Read-Log-Update

A Lightweight Synchronization Mechanism for Concurrent Programming

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Concurrent Data Structure

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    Hide race conditions from programmers

Read-Copy Update

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- Linux kernel has 6,500+ RCU calls

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- Allow **only single pointer update**
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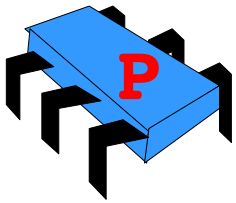
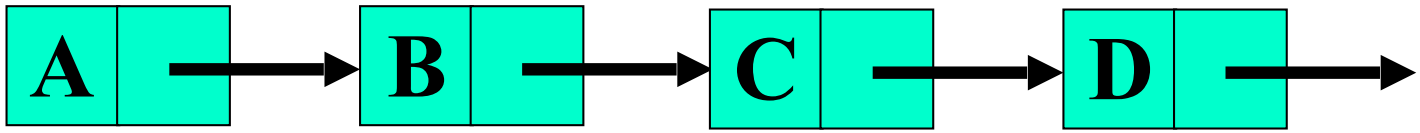
2 Key Technique in RCU

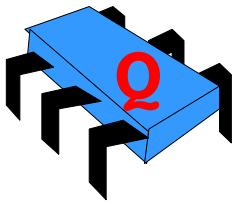
- RCU-Duplication
  - Duplicate objects & modify copies
  - Commit through updating a single pointer
- RCU-Epoch
  - Wait for all previous readers to finish
  - Safe to deallocate old objects

