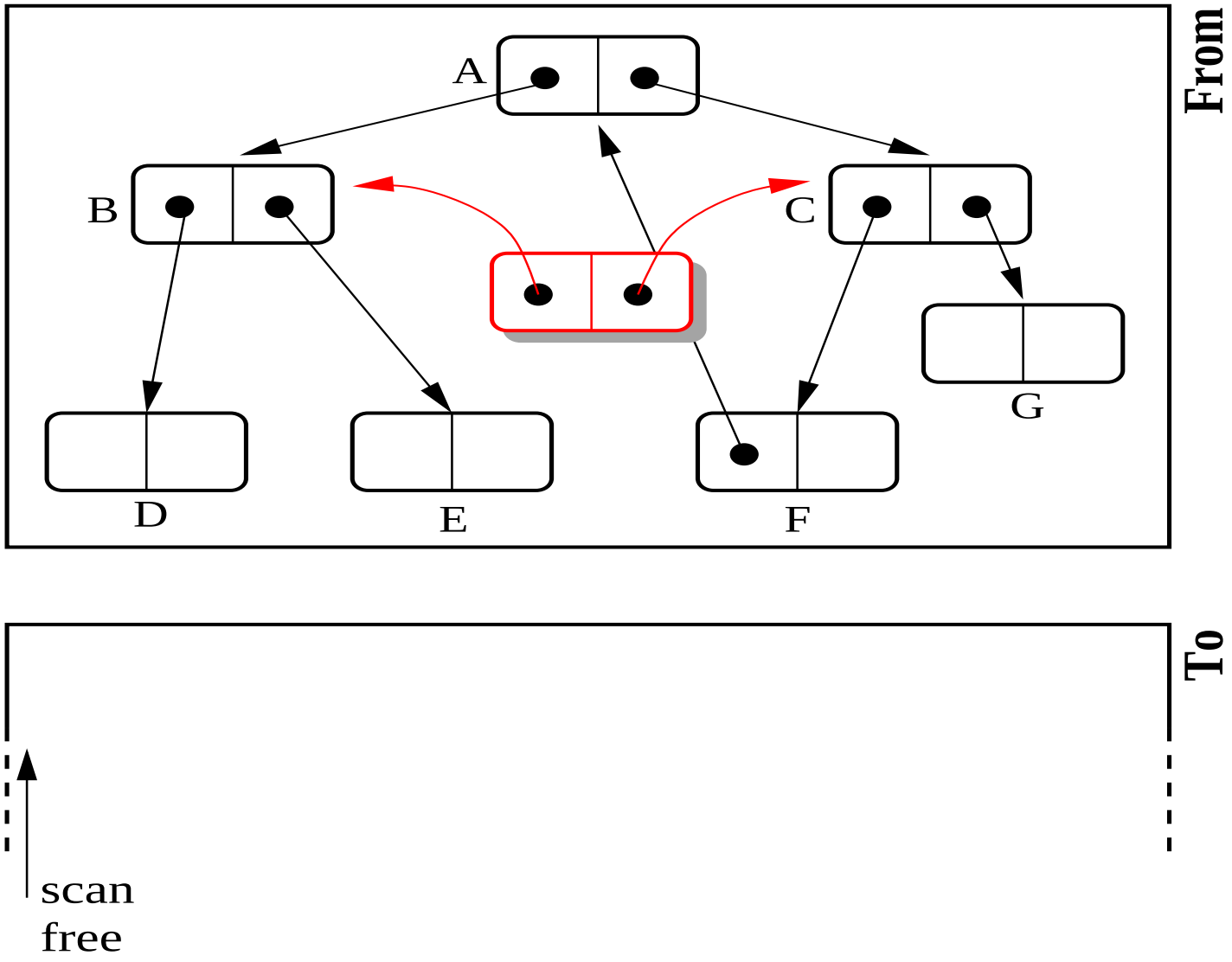
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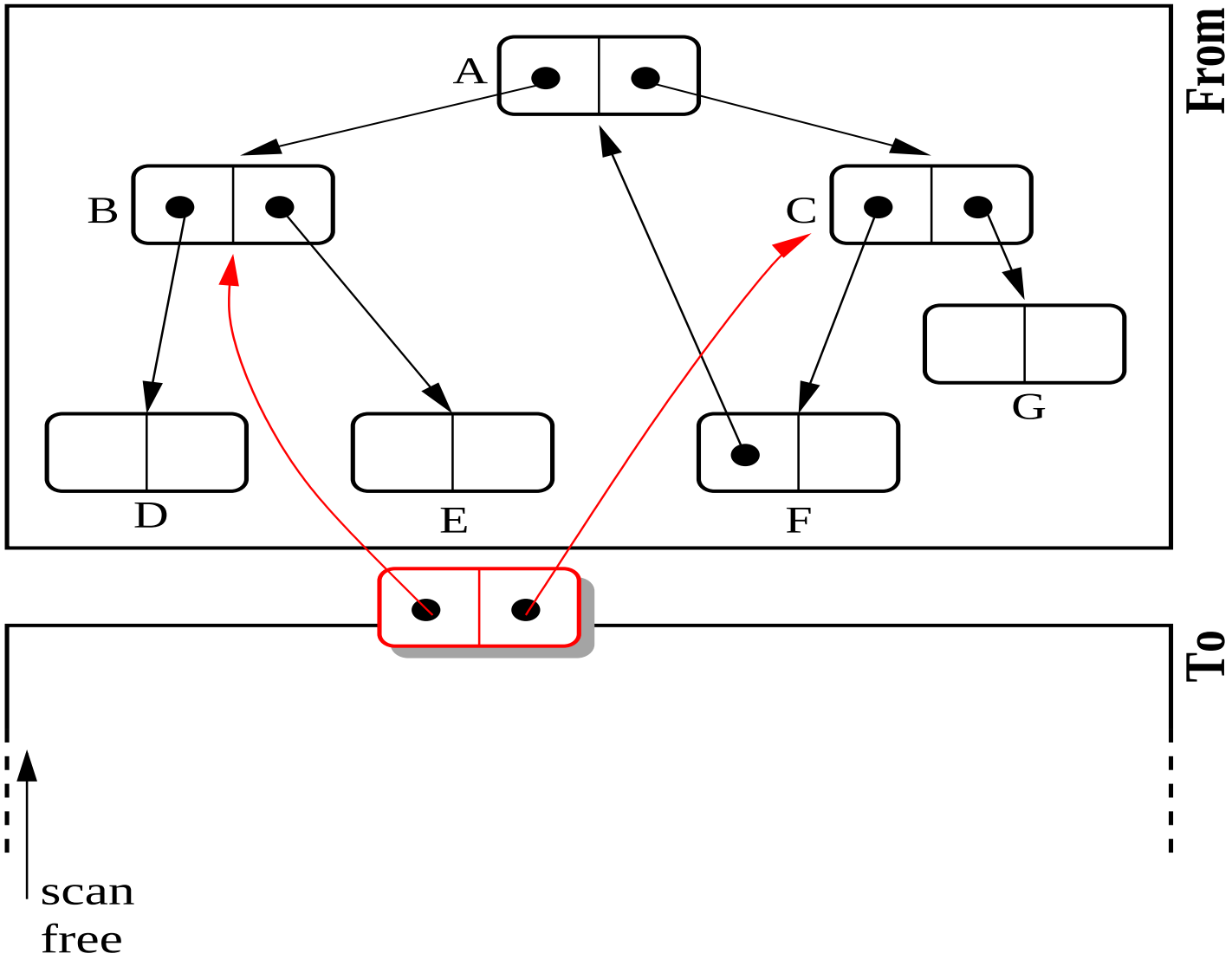
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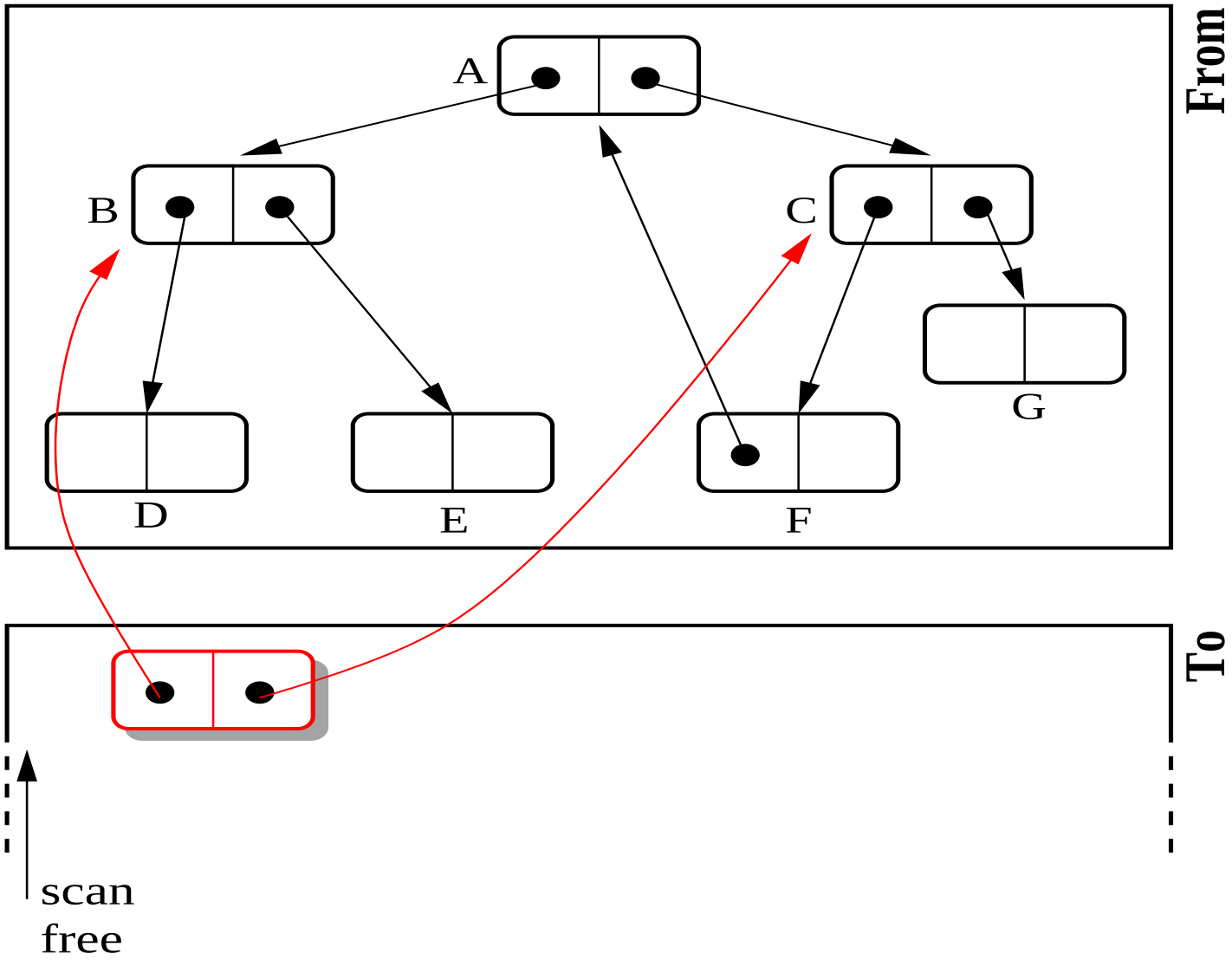
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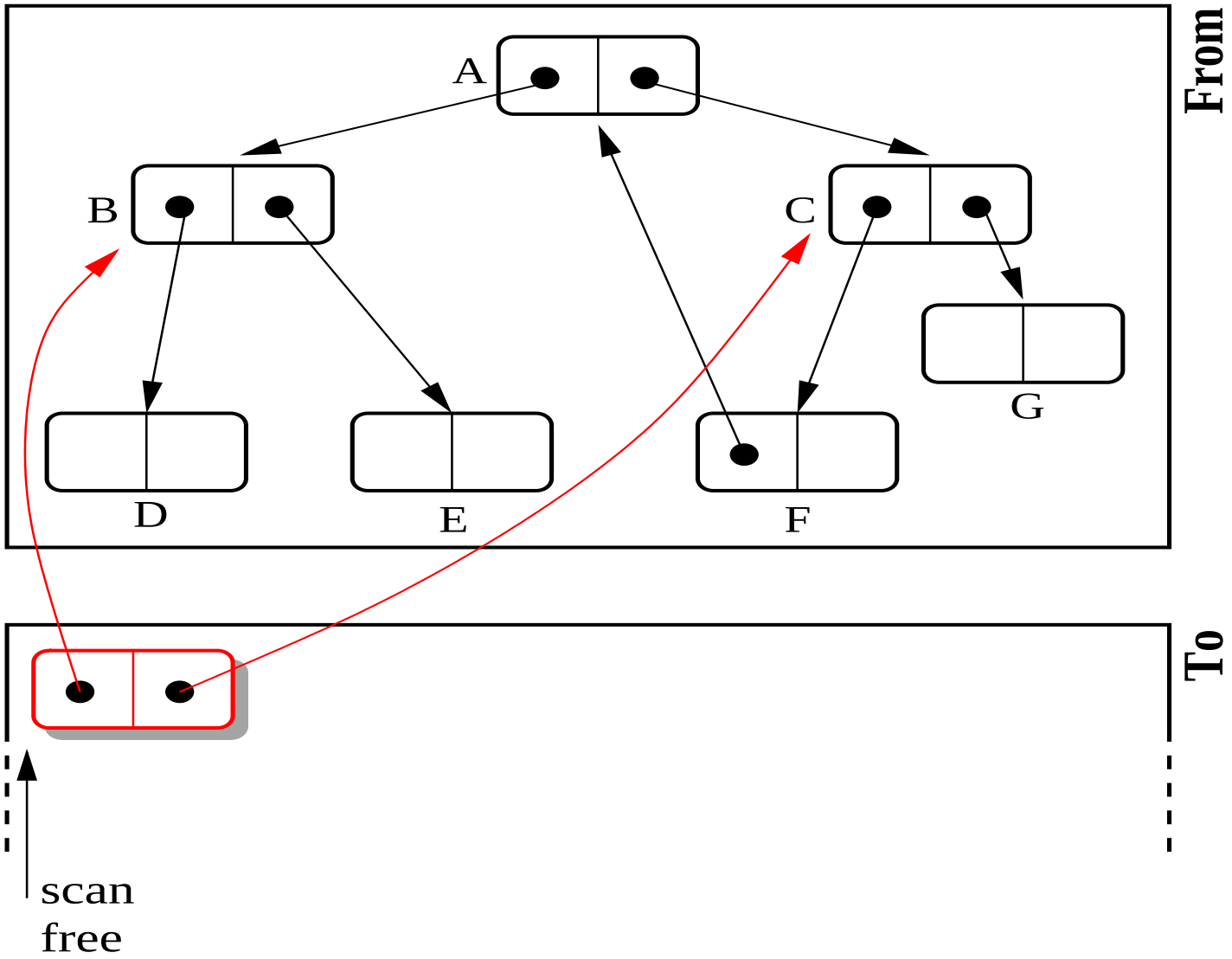
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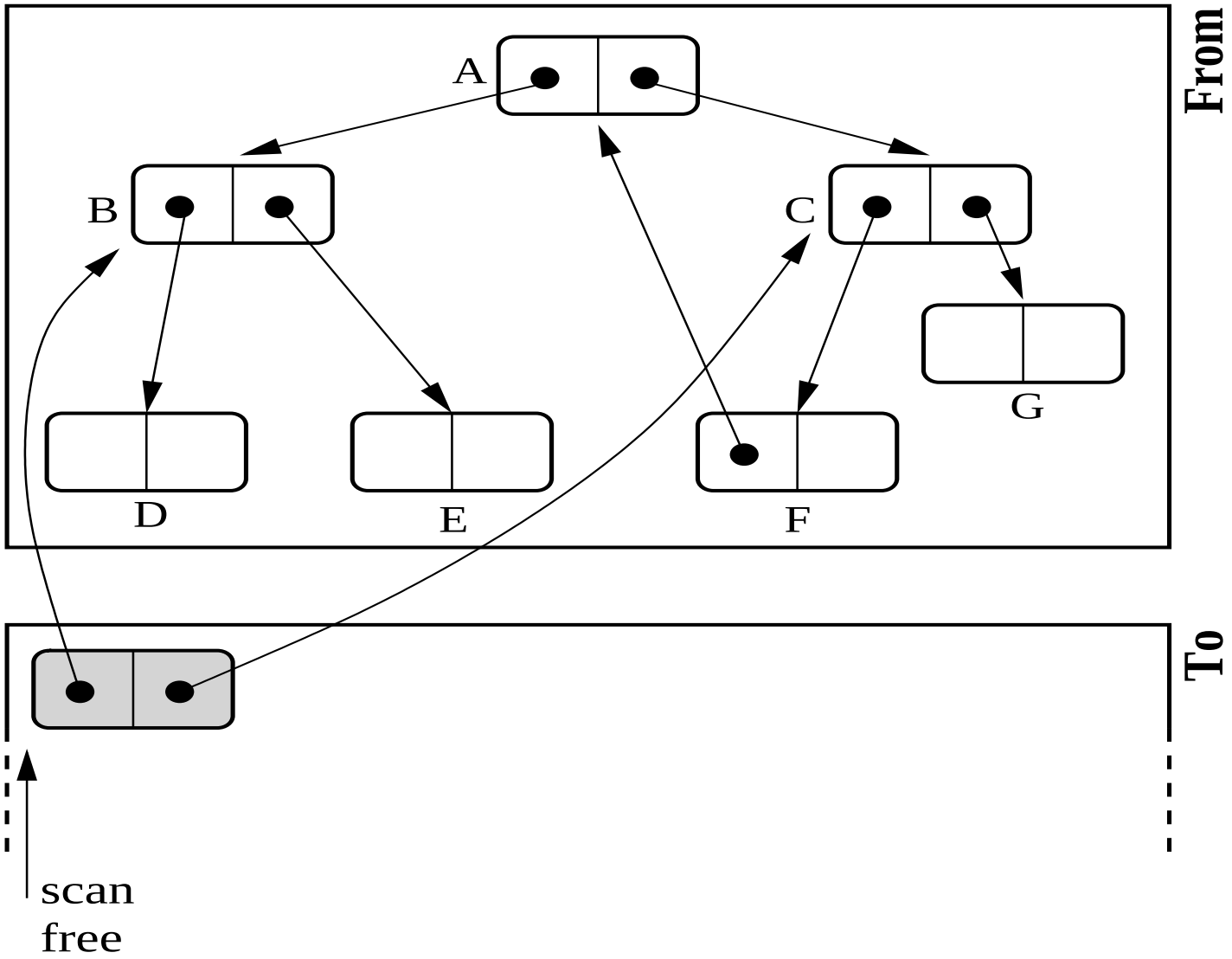
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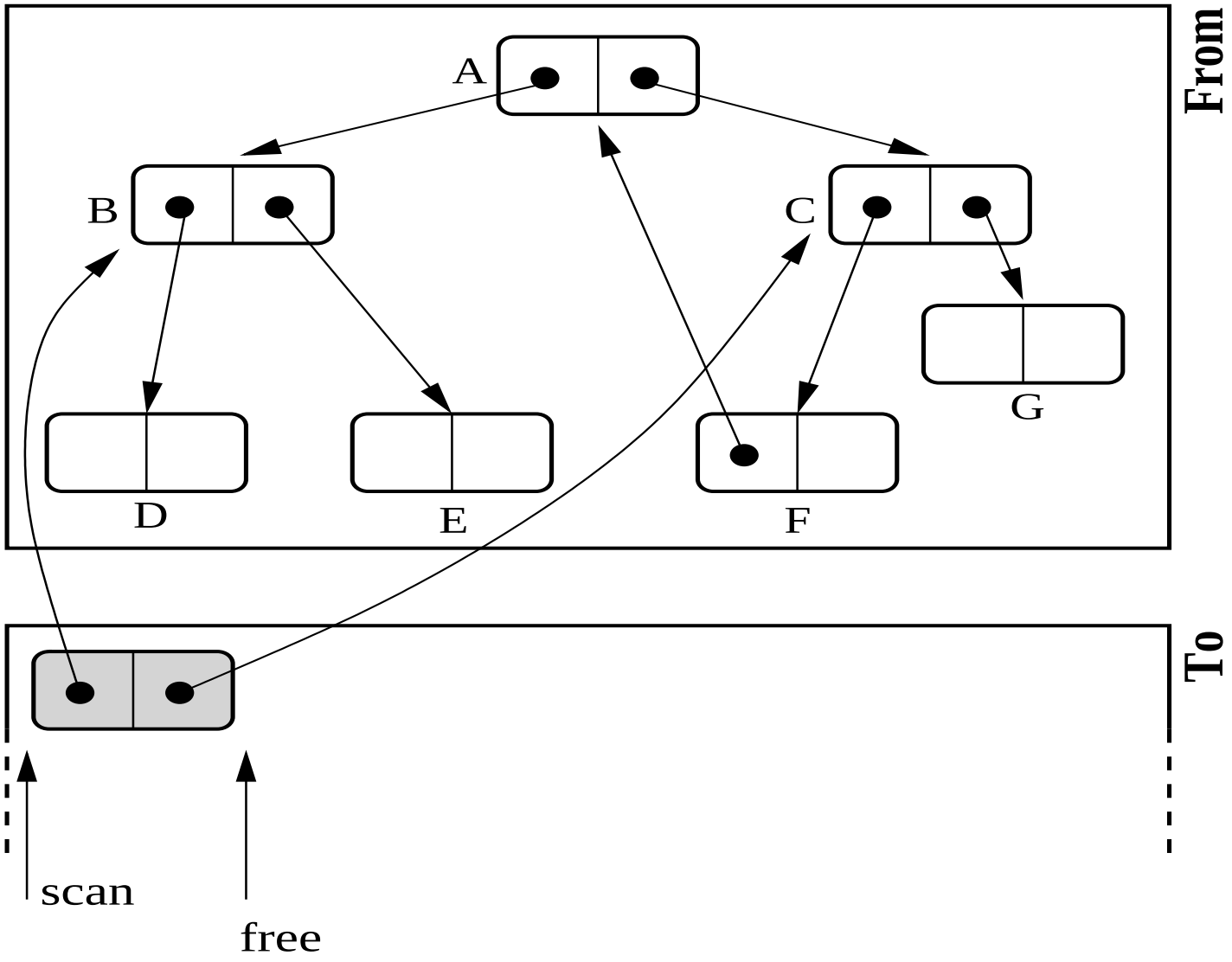
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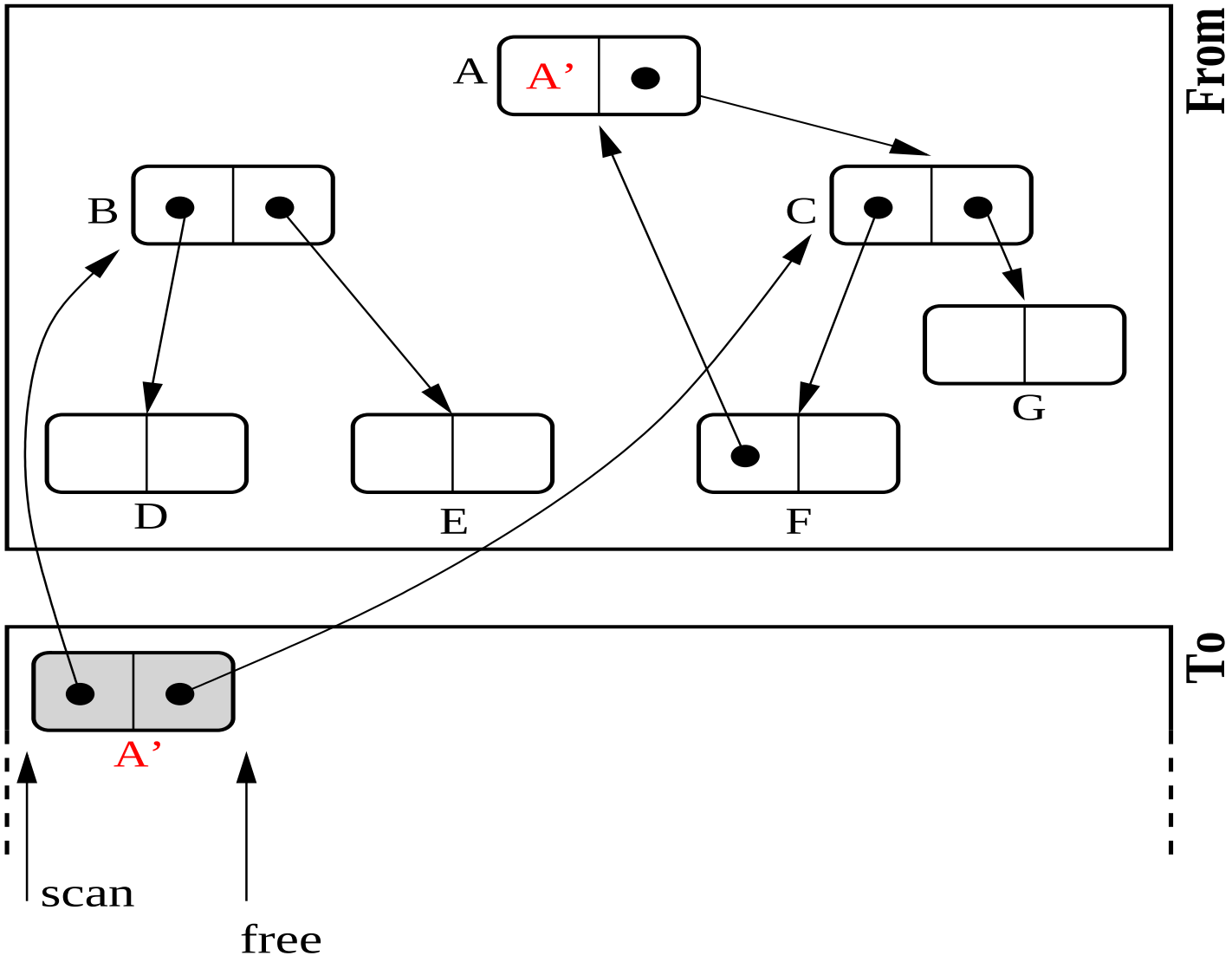
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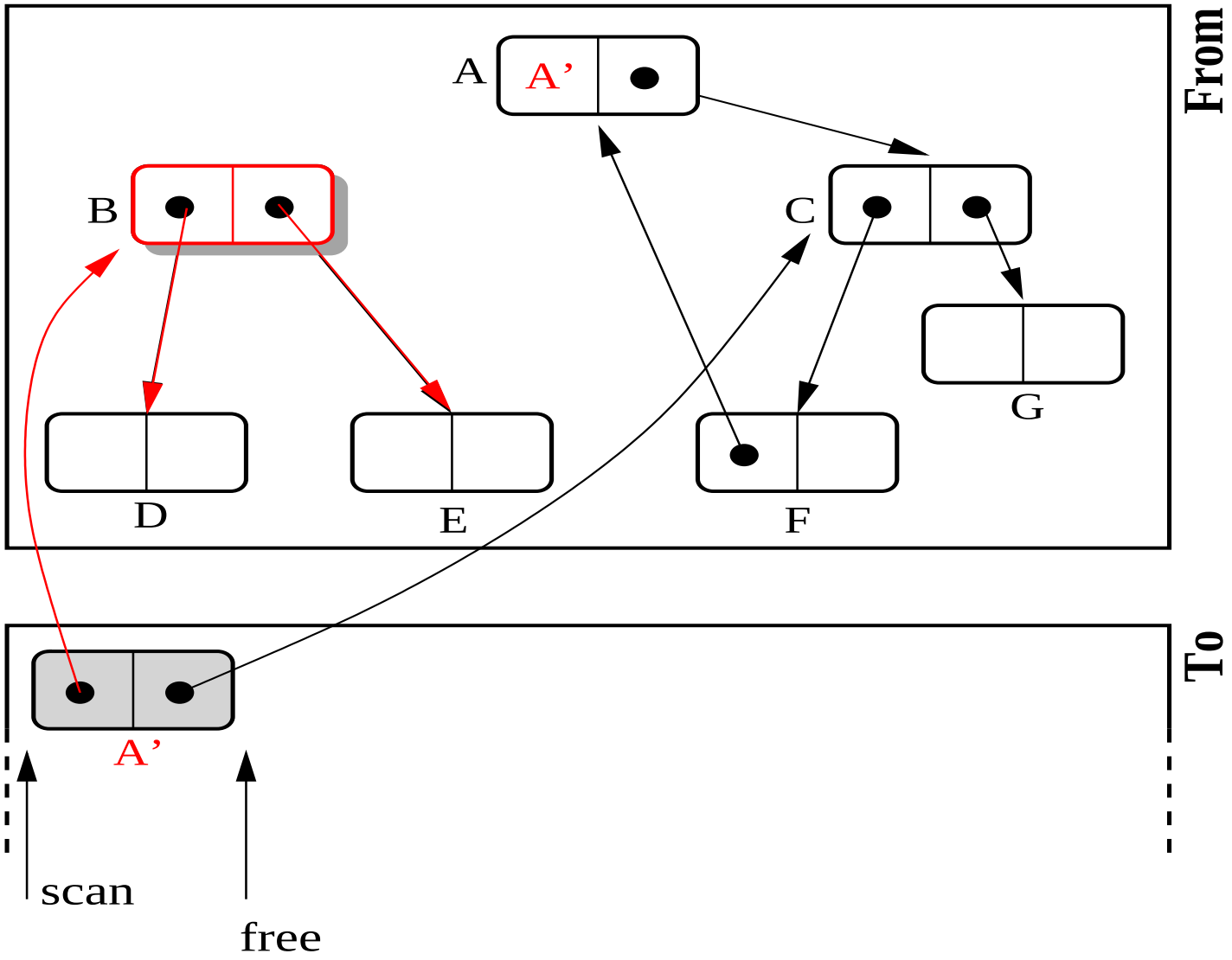
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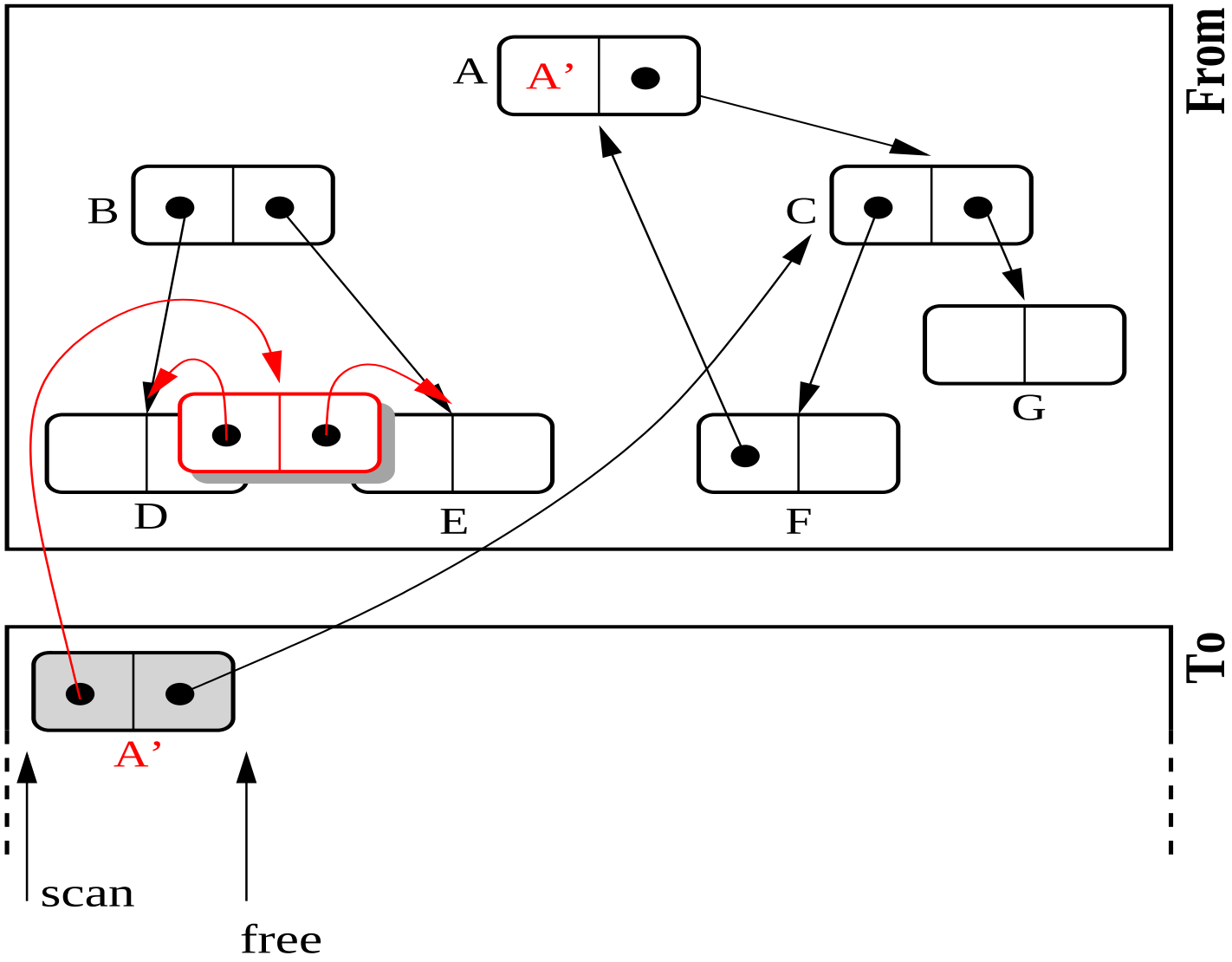
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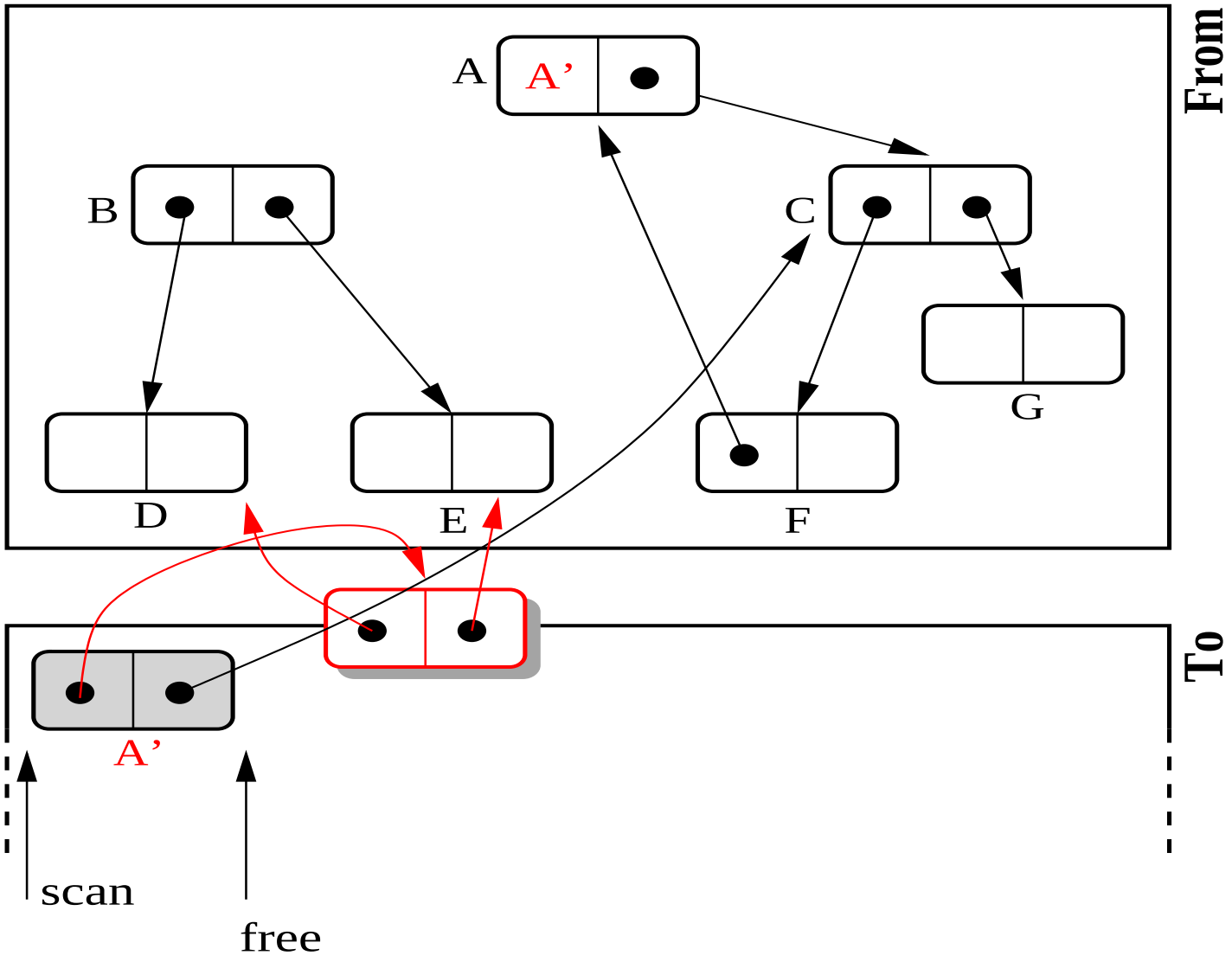
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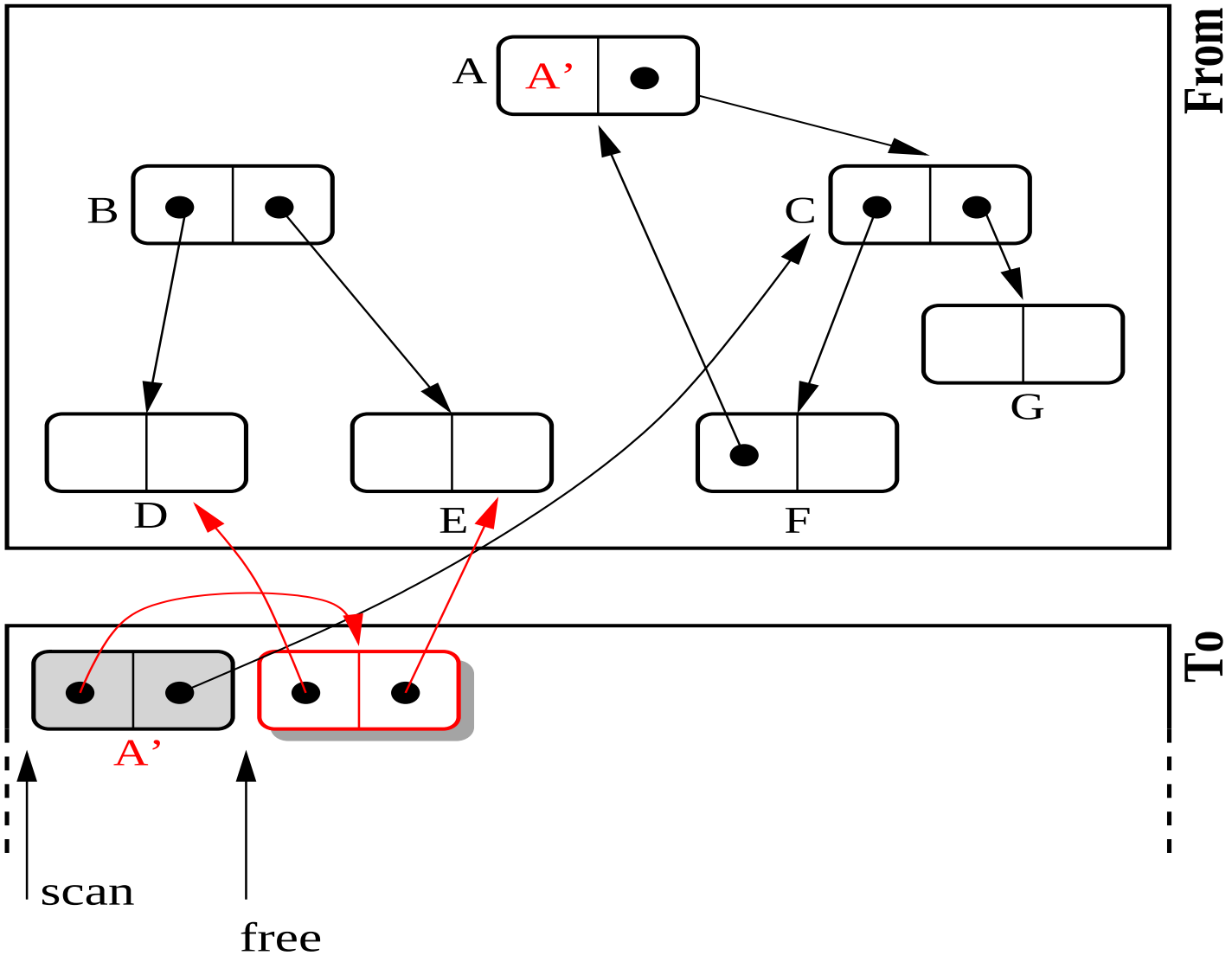
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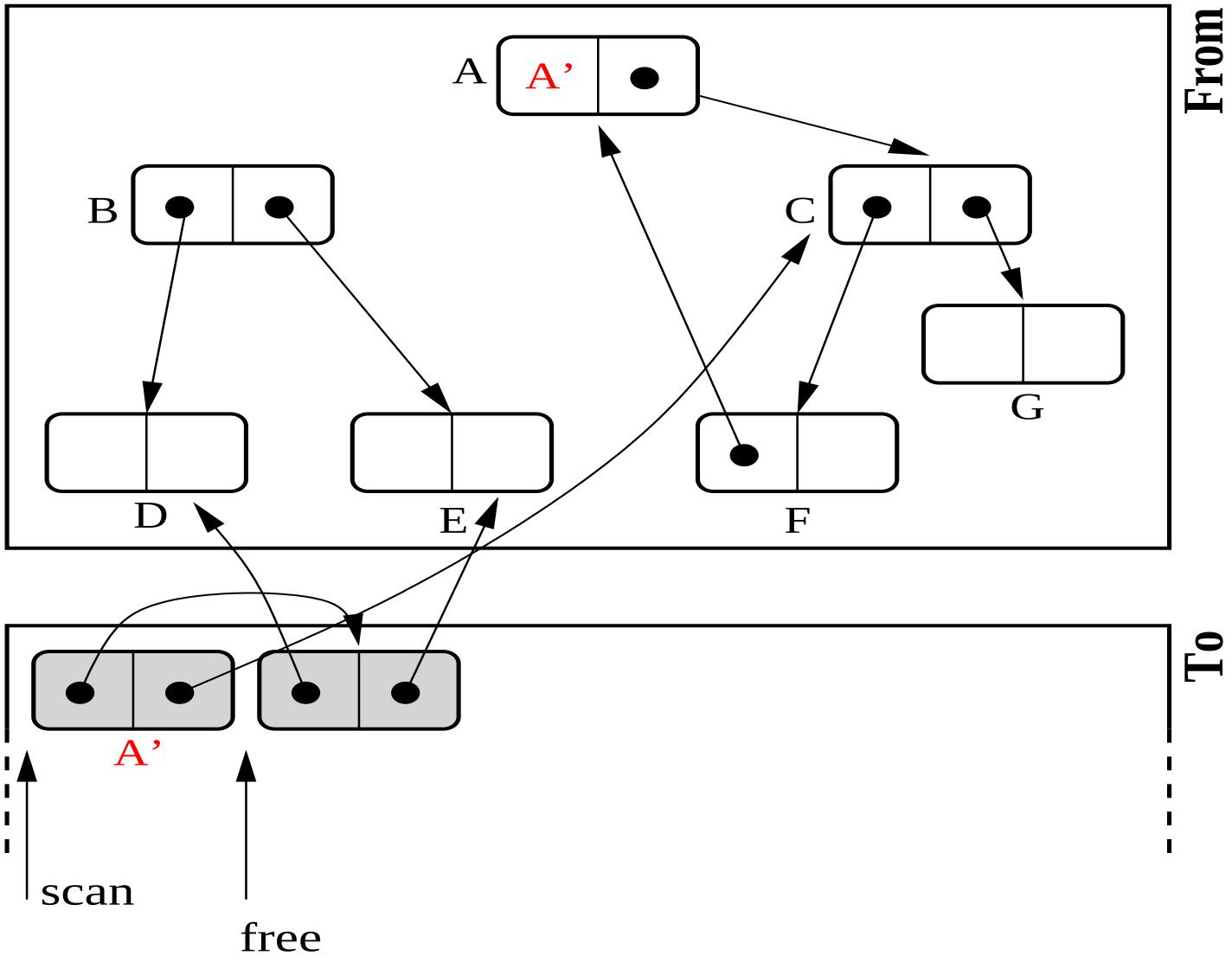
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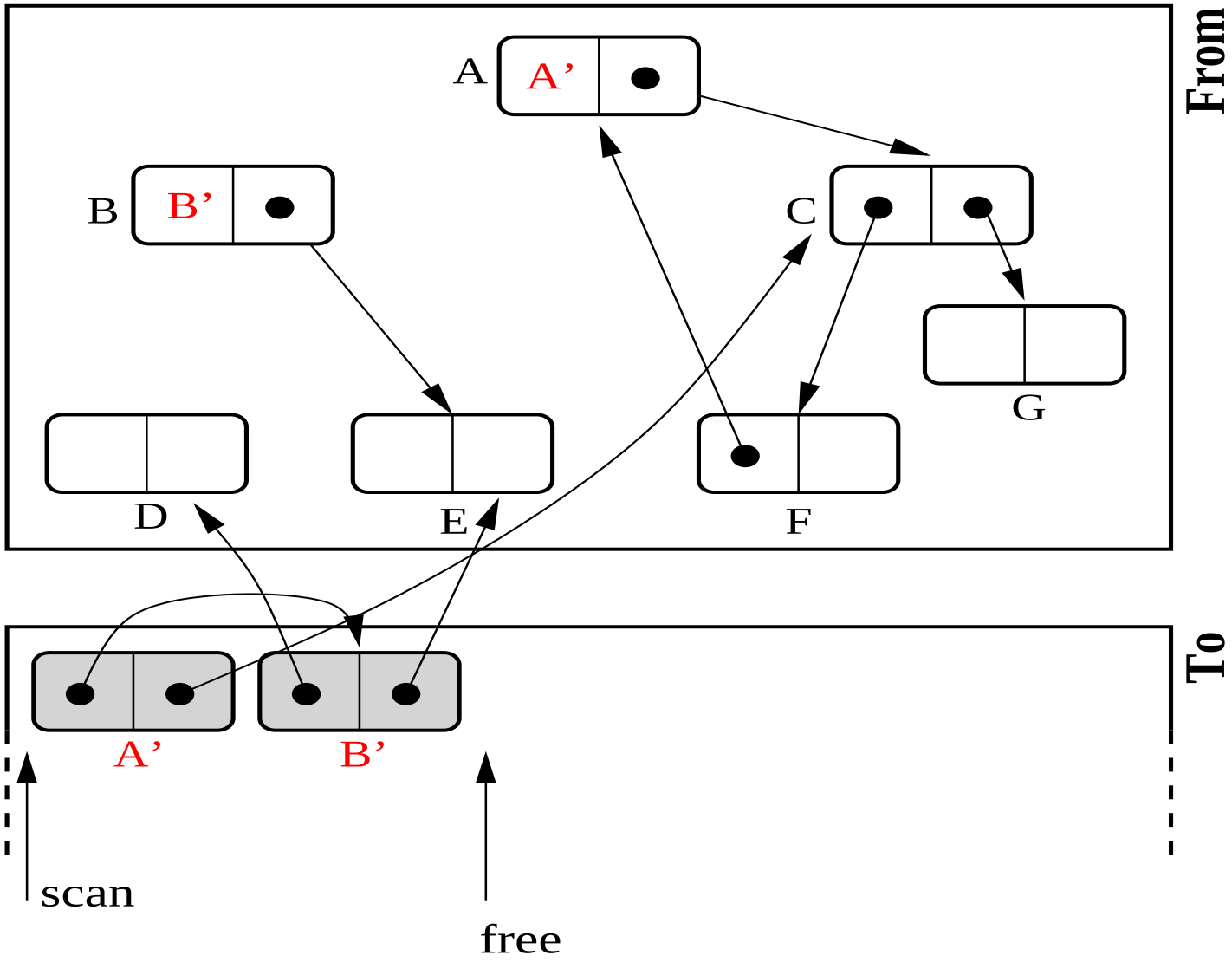
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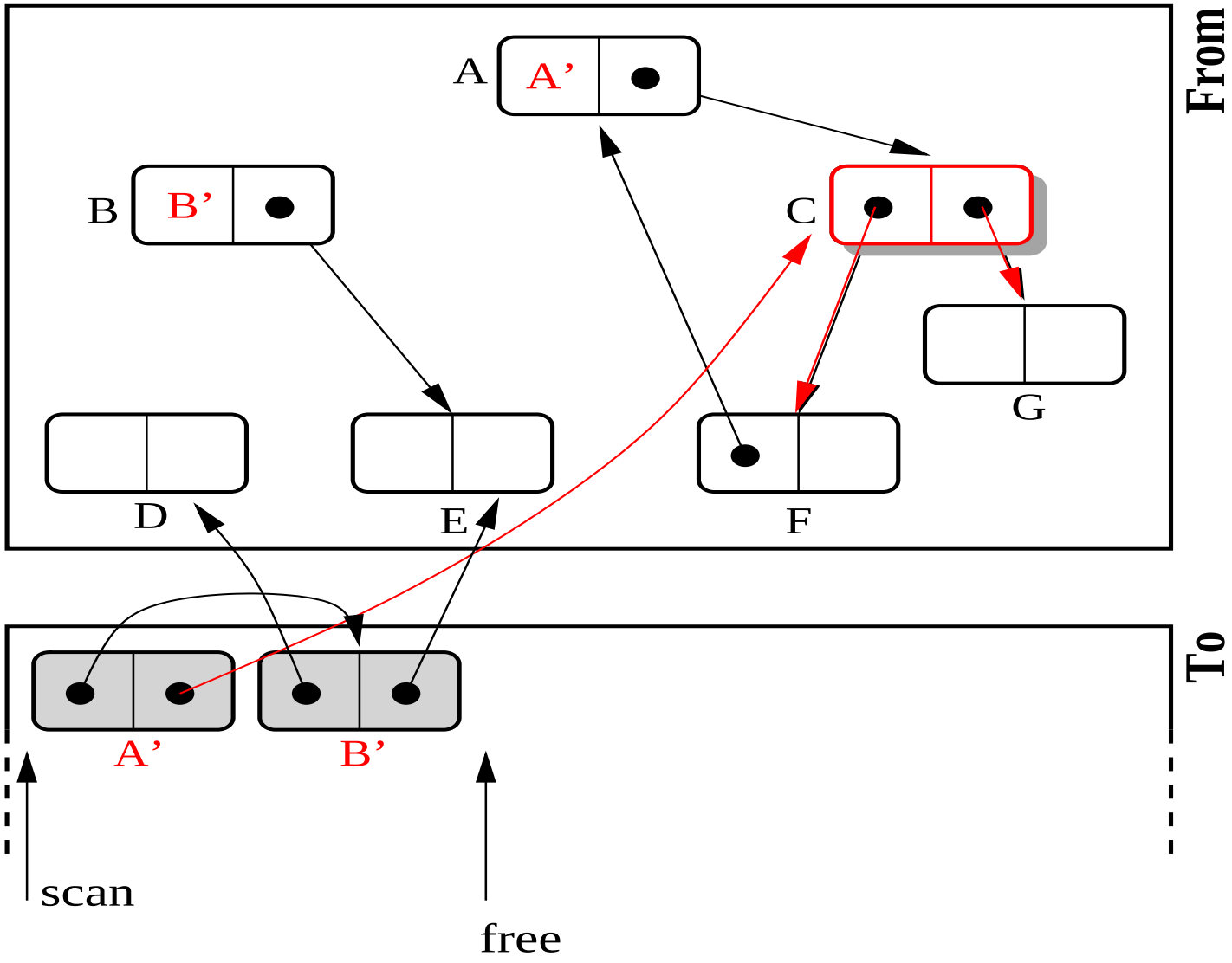
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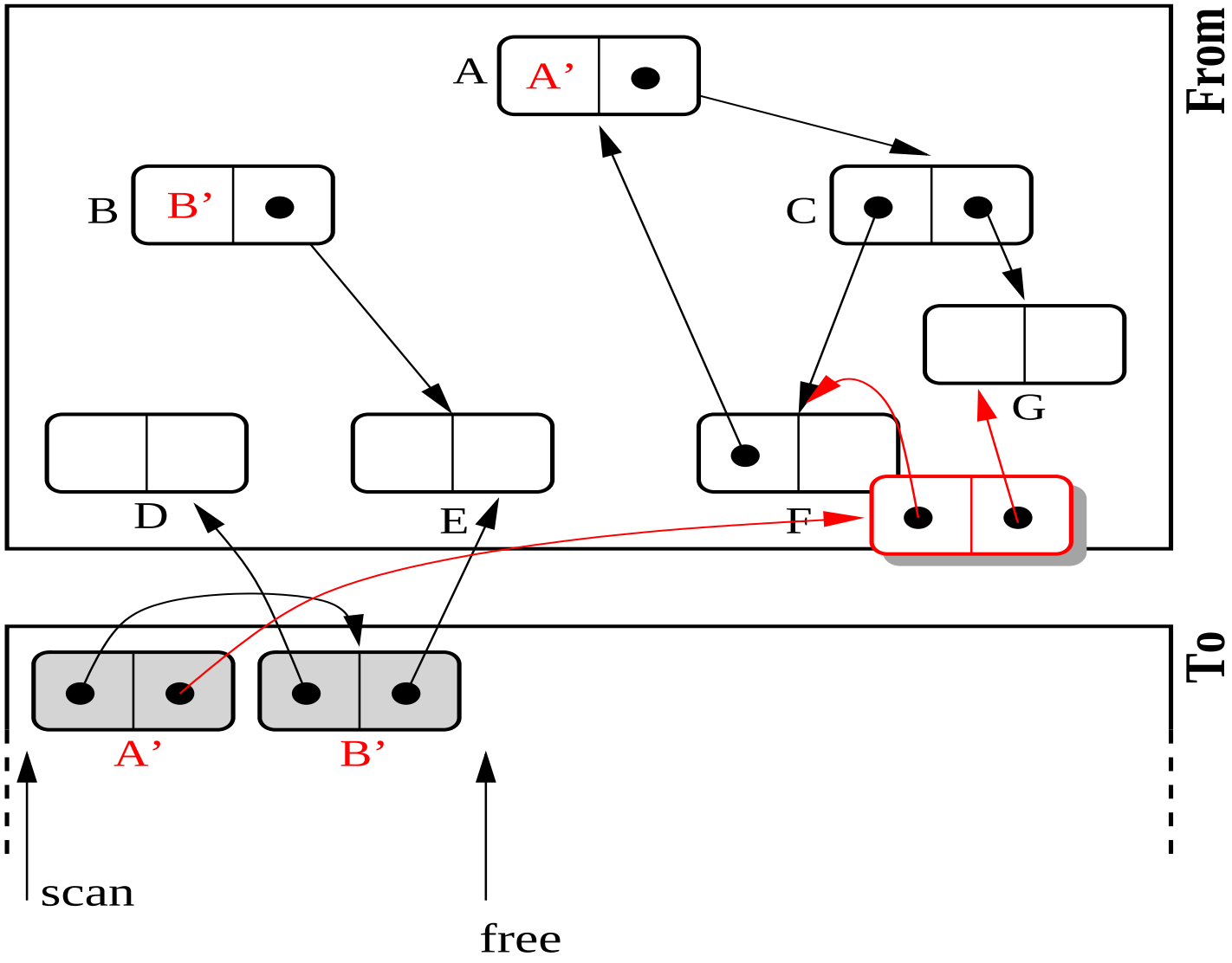
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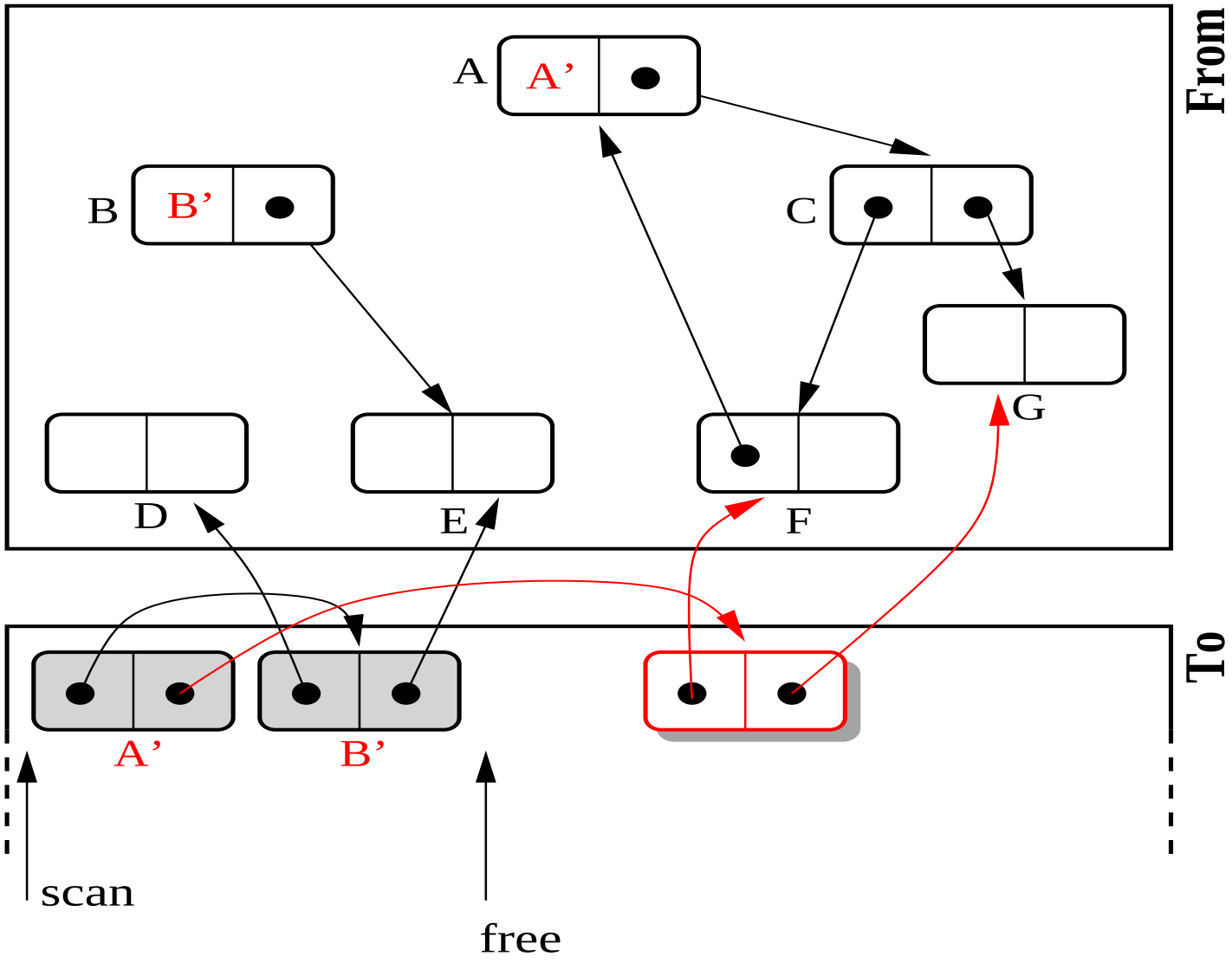
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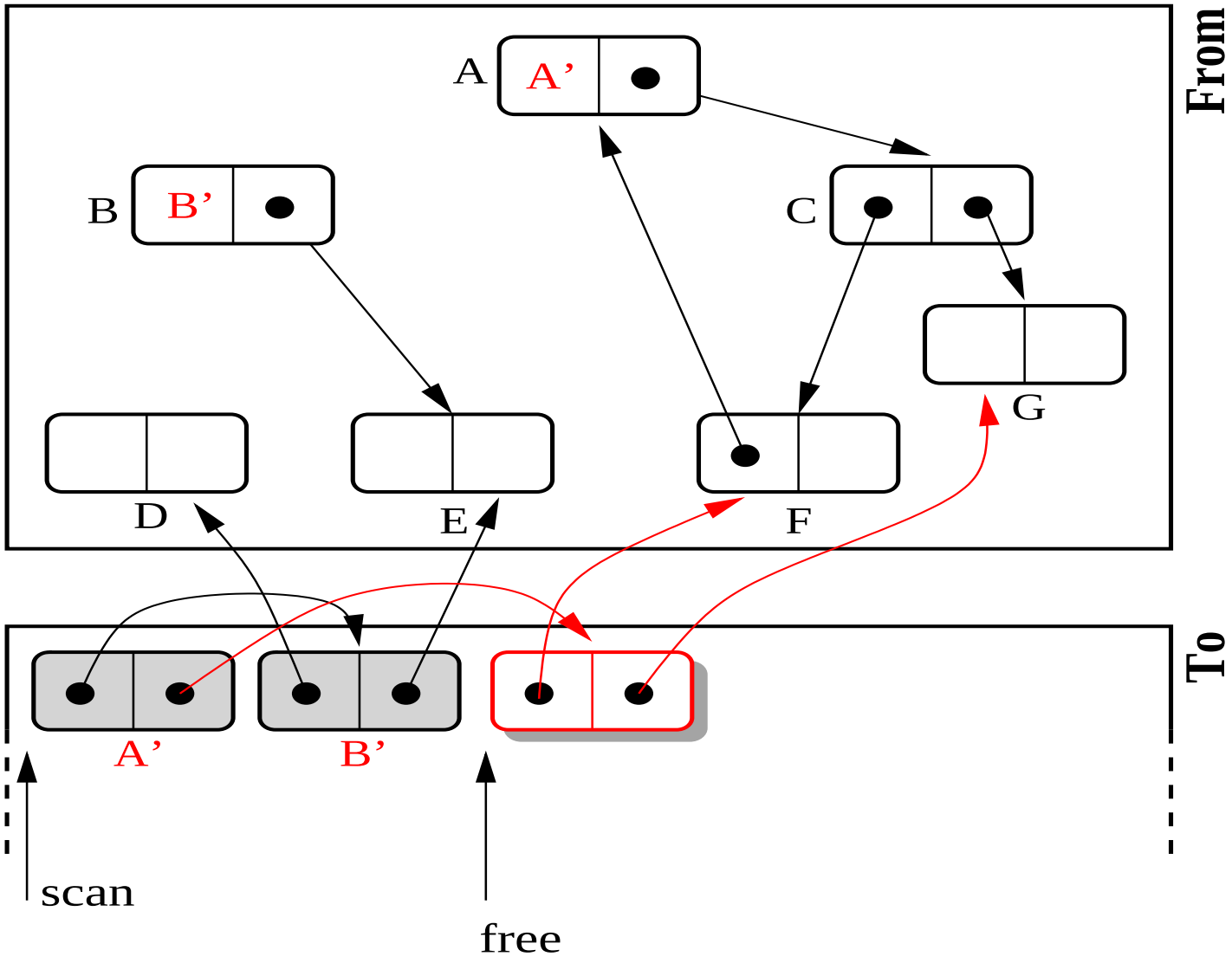
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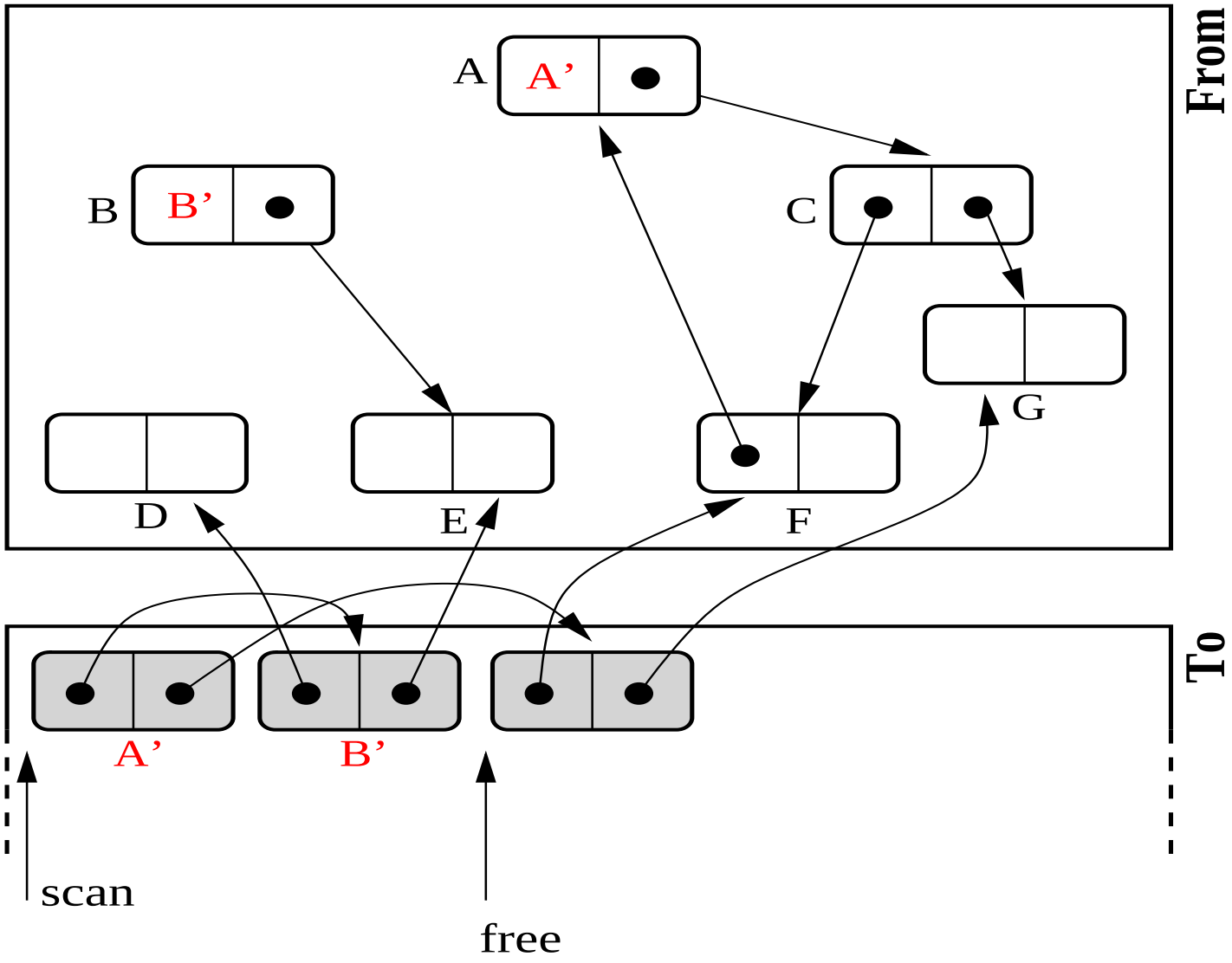
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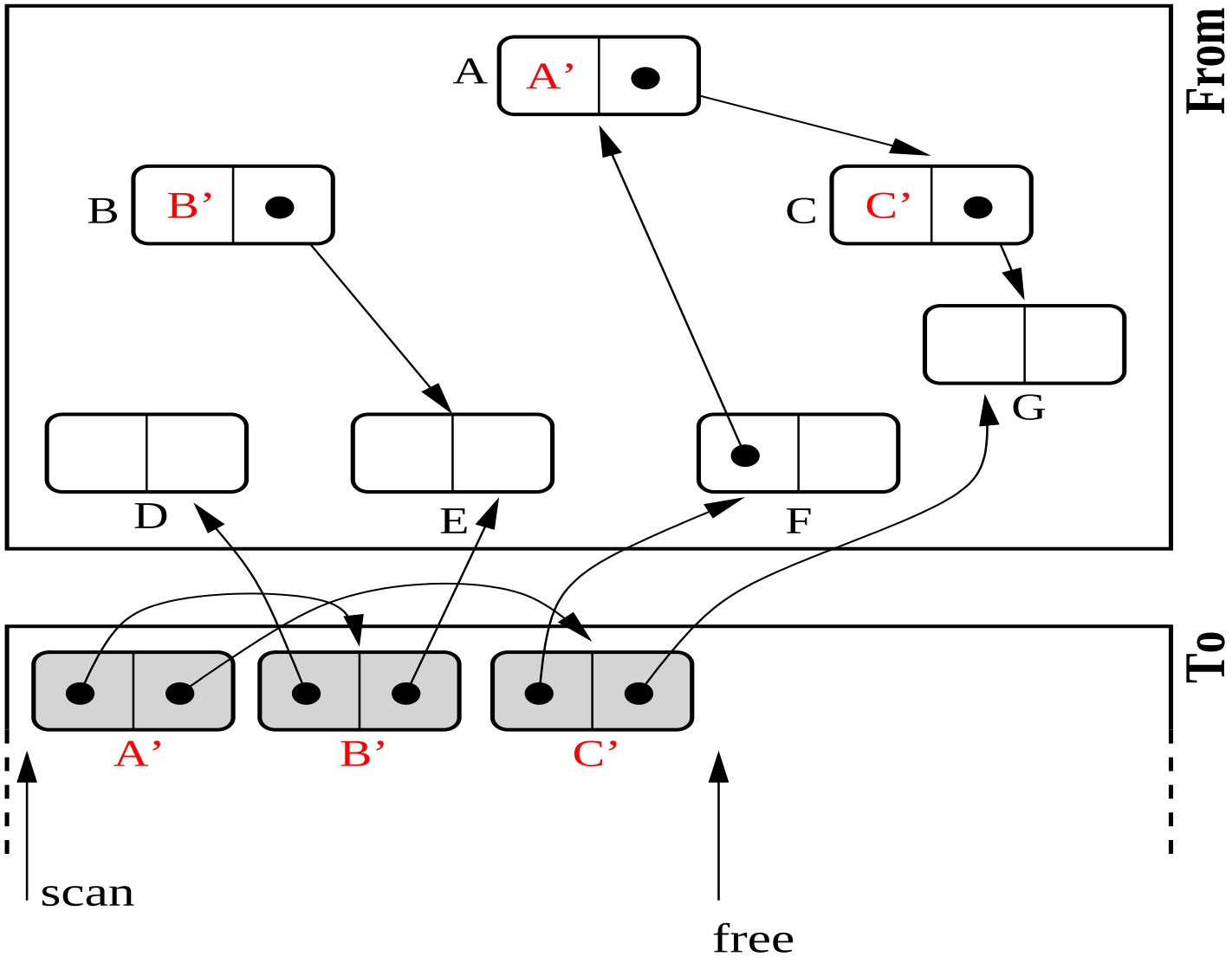
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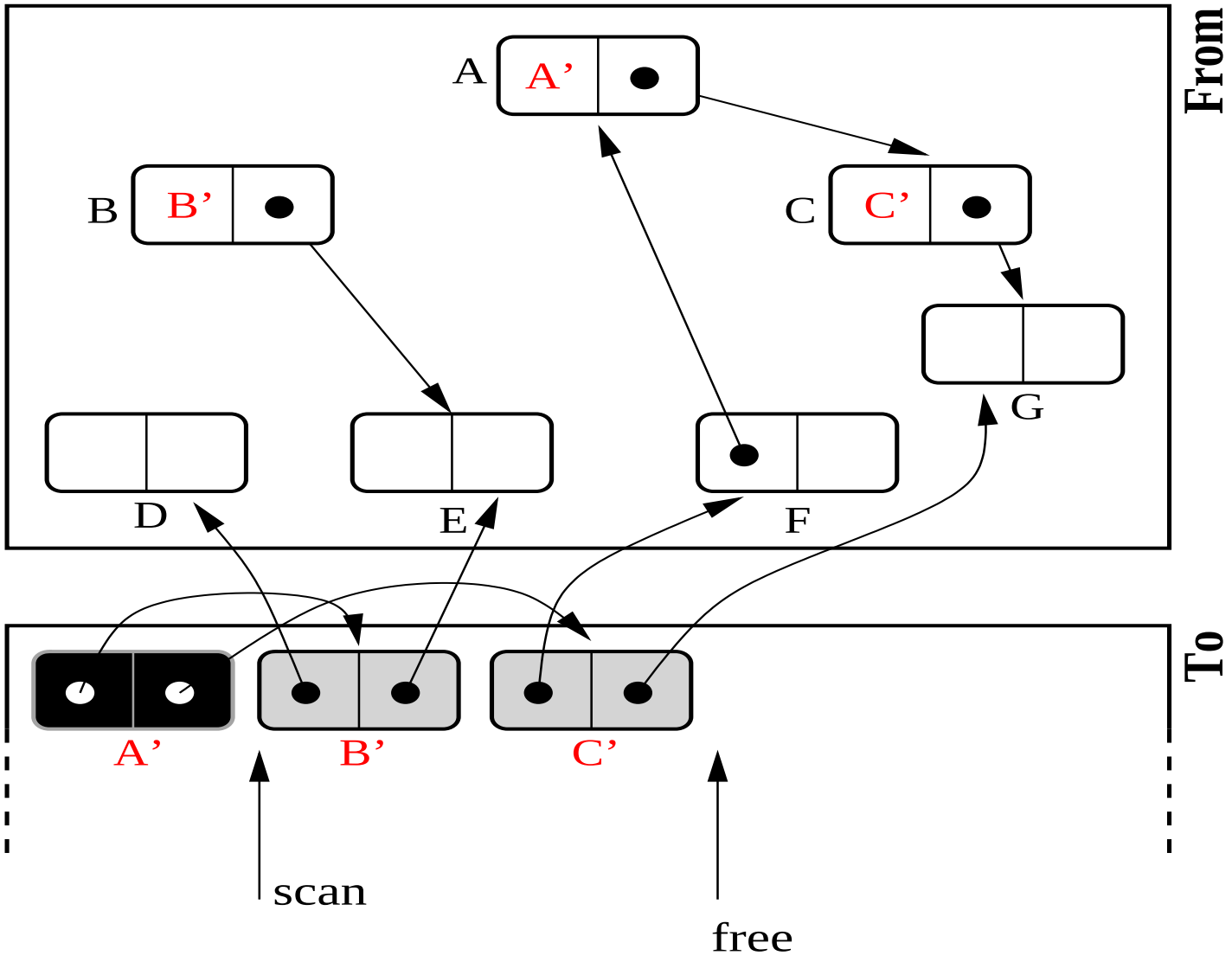
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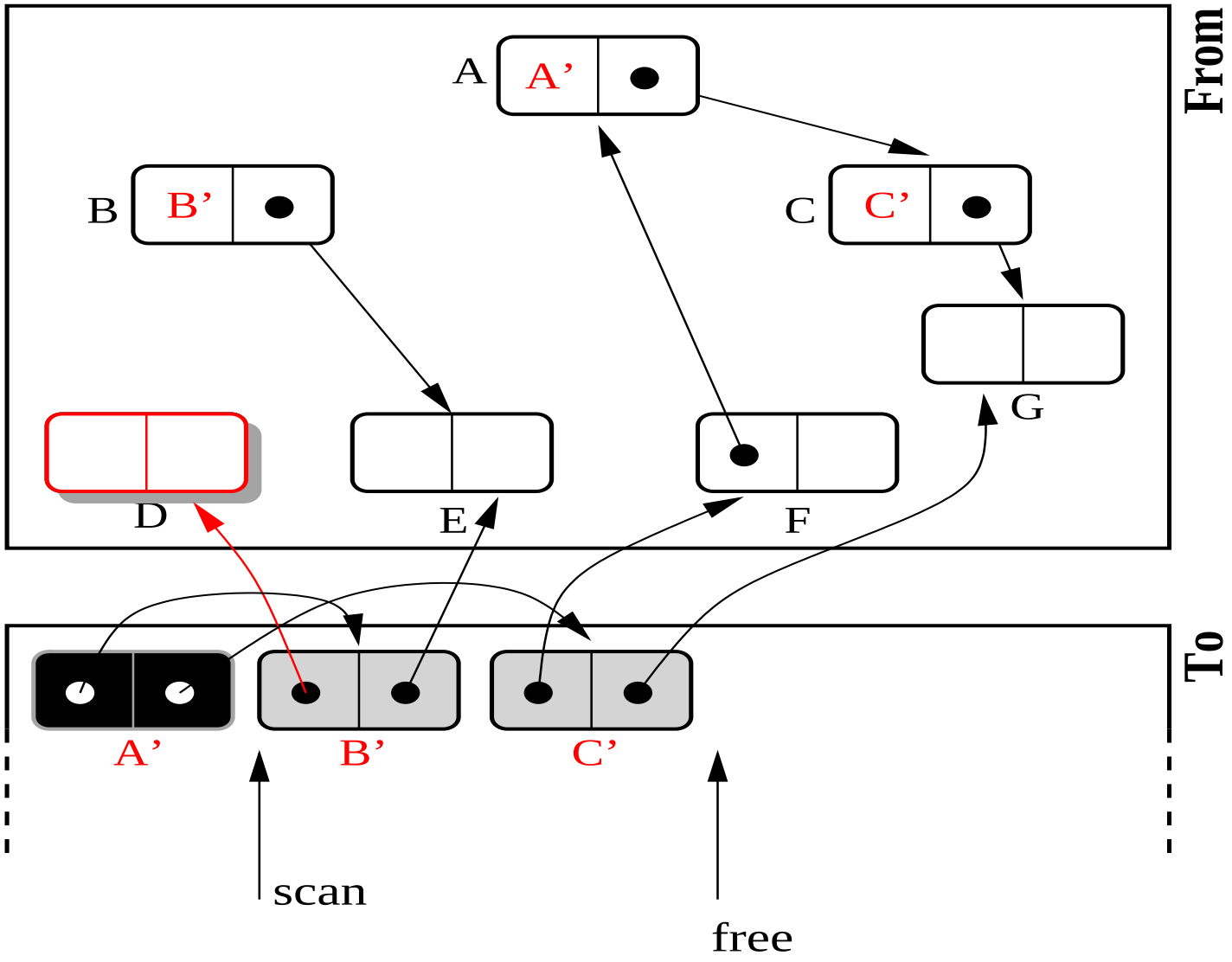