Read-Copy Update

Update C



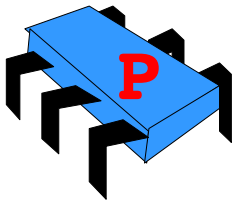




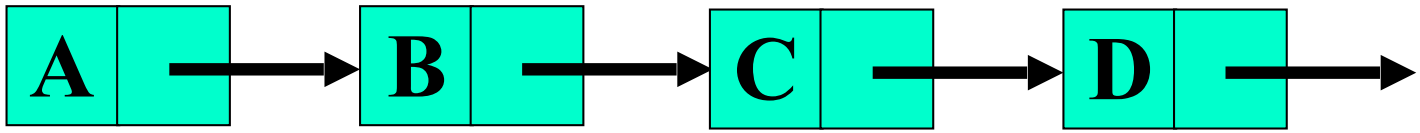
Lookup C

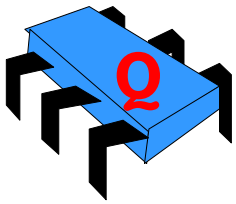
Read-Copy Update

Update C



Writer-Lock





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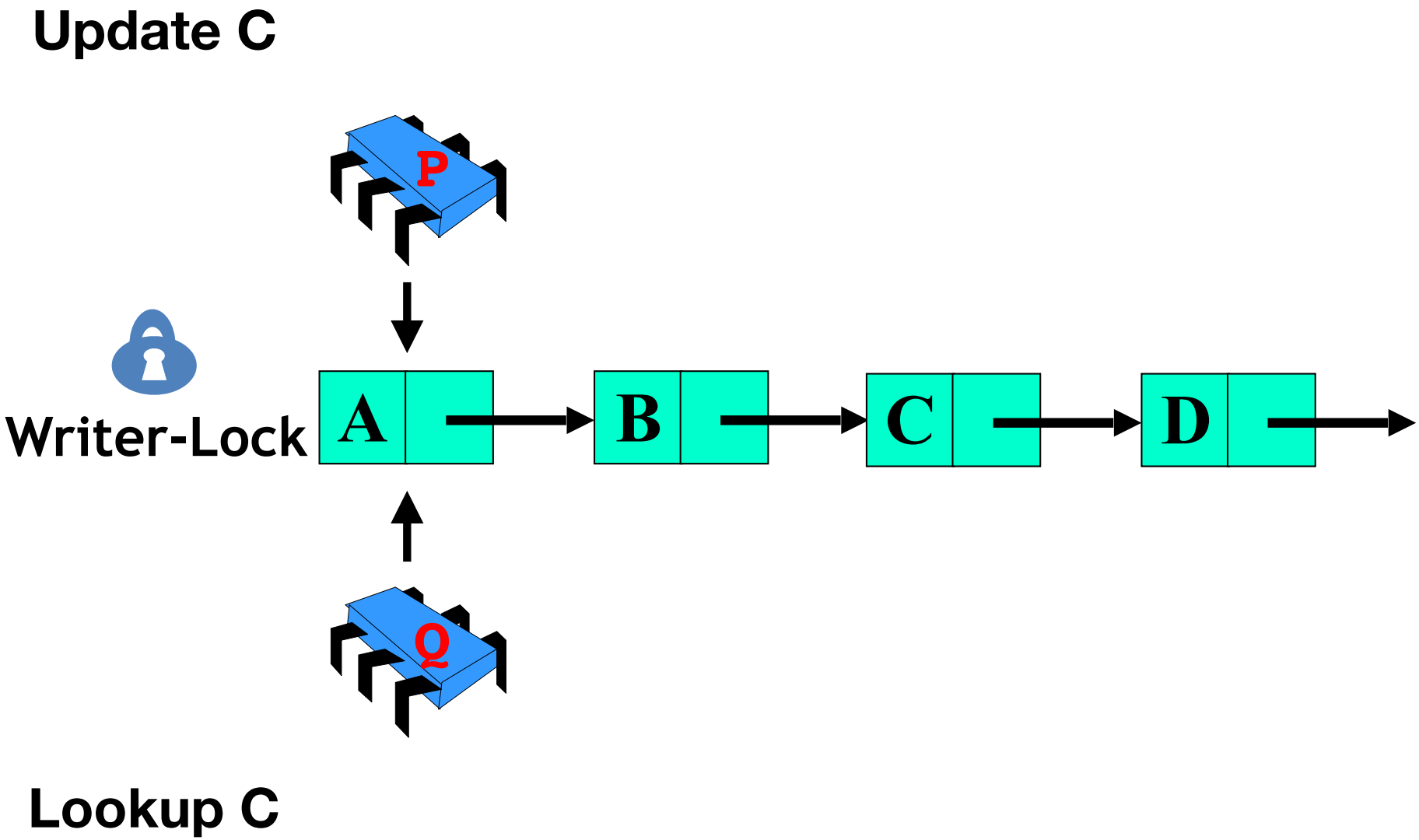

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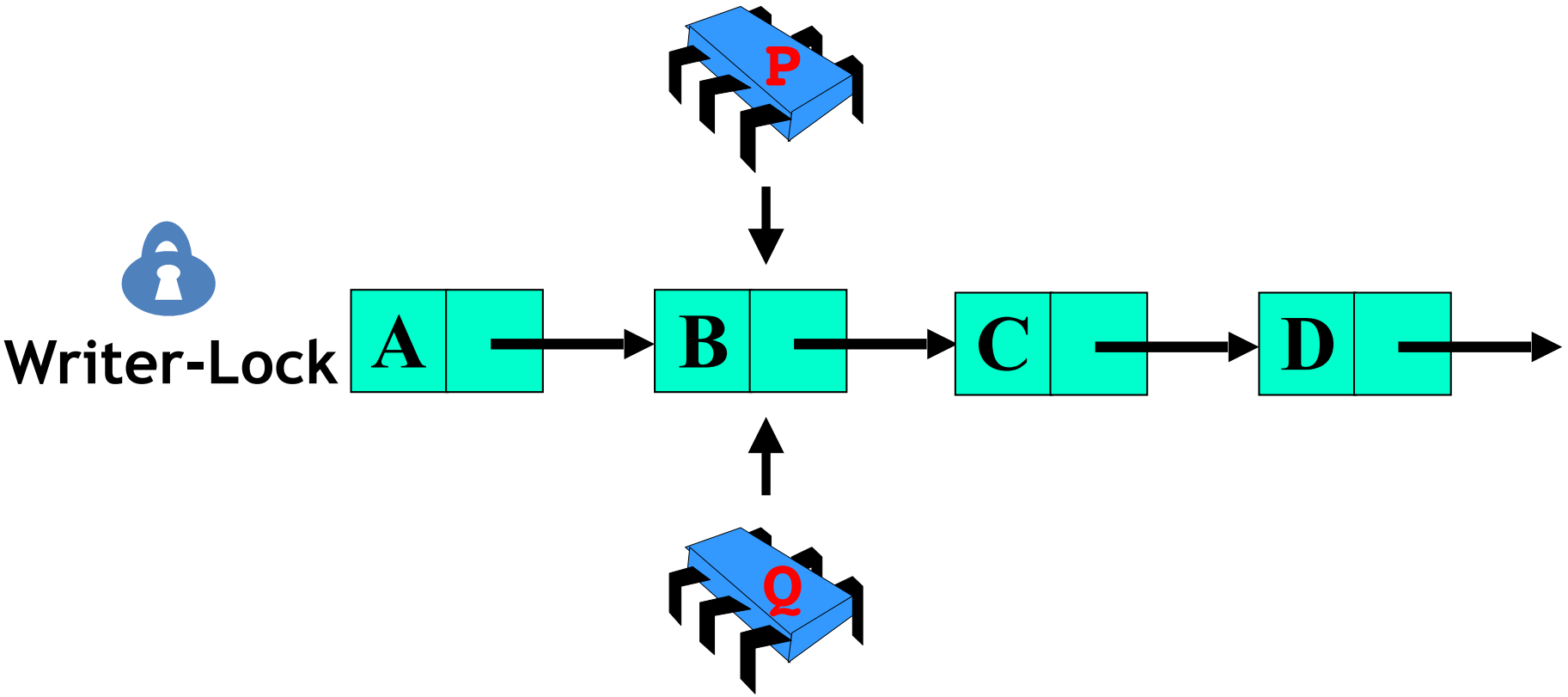