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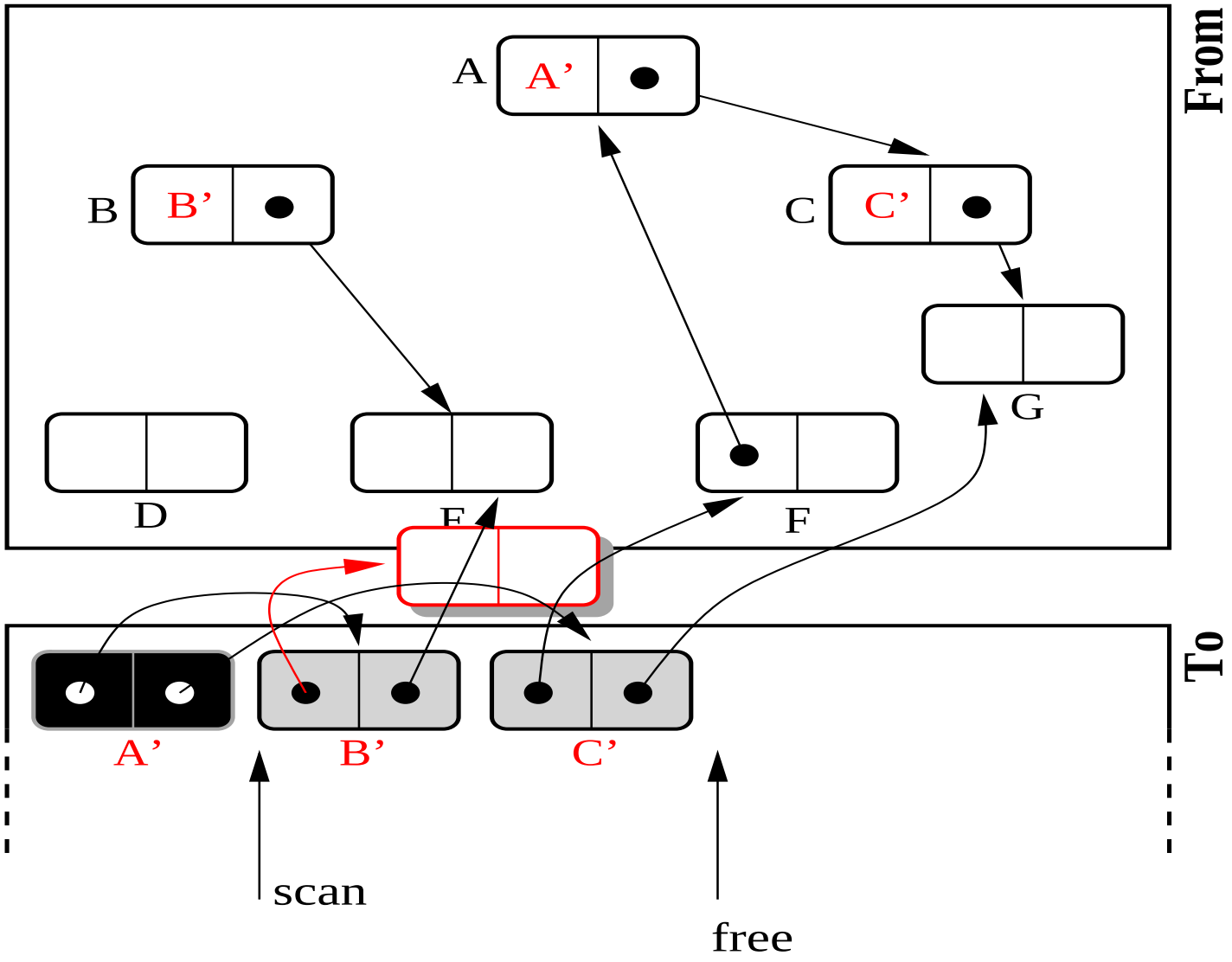
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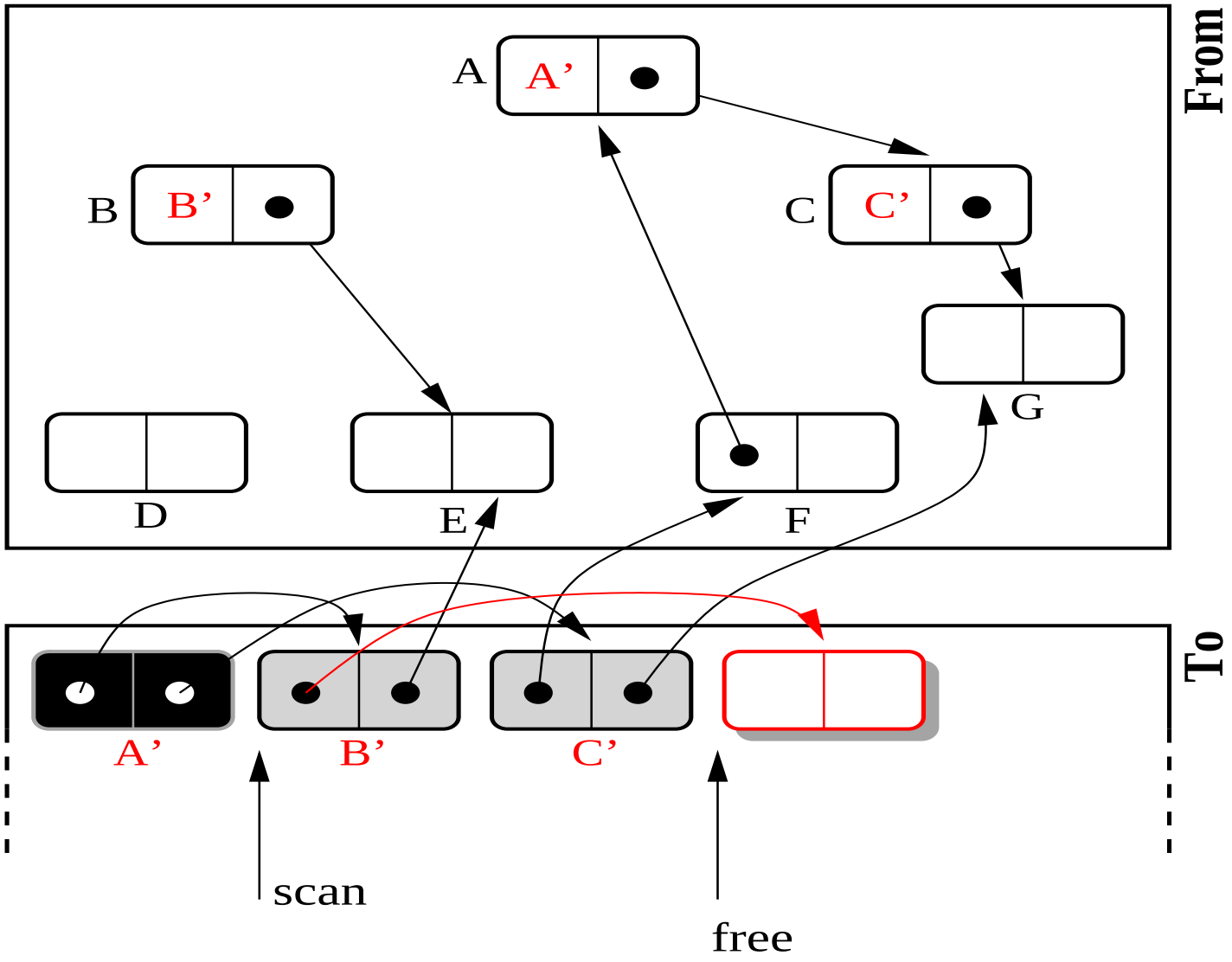
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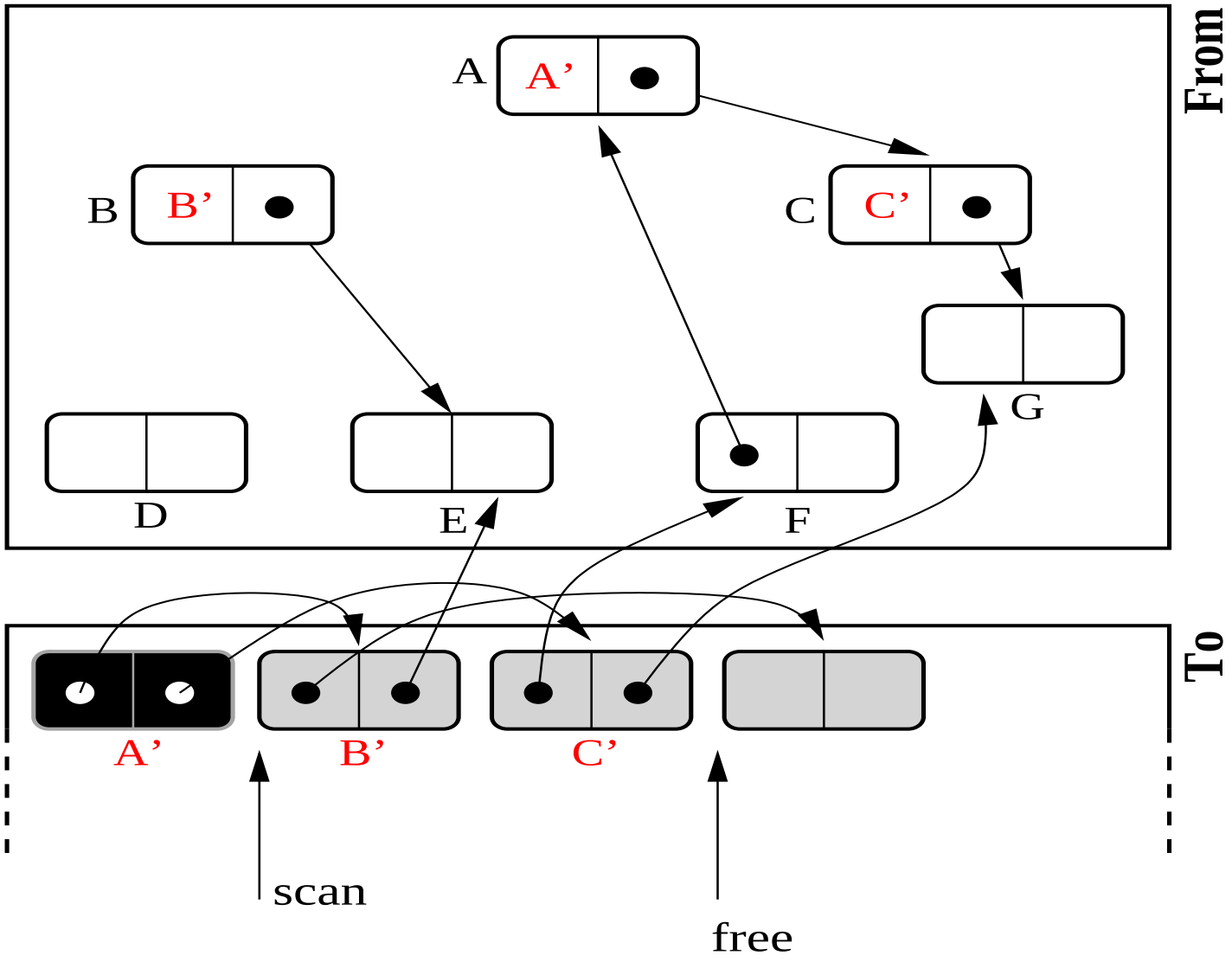
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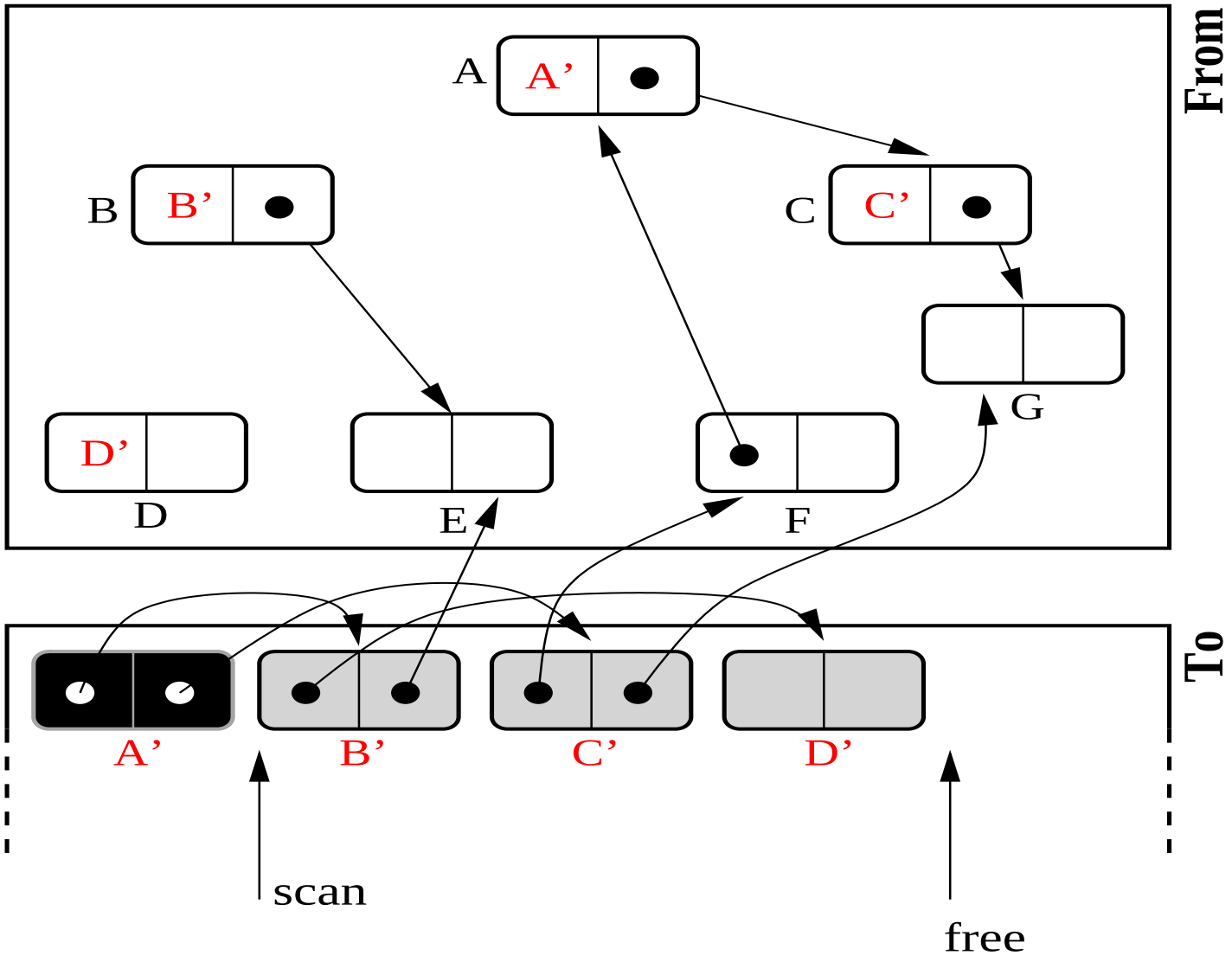
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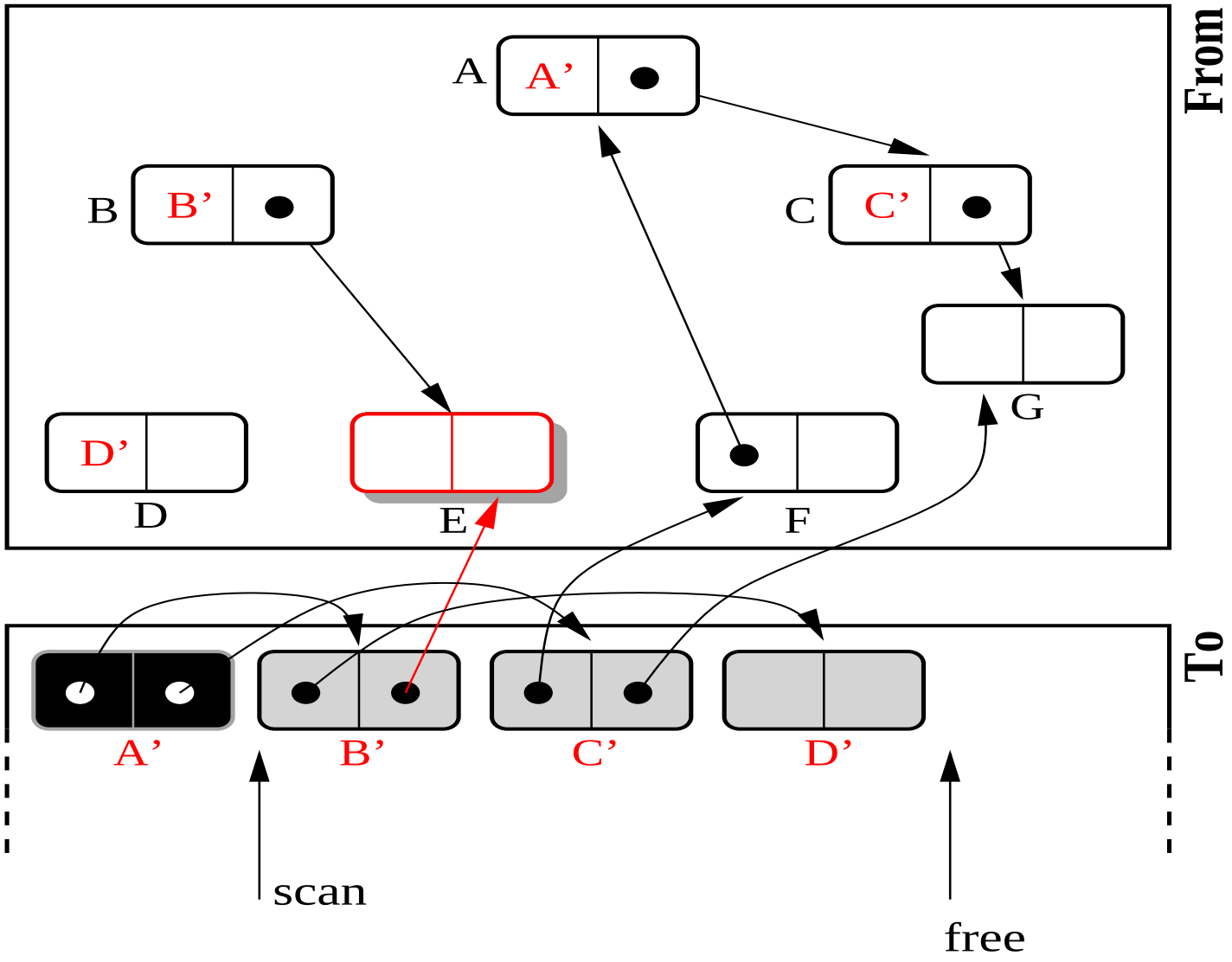
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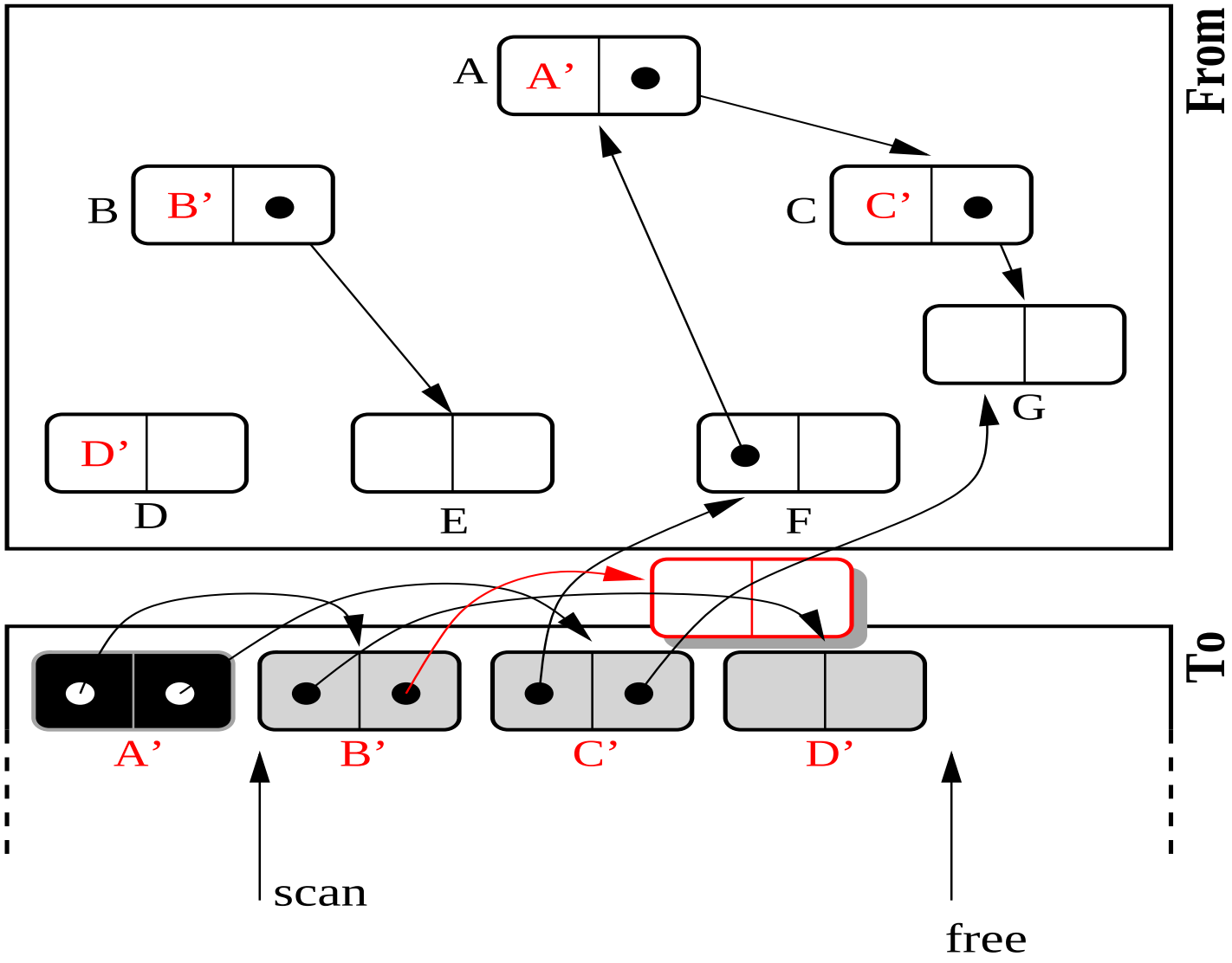
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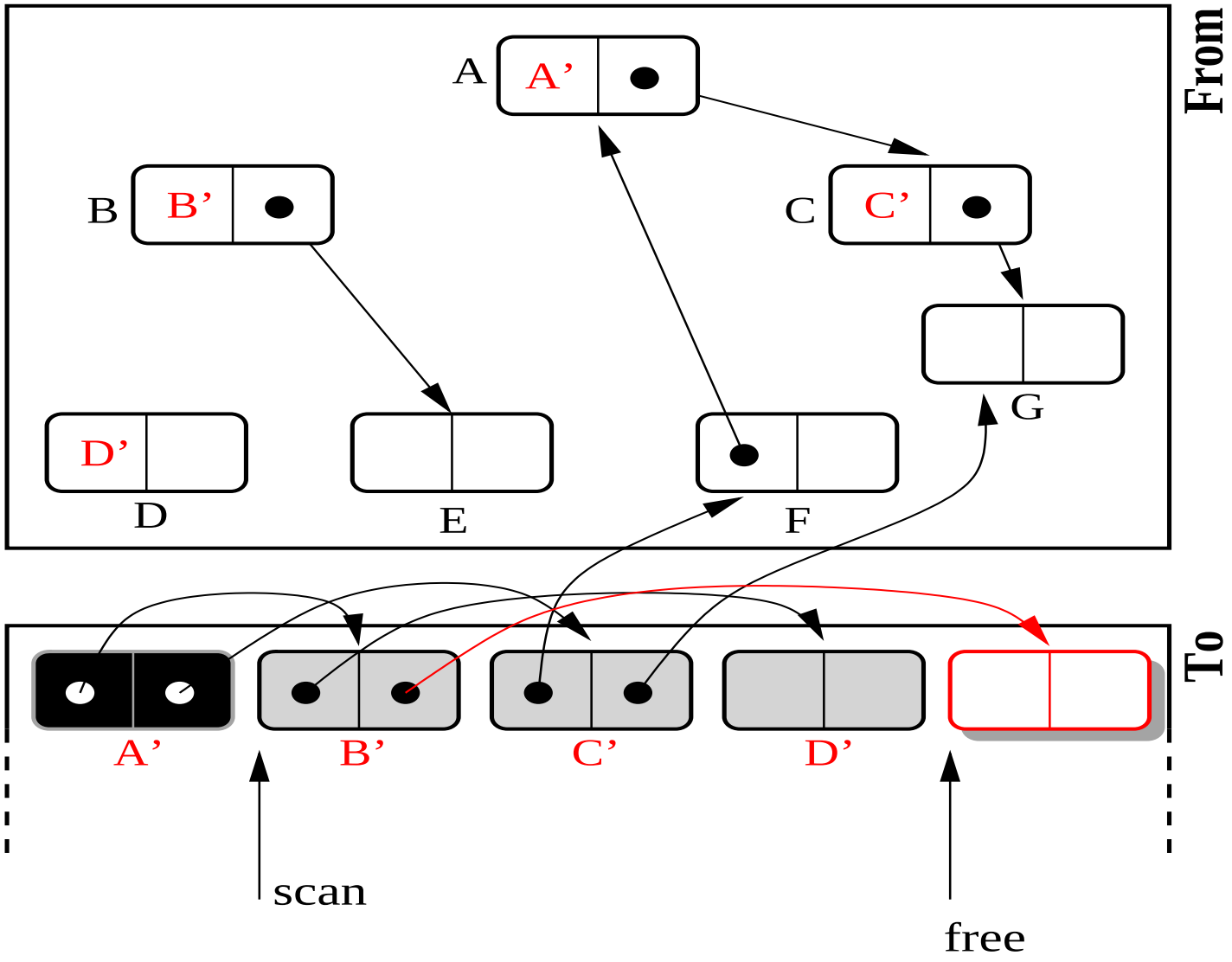
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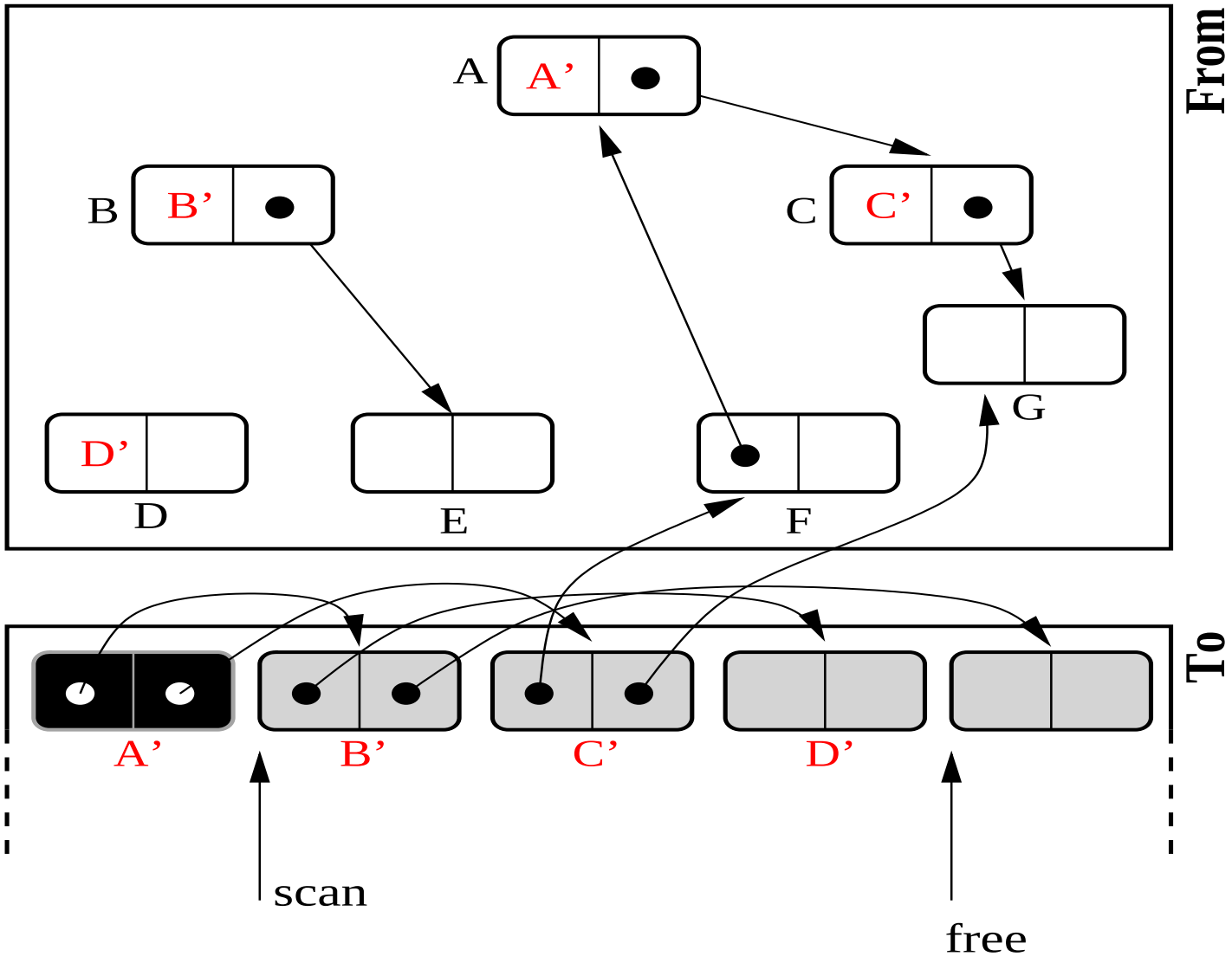
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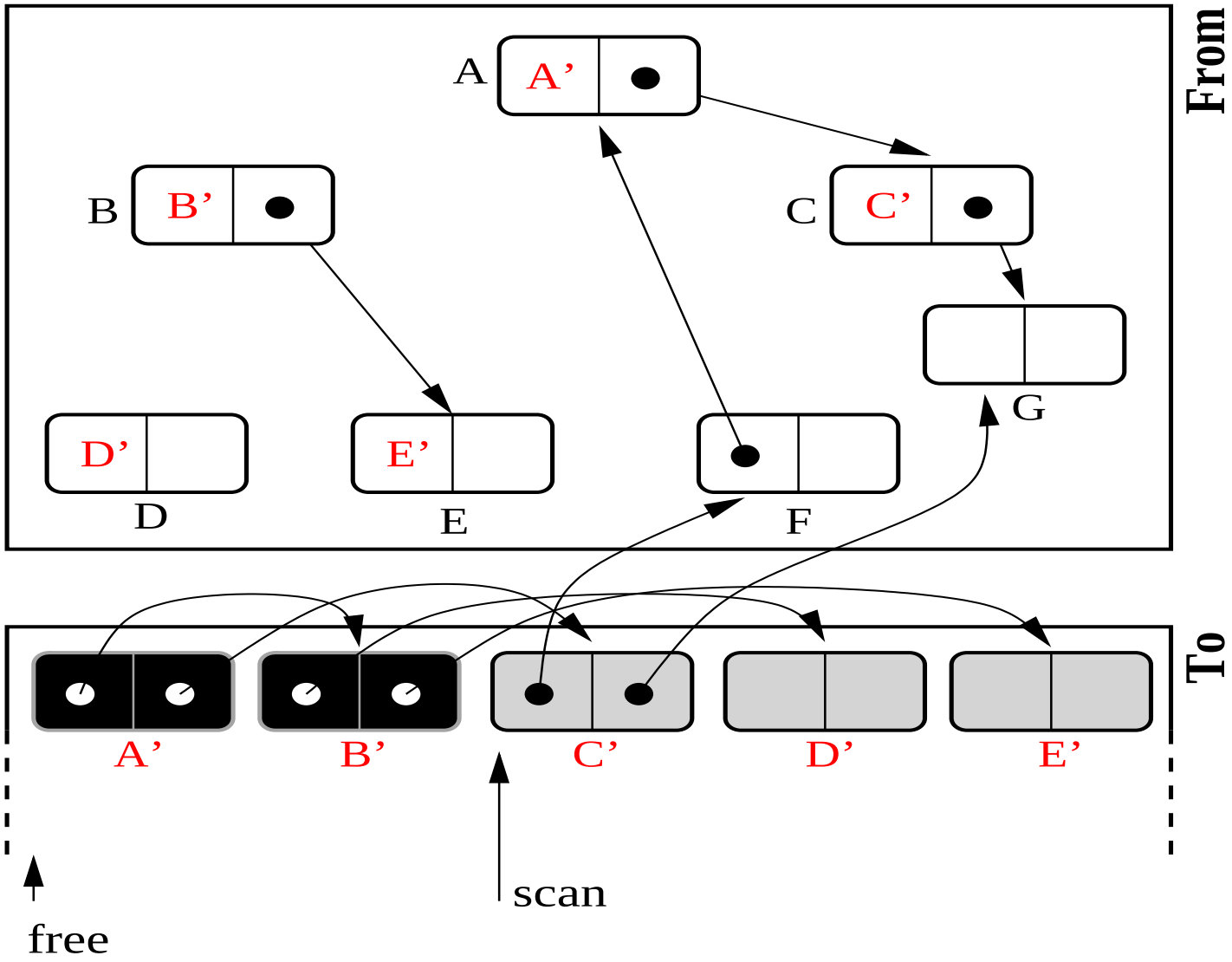
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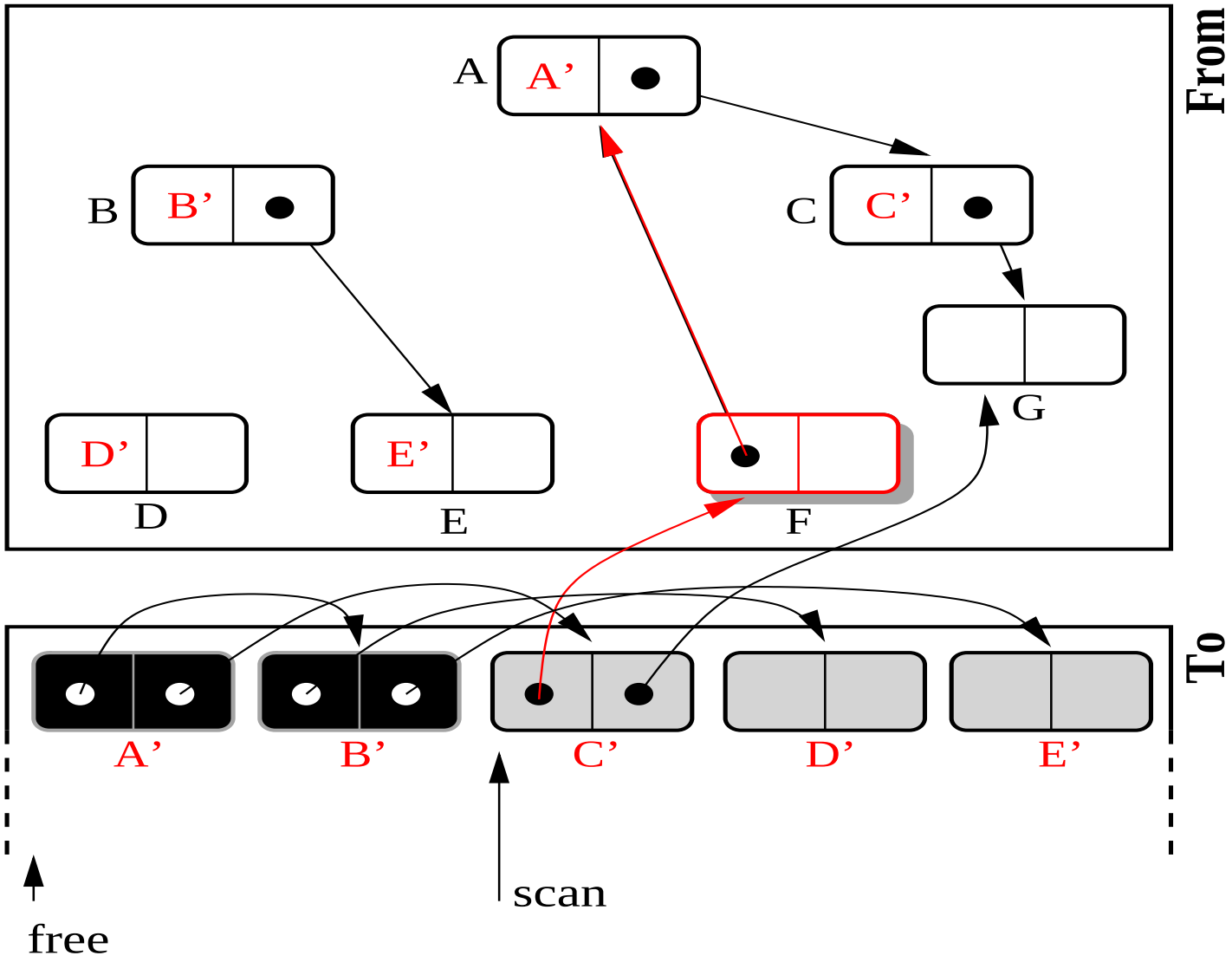
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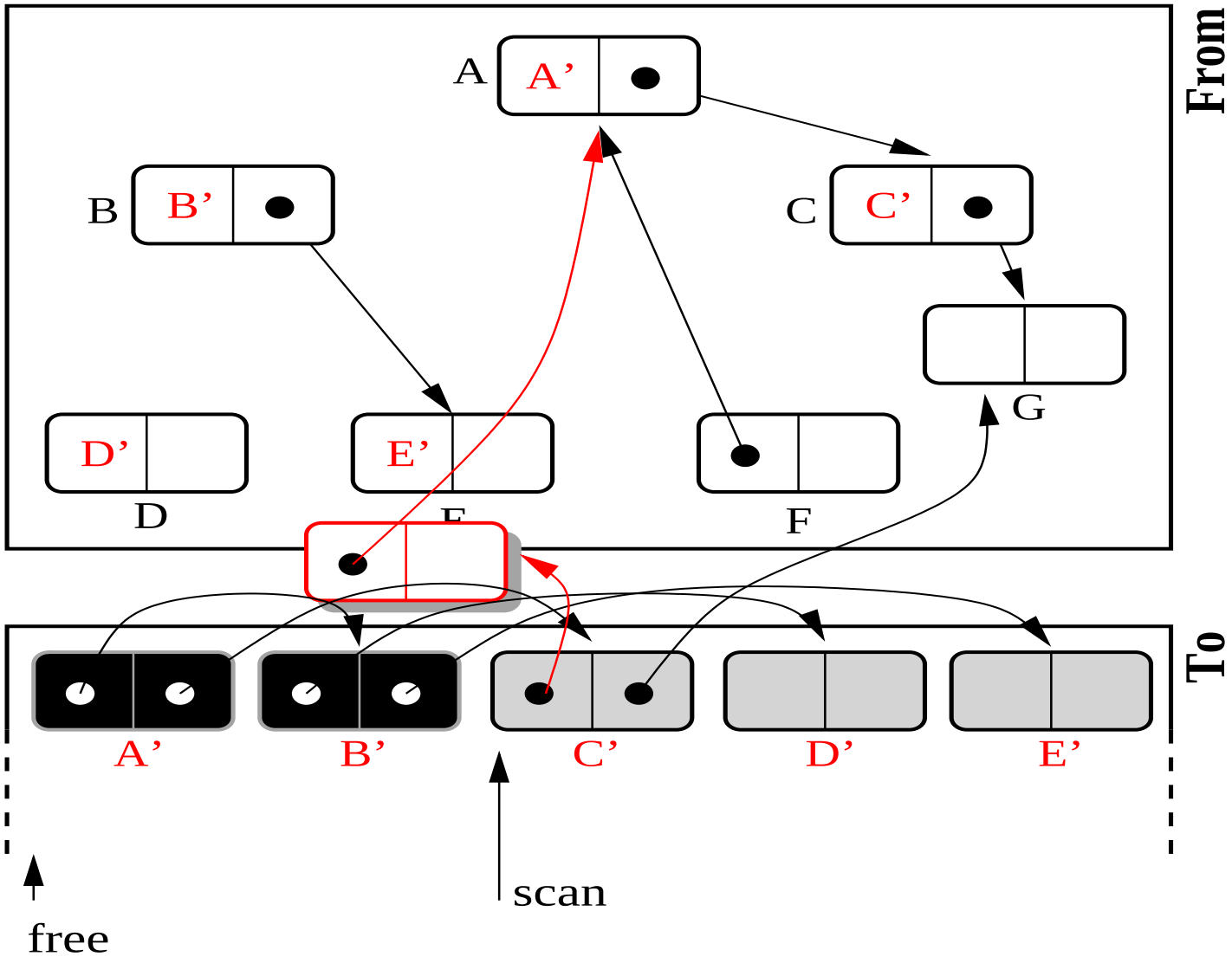
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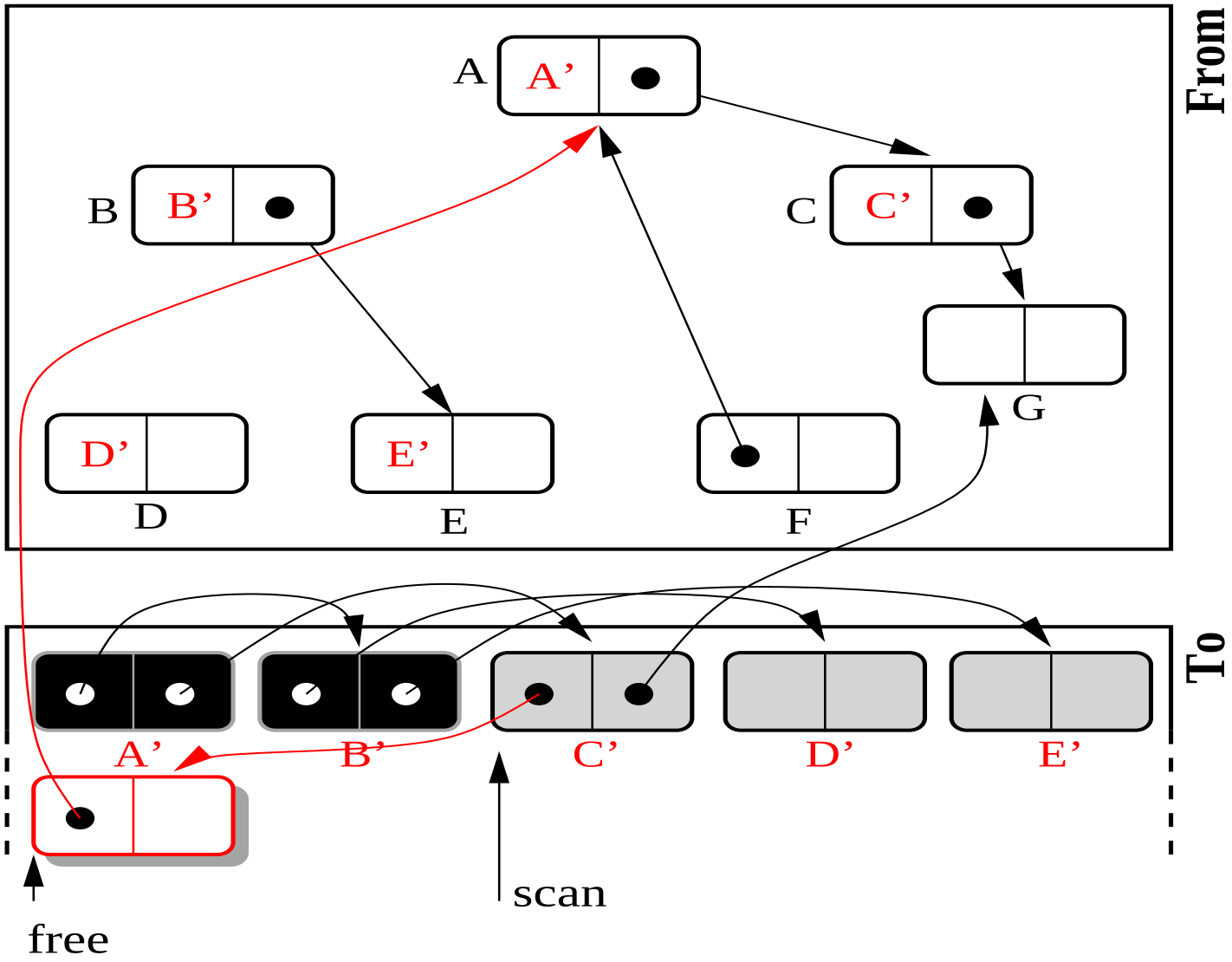
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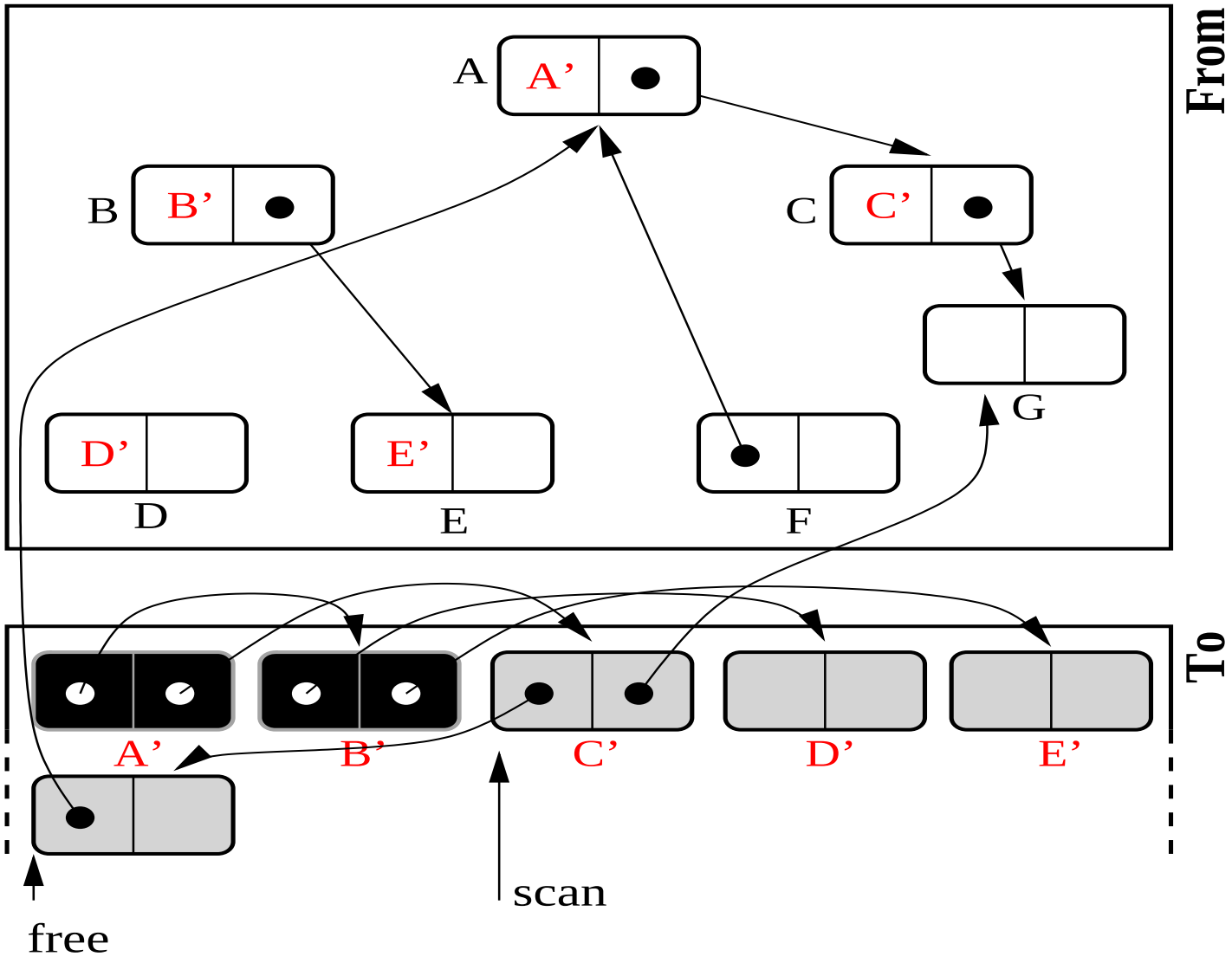
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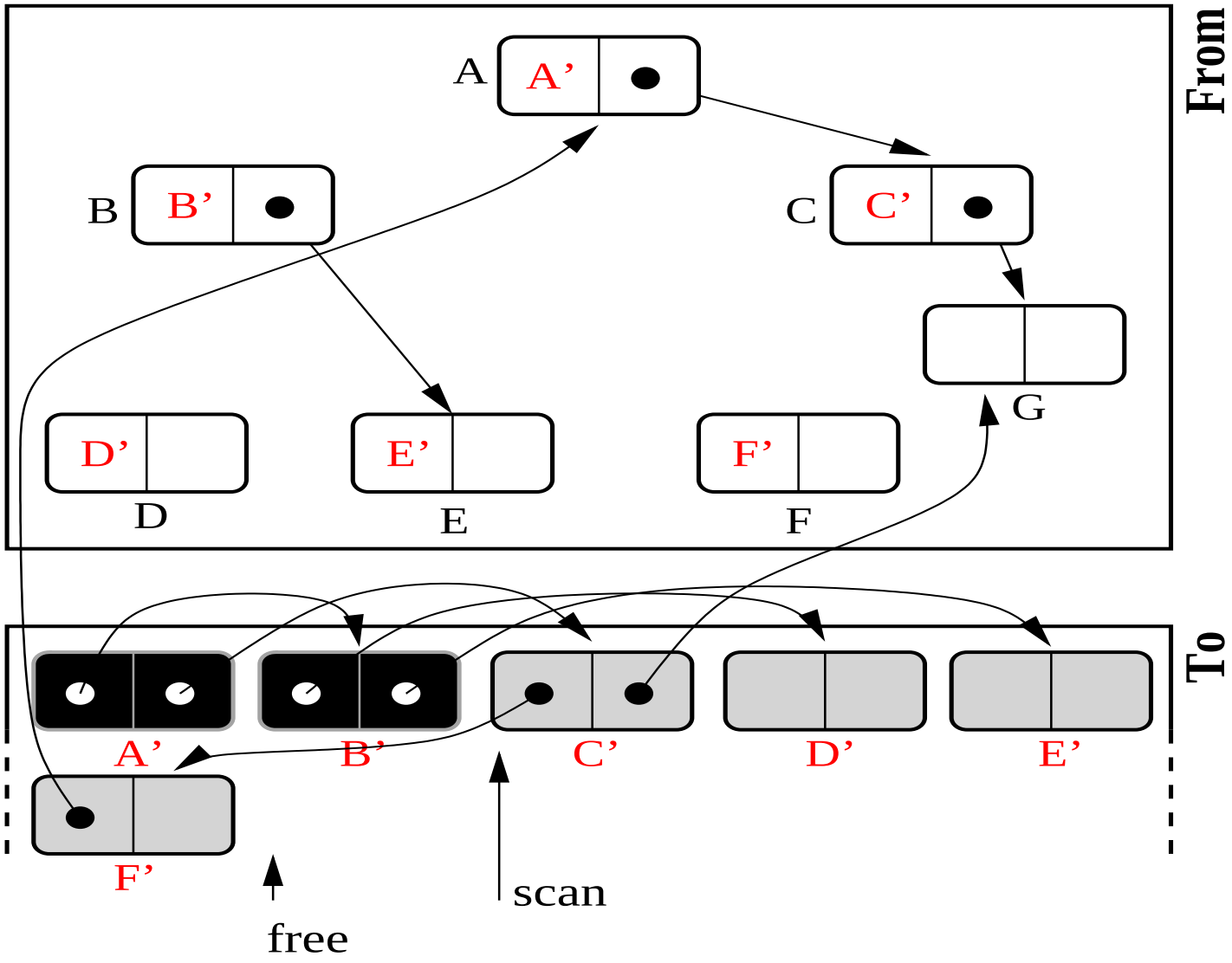
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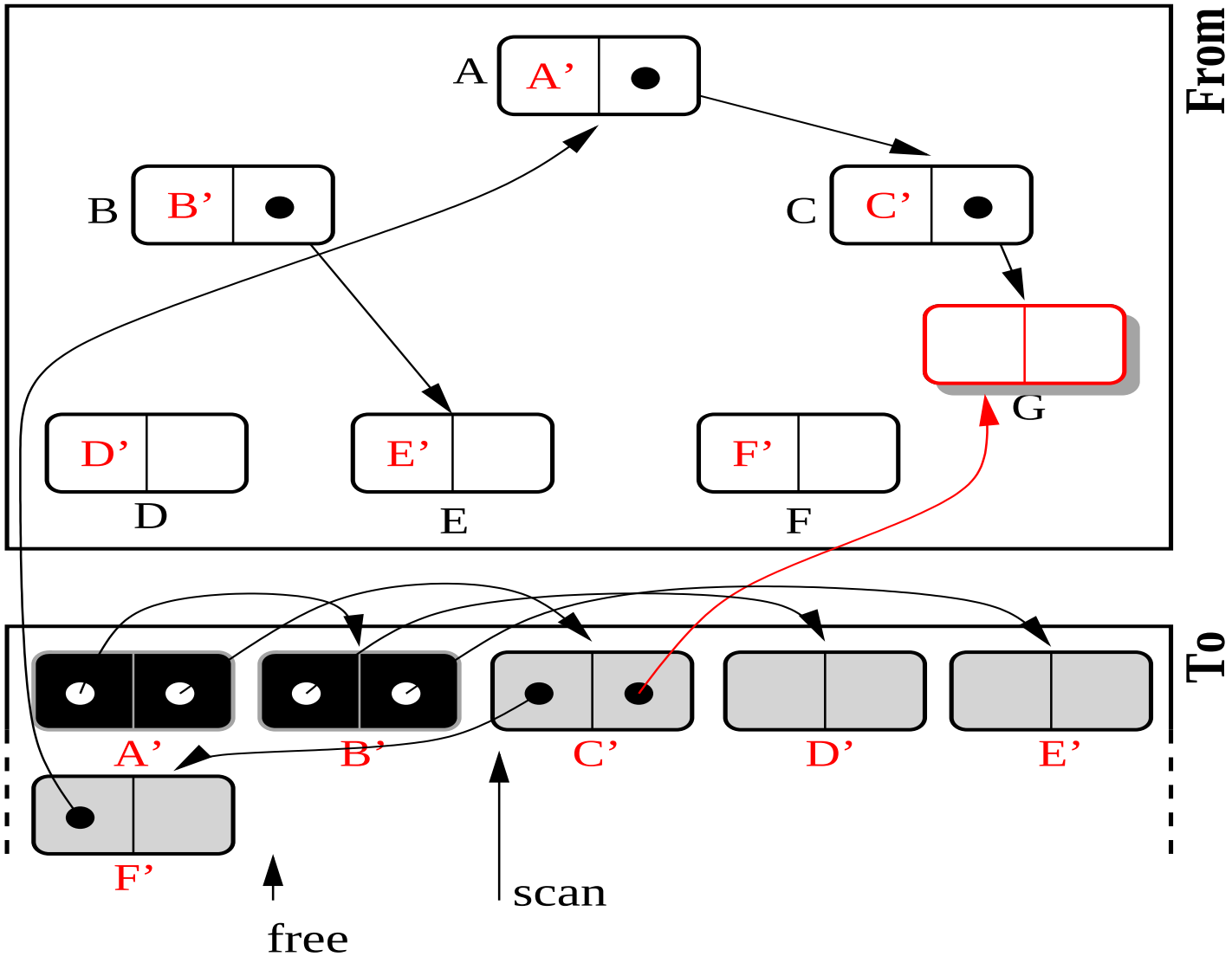
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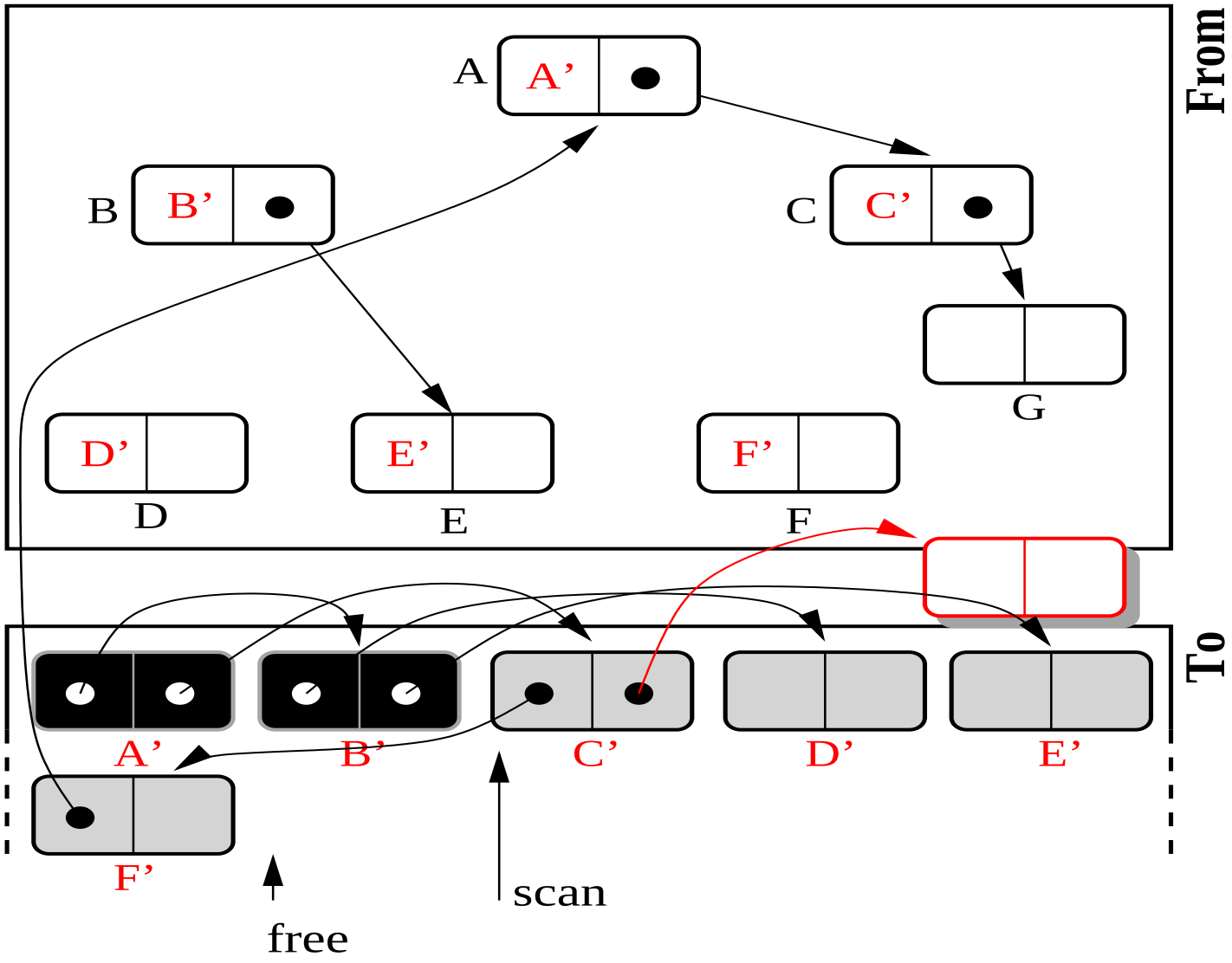
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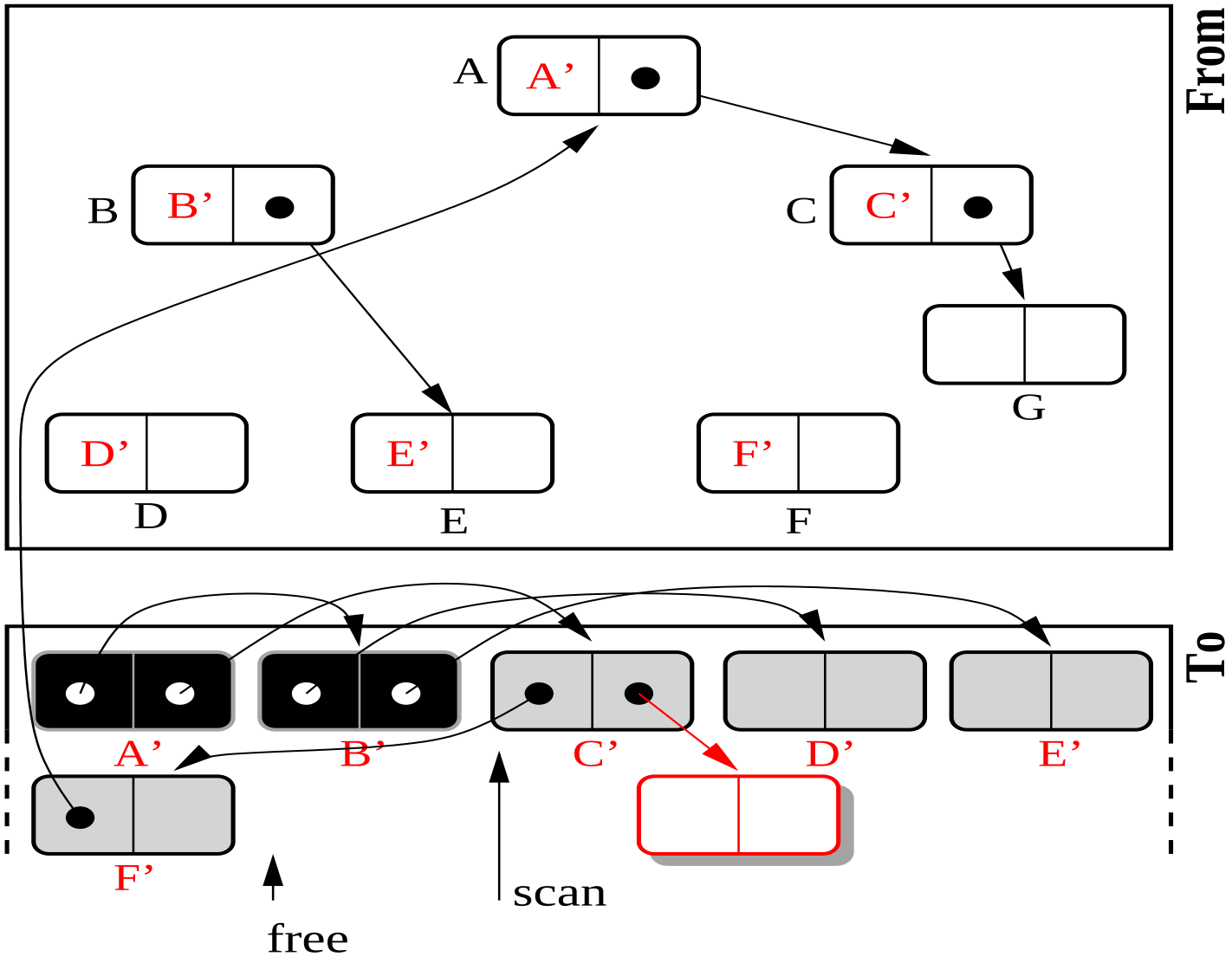
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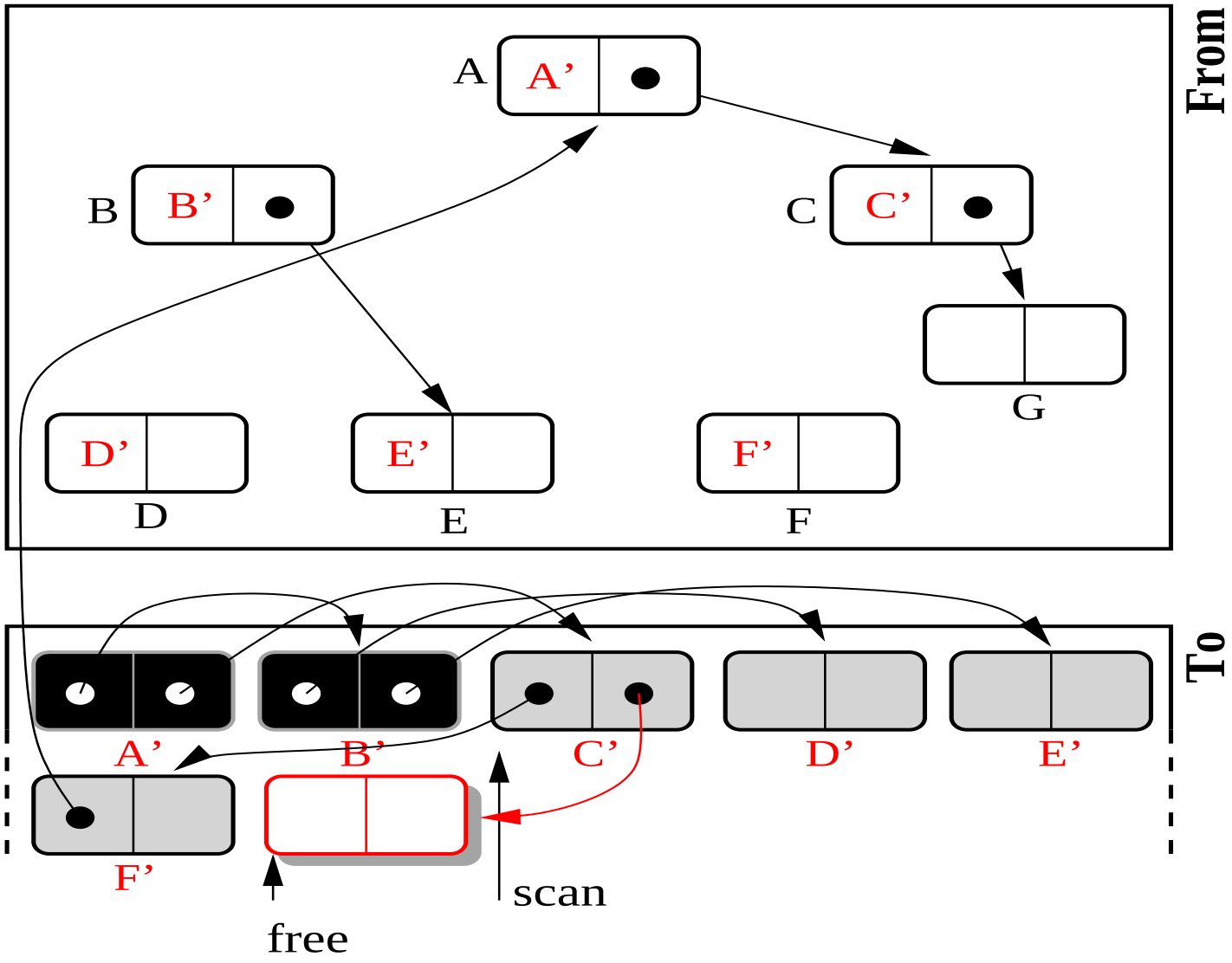
From
A
A'
B
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C
C'
G
D'
D
E'
E
F'
F
To
A'
B'
C'
D'
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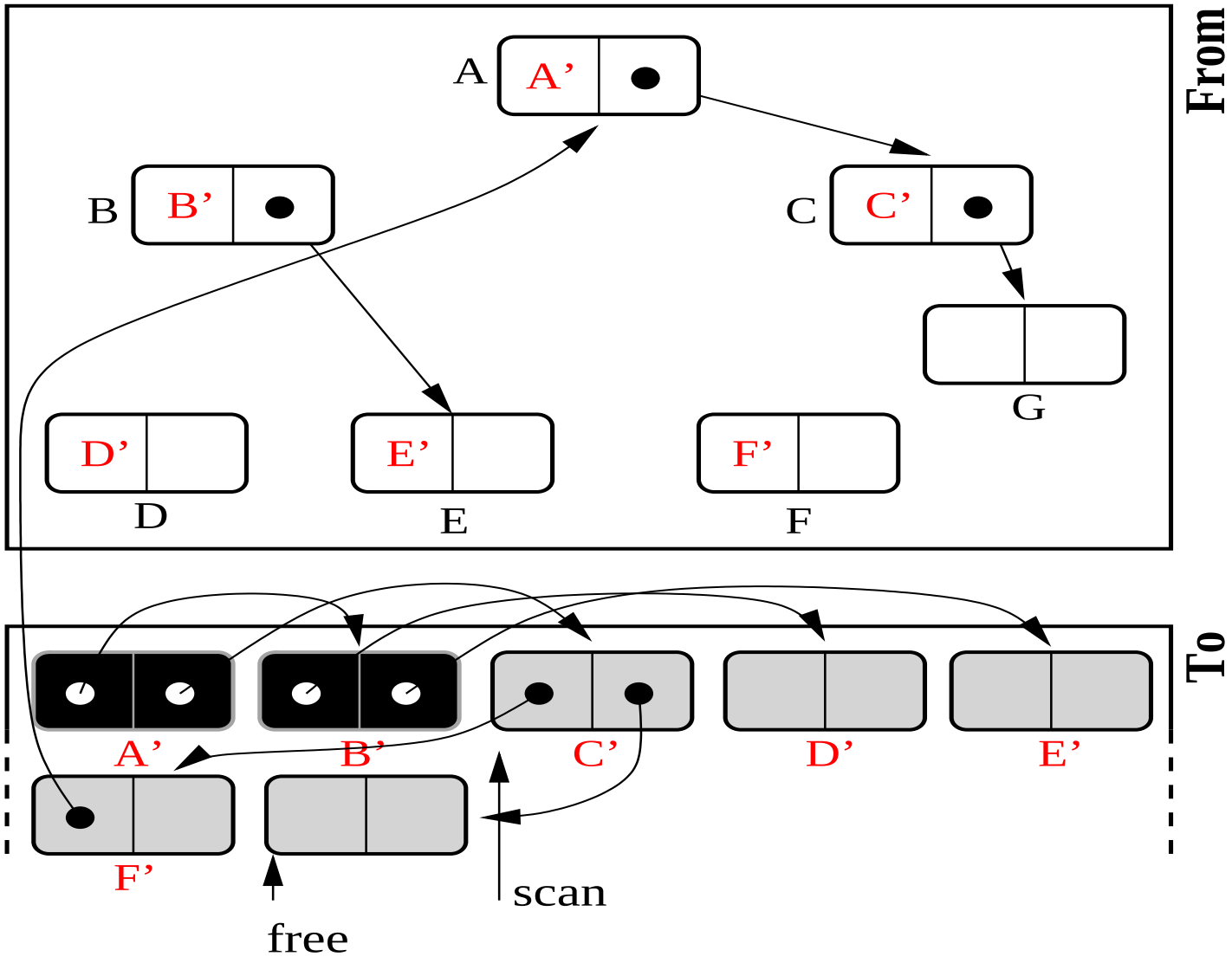
F'
free
scan


From
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To
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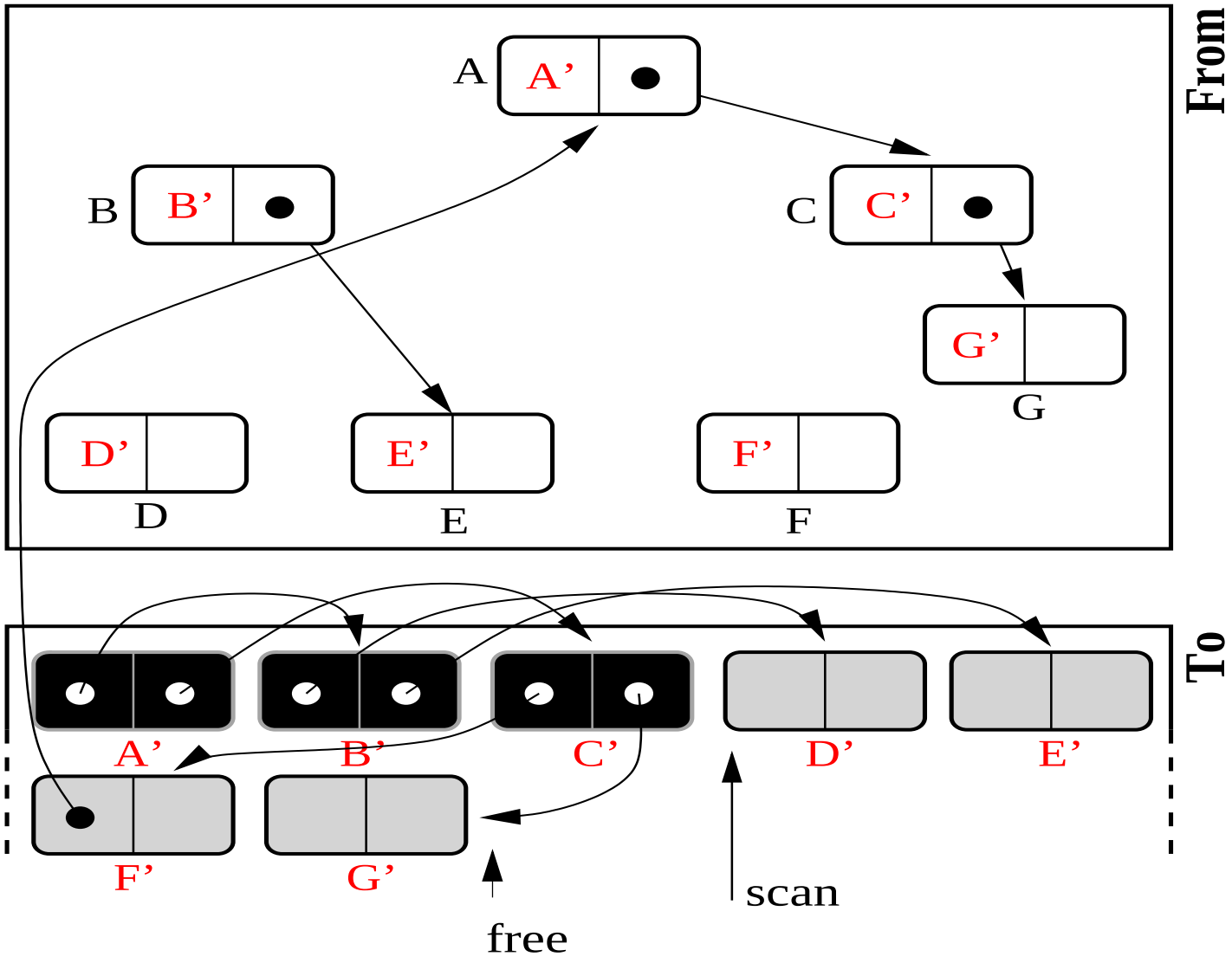
free
scan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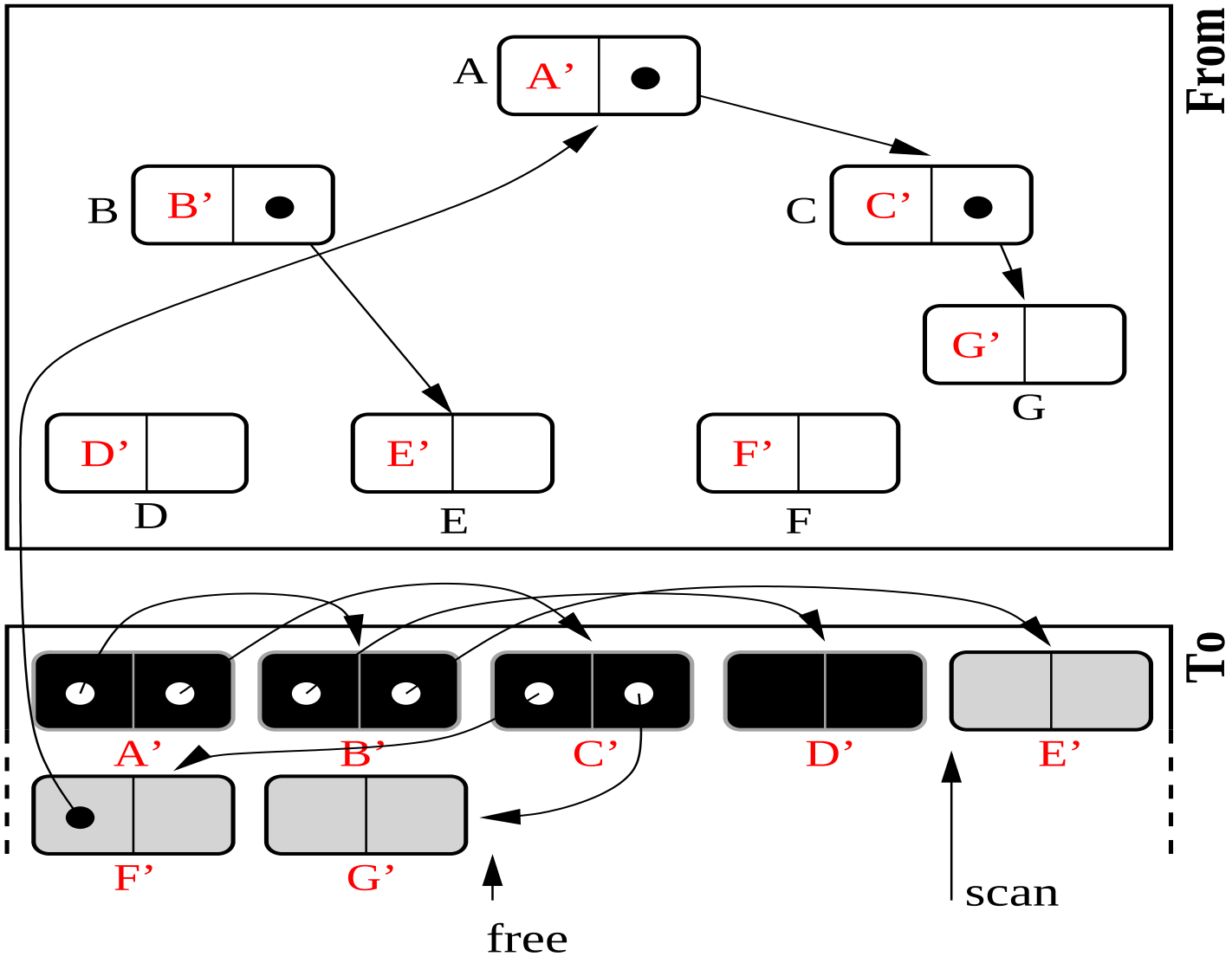
free
scan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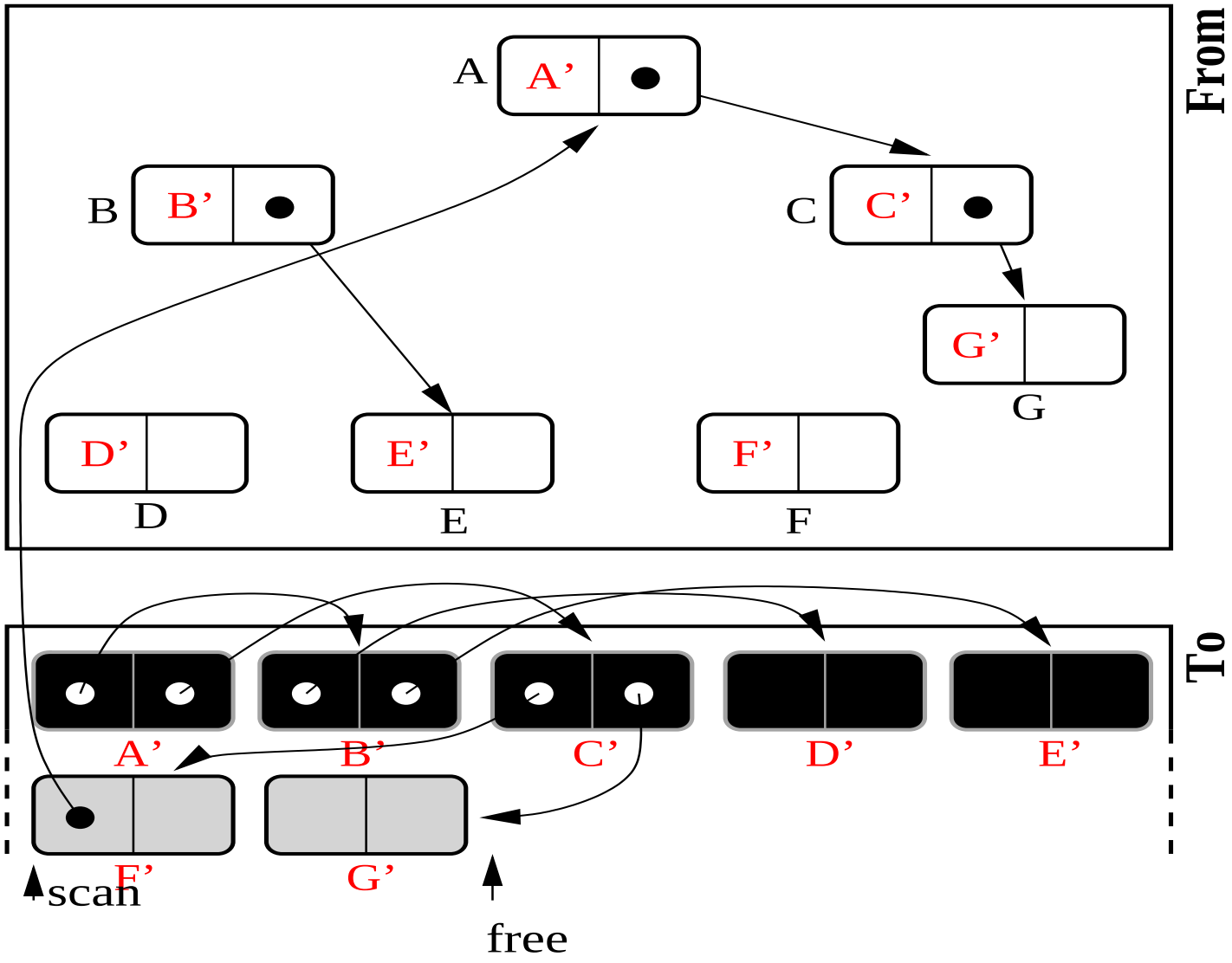
free
scan