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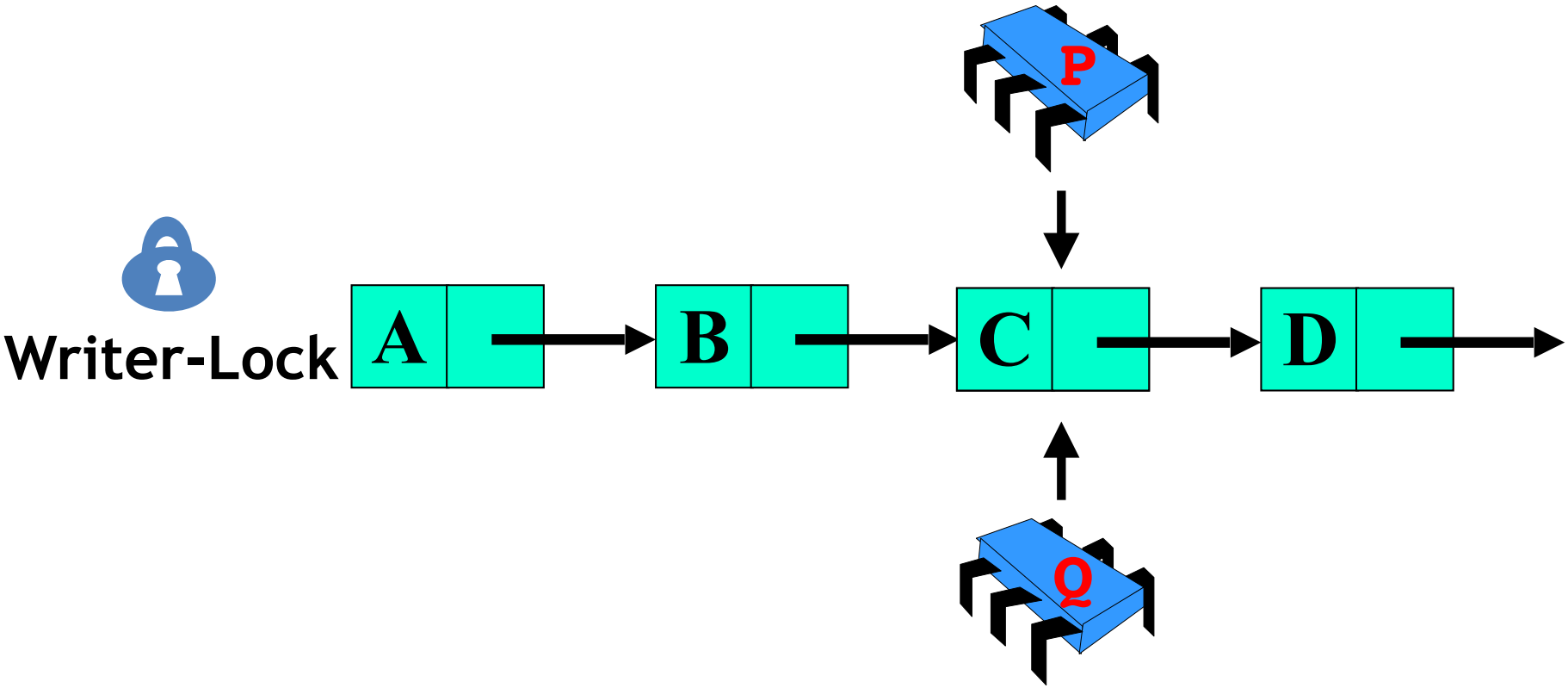

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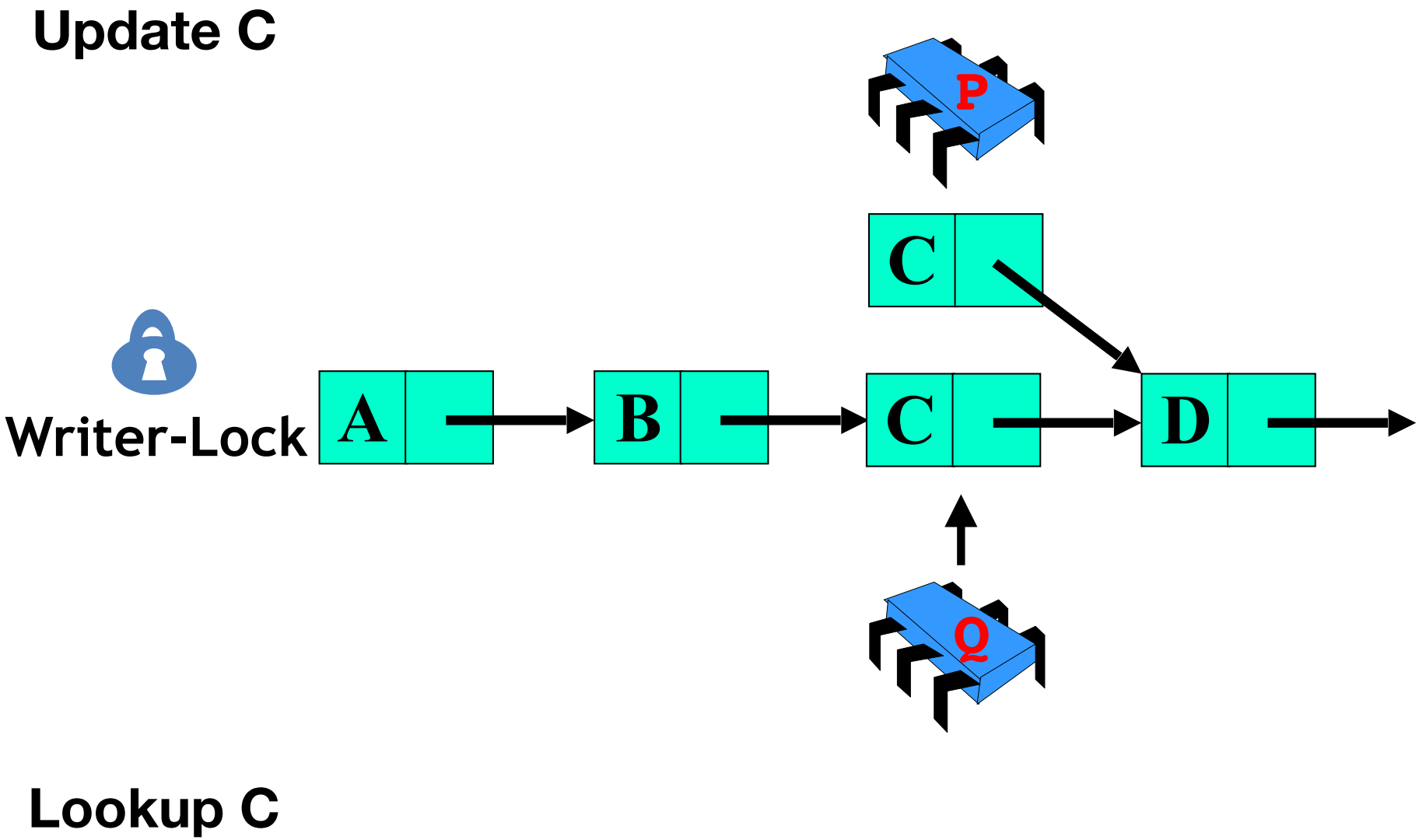