From
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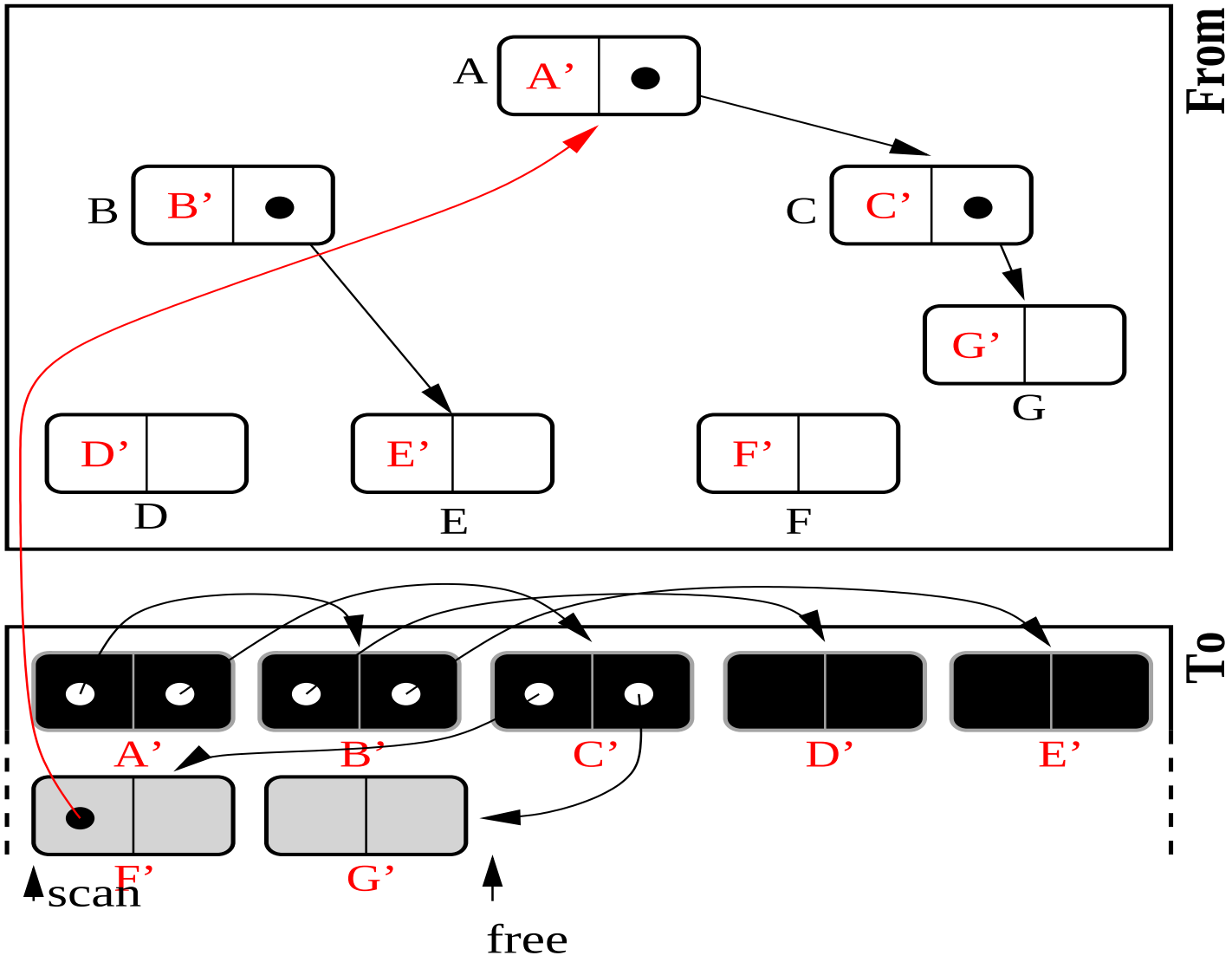
scan
free


From
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To
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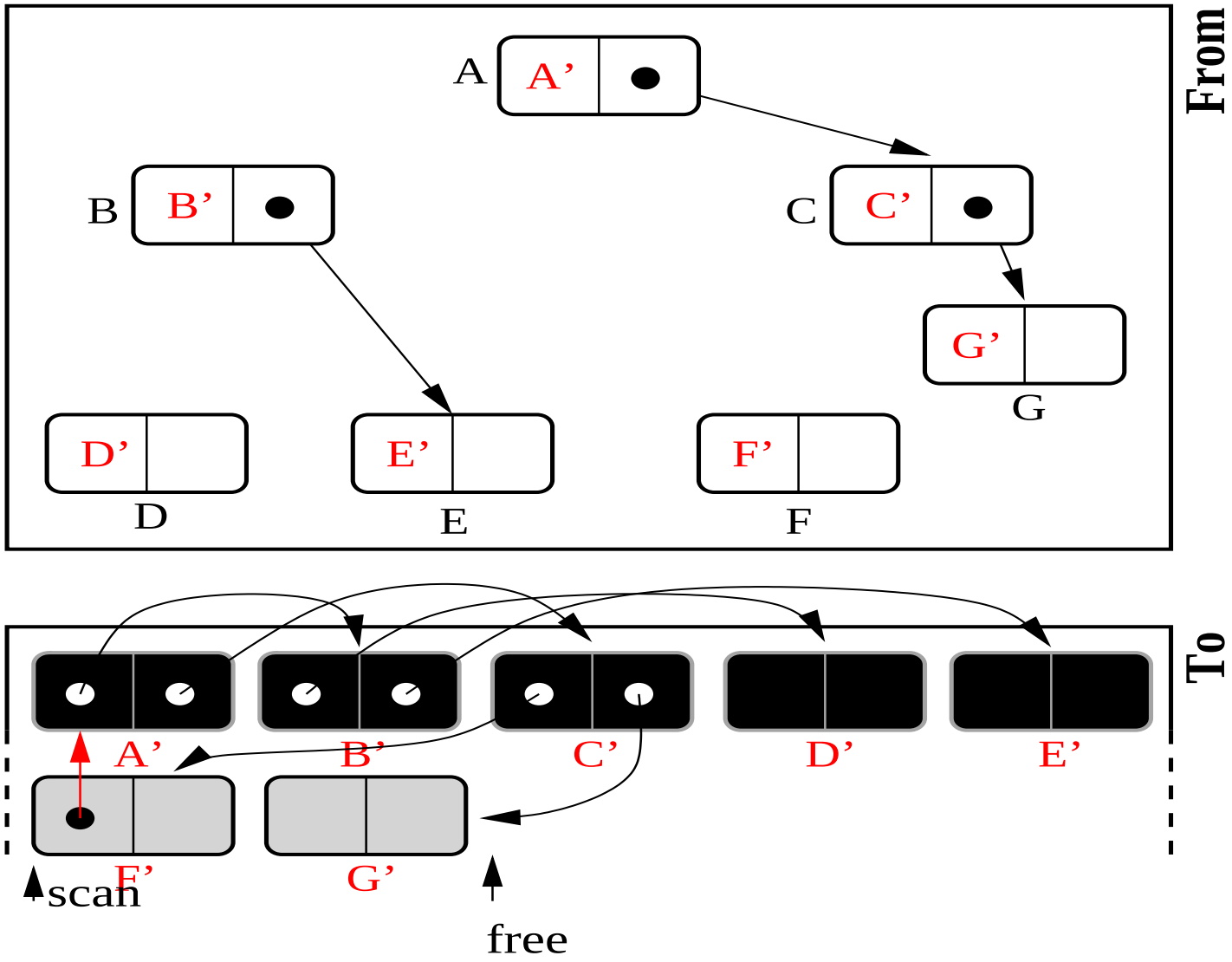
scan
free