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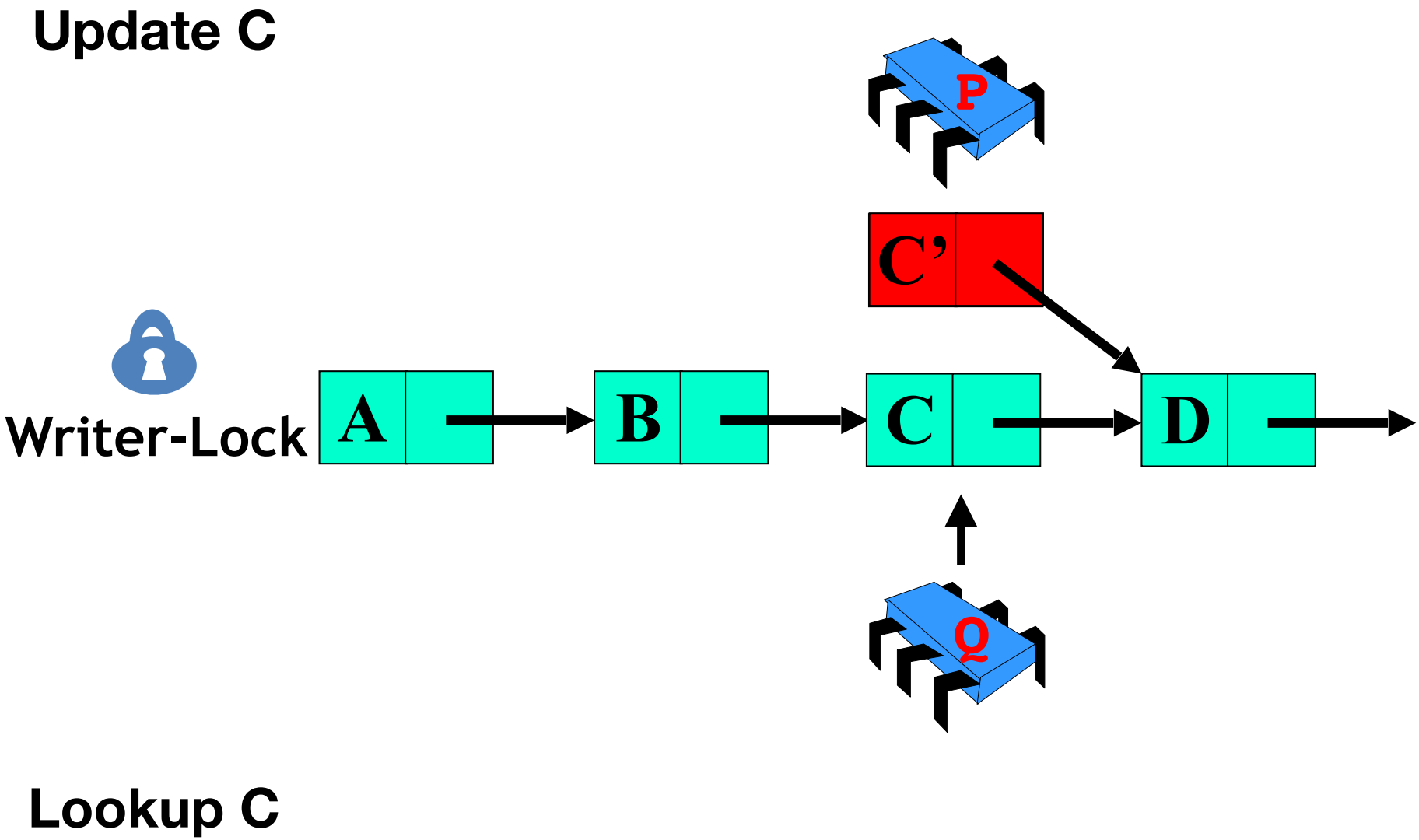
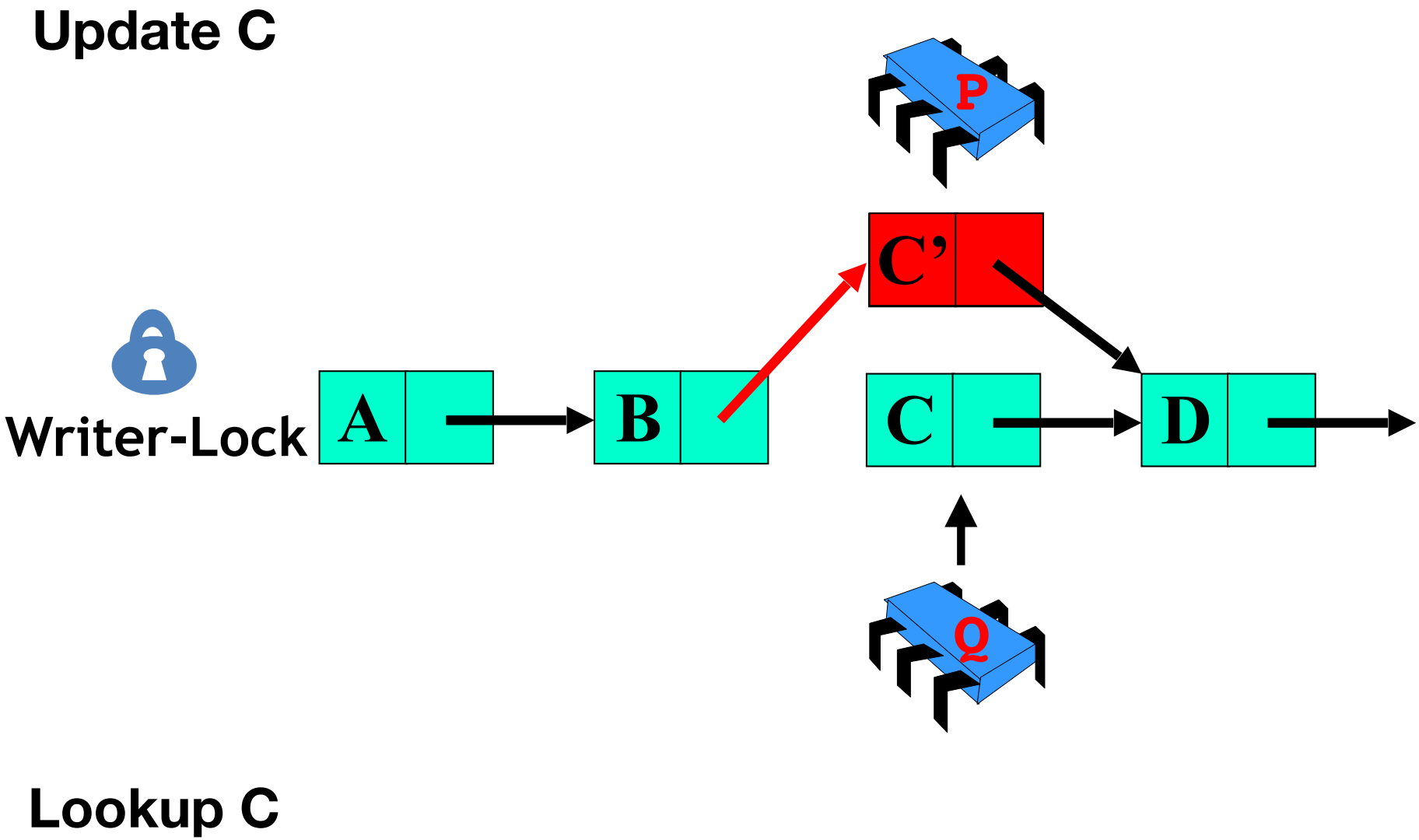