From
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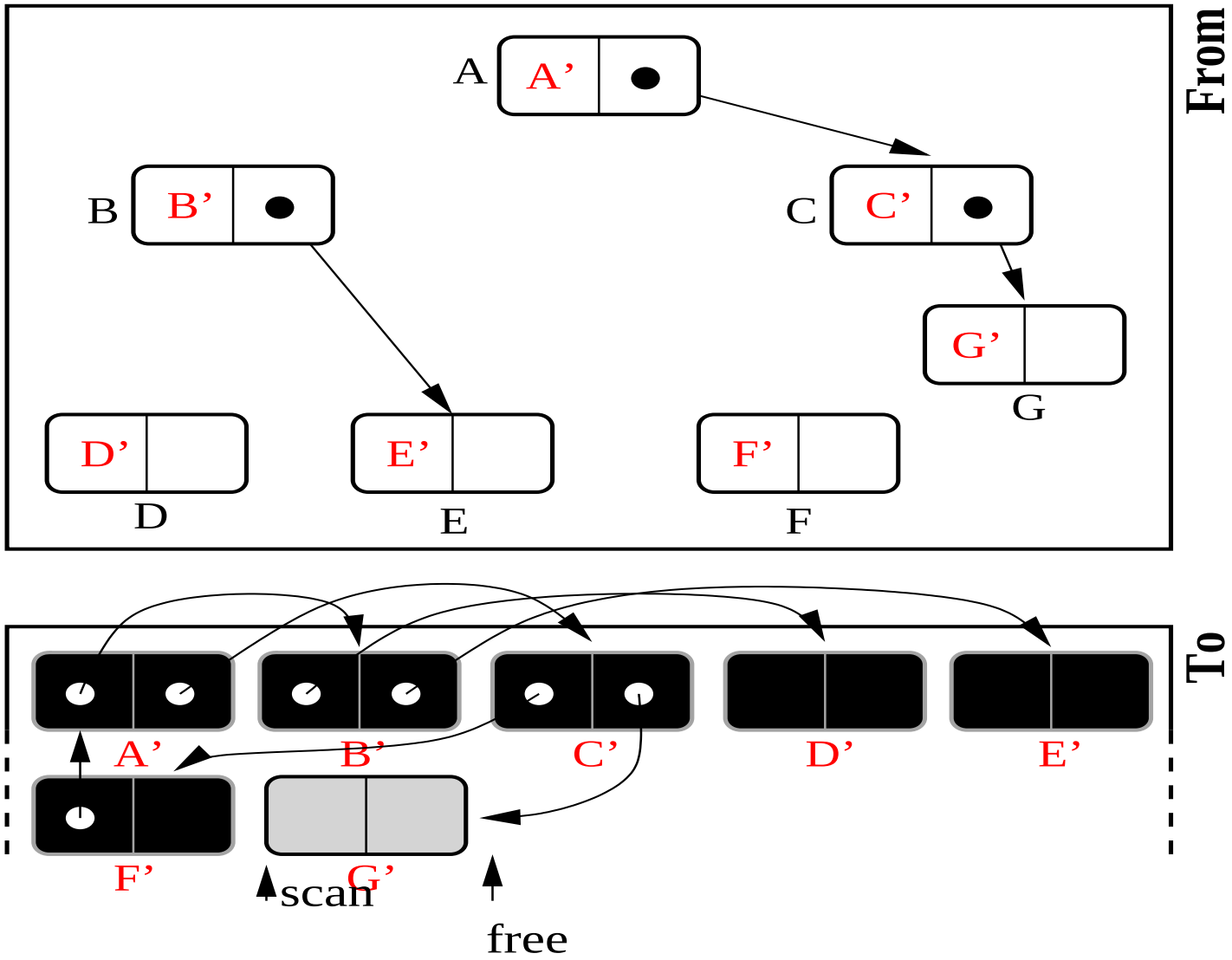
scan
free


From
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To
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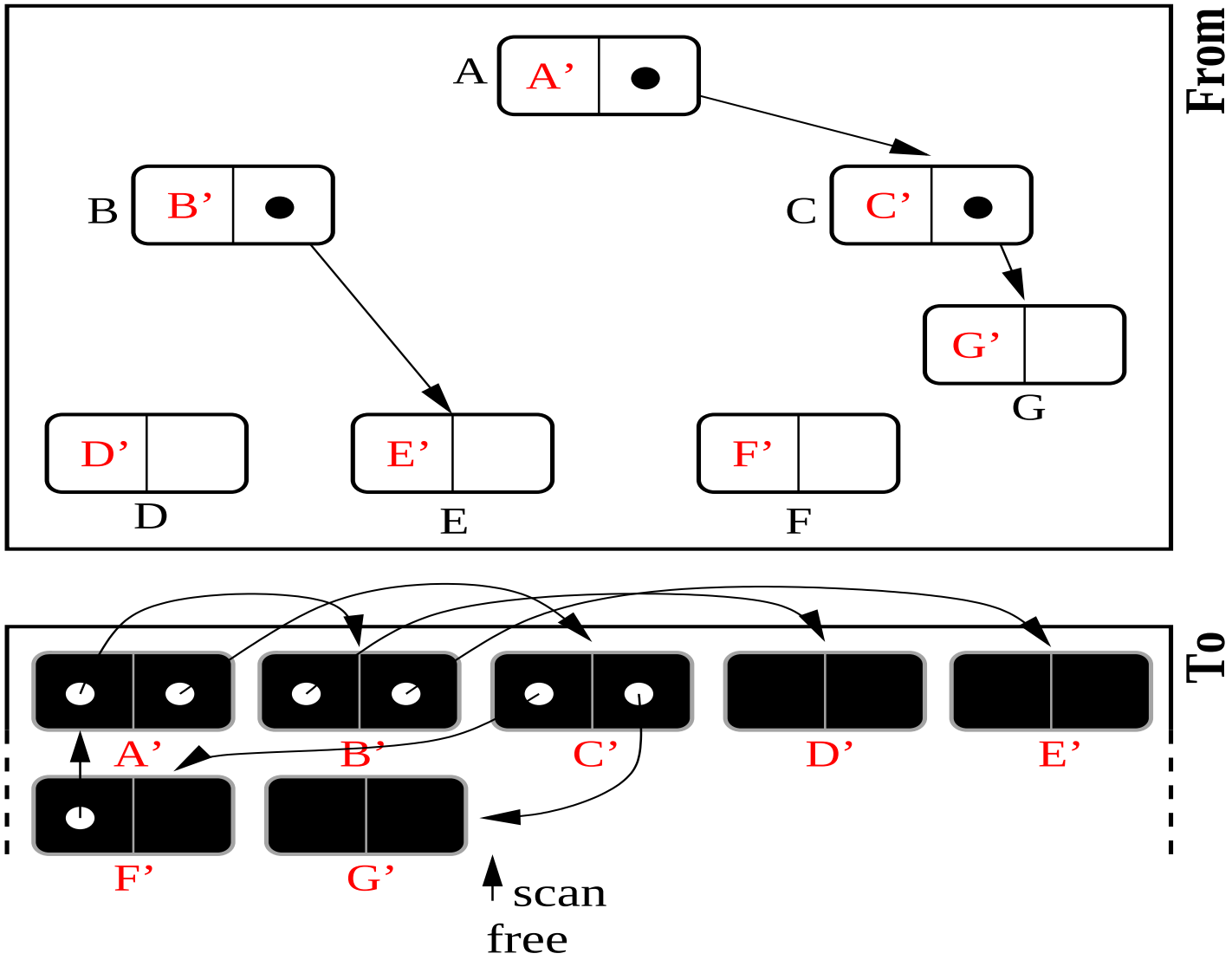
scan
free