Read-Copy Update



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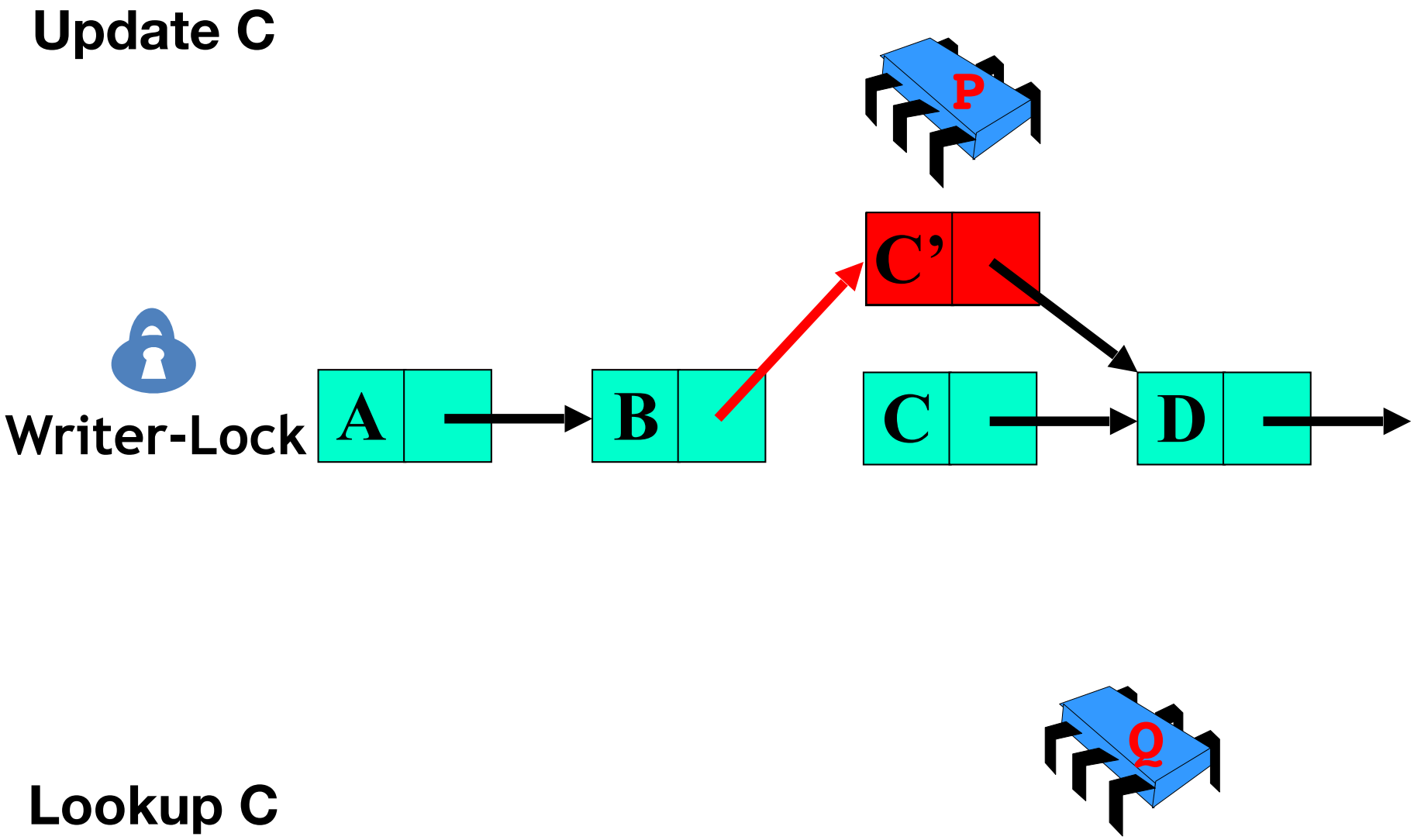