From
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F'
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scan
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6 Assumptions

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- Size of nodes known

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- Child fields known

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- Child fields known
- Two logically contiguous areas for the heap
- Ability to mark nodes

7 Properties

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- Covers cycles / sharing
- Heap is compacted
- Stop/start collector
- Nothing to do between GCs

8 Disadvantages

High Level

Low Level

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- Copying large objects is expensive

Low Level

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- Twice the logical memory needed

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- Breadth first $\Rightarrow$ decreased locality

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High Level

- Copying large objects is expensive
- Twice the logical memory needed

Low Level

- Breadth first $\Rightarrow$ decreased locality
- Paging issues

9 Variations(1)

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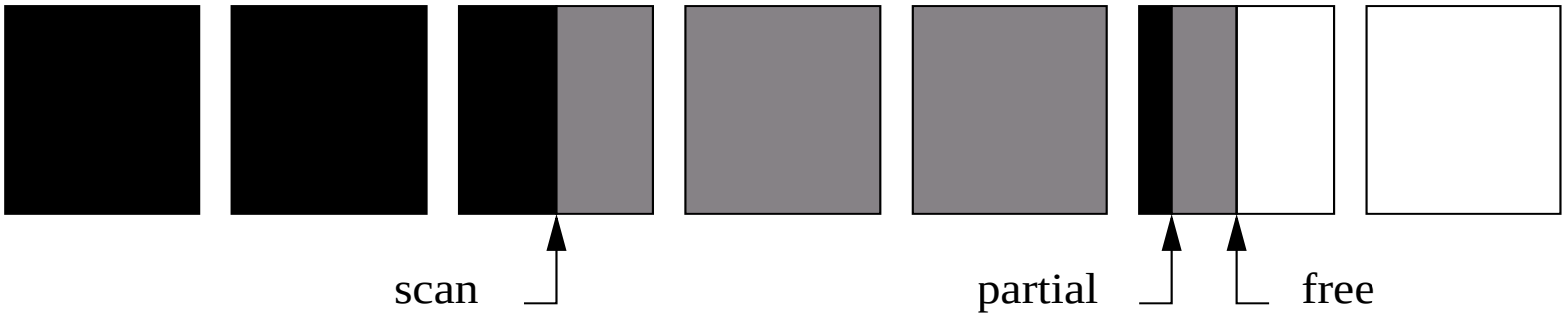
- Areas for long living objects
  (only scanned, not copied)
- Maintain locality by using other exploration strategies
  (but then stack becomes an issue)

10 Variations(2)

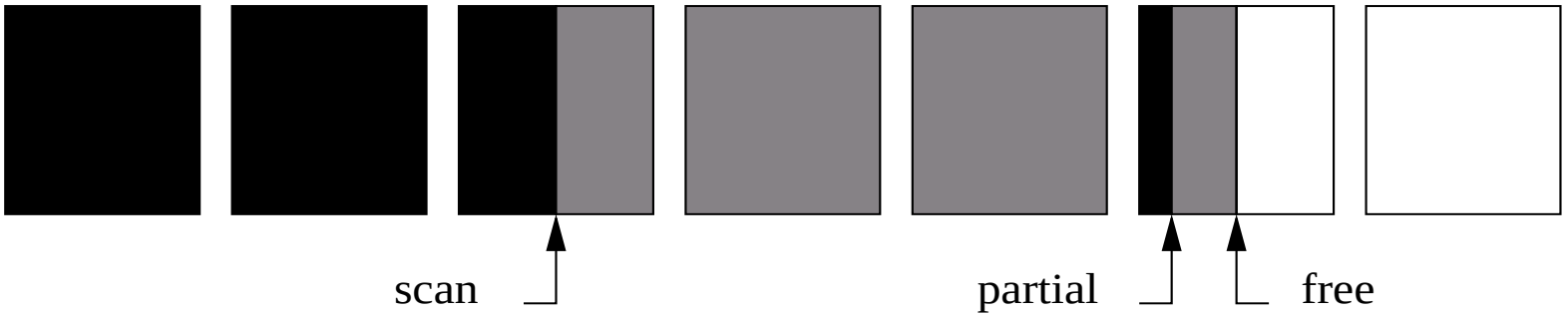
Approximately depth-first copying(1)



10 Variations(2)

Approximately depth-first copying(1)

Modification of Cheney's agorithm by Moon (1984)



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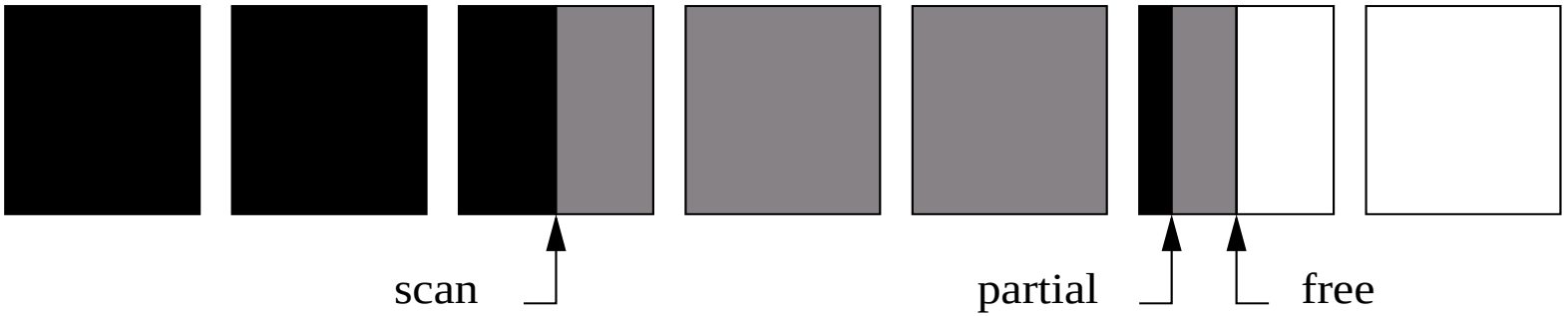
Approximately depth-first copying(1)

Modification of Cheney's agorithm by Moon (1984)

- Always start scanning on the last partially filled page in To-space

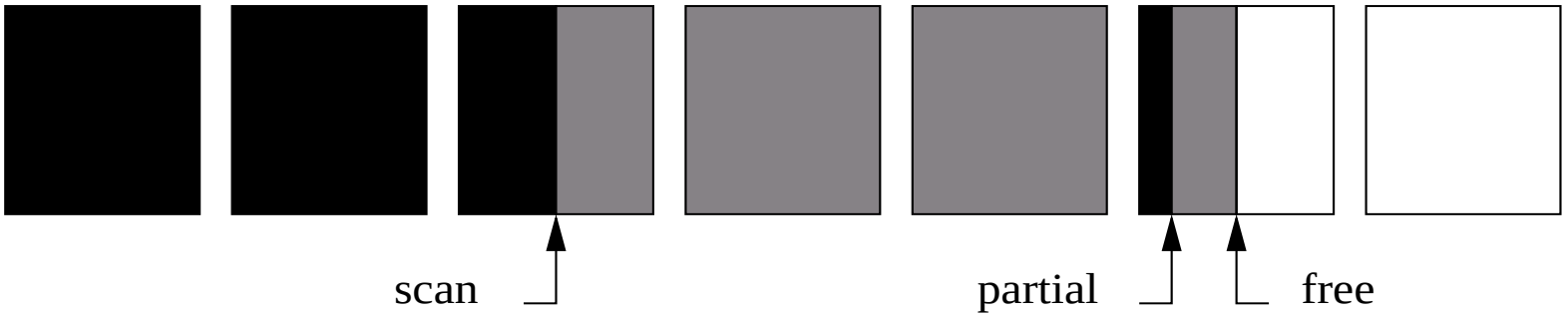


10 Variations(2)

Approximately depth-first copying(1)

Modification of Cheney's agorithm by Moon (1984)

- Always start scanning on the last partially filled page in To-space
- When that page is completed, continue with ordinary scan

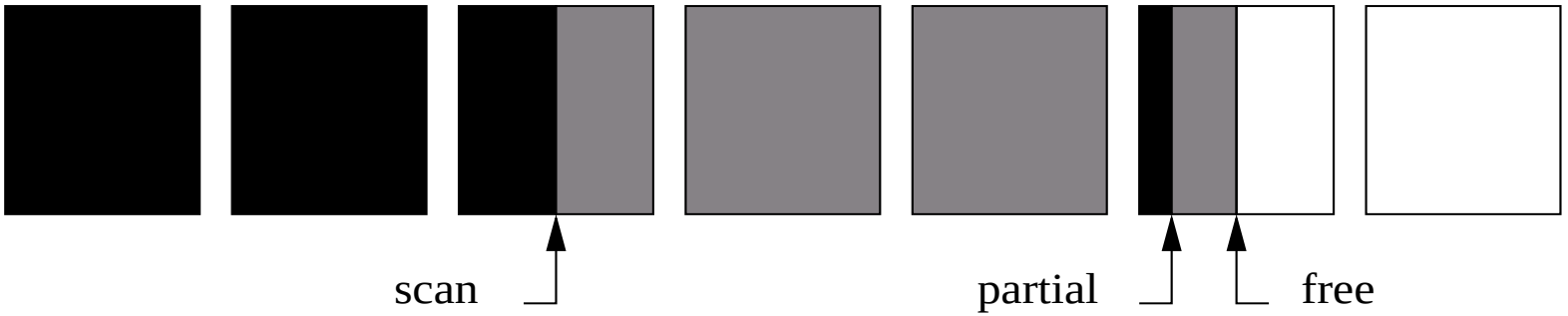


10 Variations(2)

Approximately depth-first copying(1)

Modification of Cheney's agorithm by Moon (1984)

- Always start scanning on the last partially filled page in To-space
- When that page is completed, continue with ordinary scan
- As soon as an object is copied, start partial scan again



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Approximately depth-first copying(2)

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11 Variations(3)

Approximately depth-first copying(2)

- Drawback: Some nodes are scanned twice
- Tests indicate a 15 percent improvement of locality
- . . . and a 6 percent increased GC time

12 Increasing efficiency

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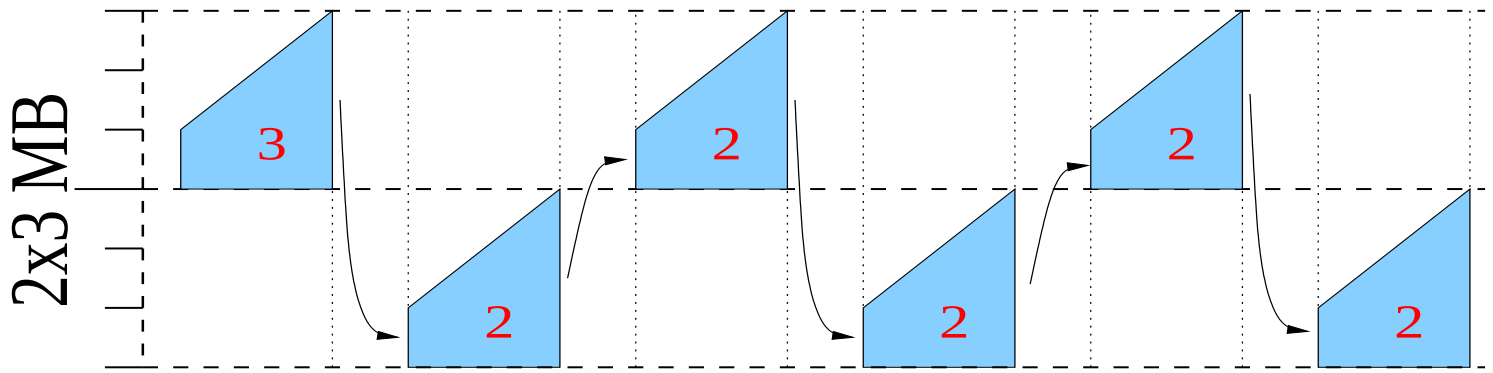
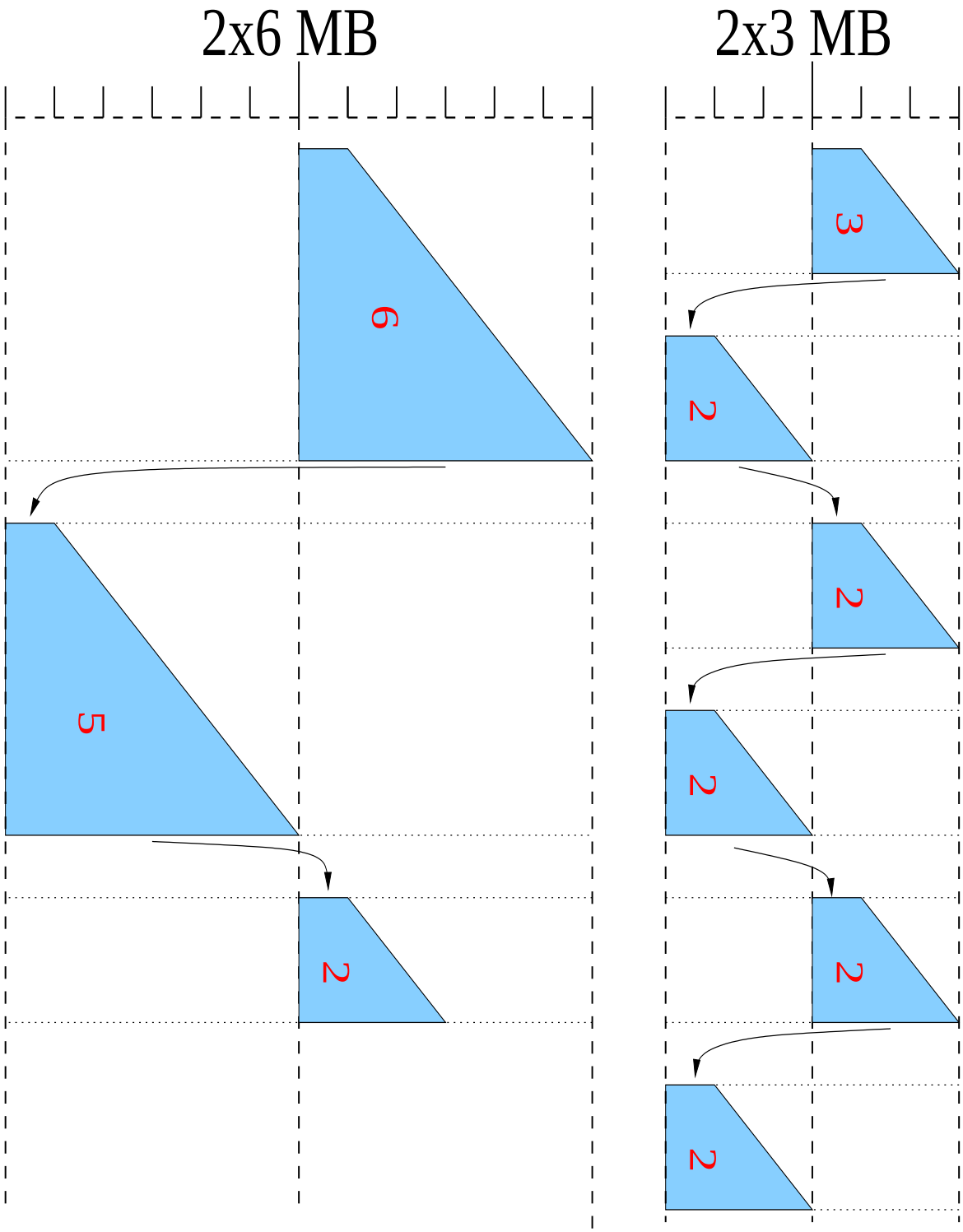
- Making the semi-spaces bigger decreases frequency of GC

12 Increasing efficiency

- Making the semi-spaces bigger decreases frequency of GC
- Less frequent GC means older objects
  $\Rightarrow$ More garbage


2x3 MB
3
2
2
2
2
2


2x6 MB
6
5
2
2x3 MB
3
2
2
2
2
2

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  (alloc. is cheap)
- Many small, short-lived objects
  (copying small objects not much more expensive than marking)
- GC delay doesn't matter (no real-time system)

14 Outlook

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- Hybrid systems can be used
  (e.g. use copying only for small objects, mark-sweep for large objects)
- Copying collection can be used as a foundation for
  - incremental
  - generational

  GC algorithms.