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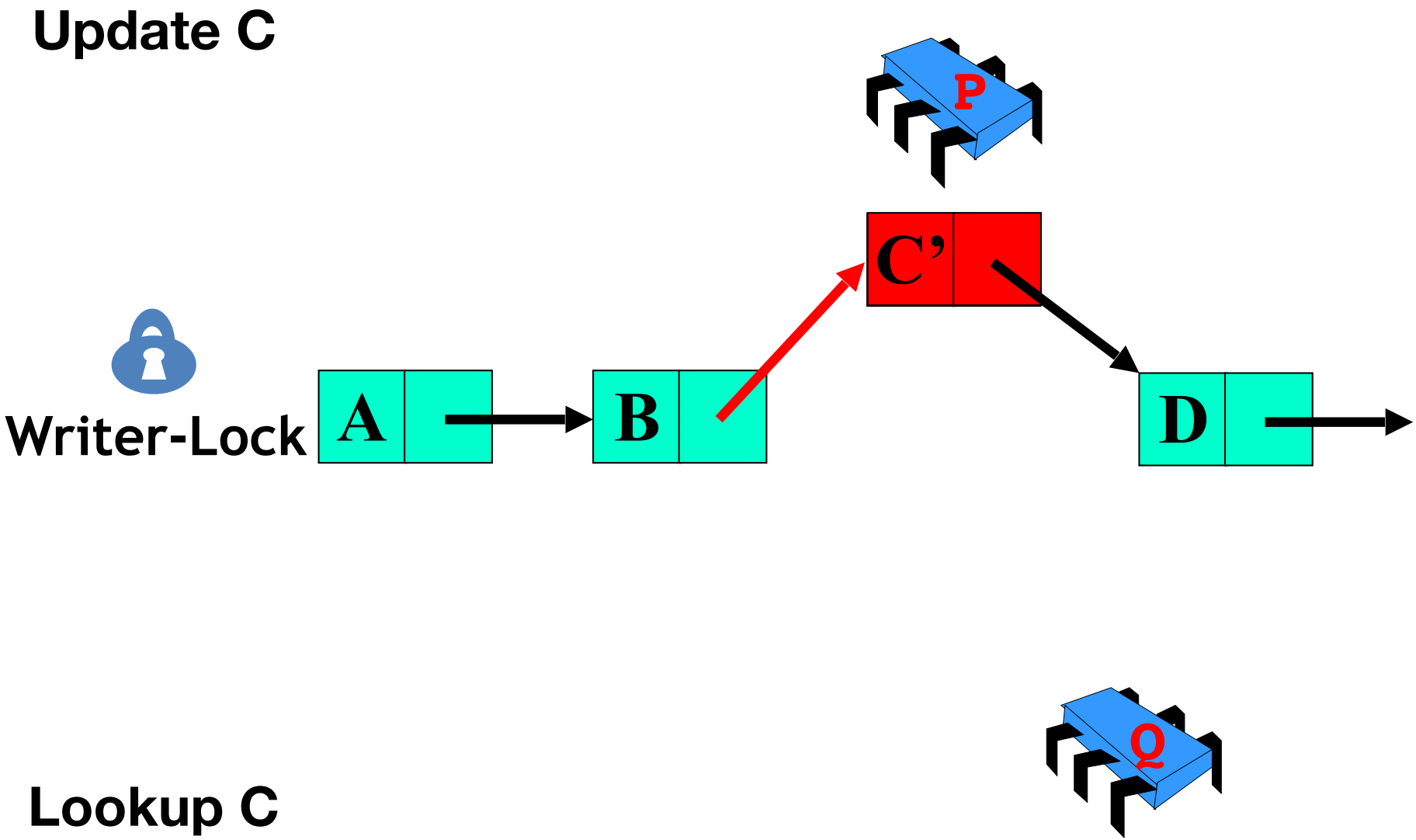
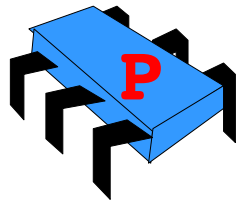
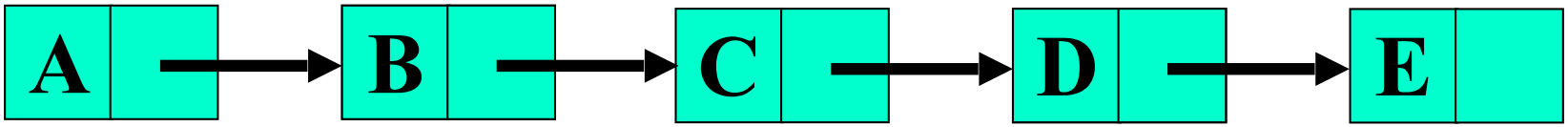
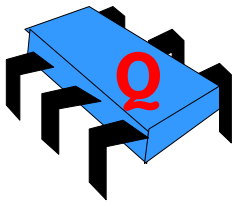


Problems with RCU

Update B & D simultaneous







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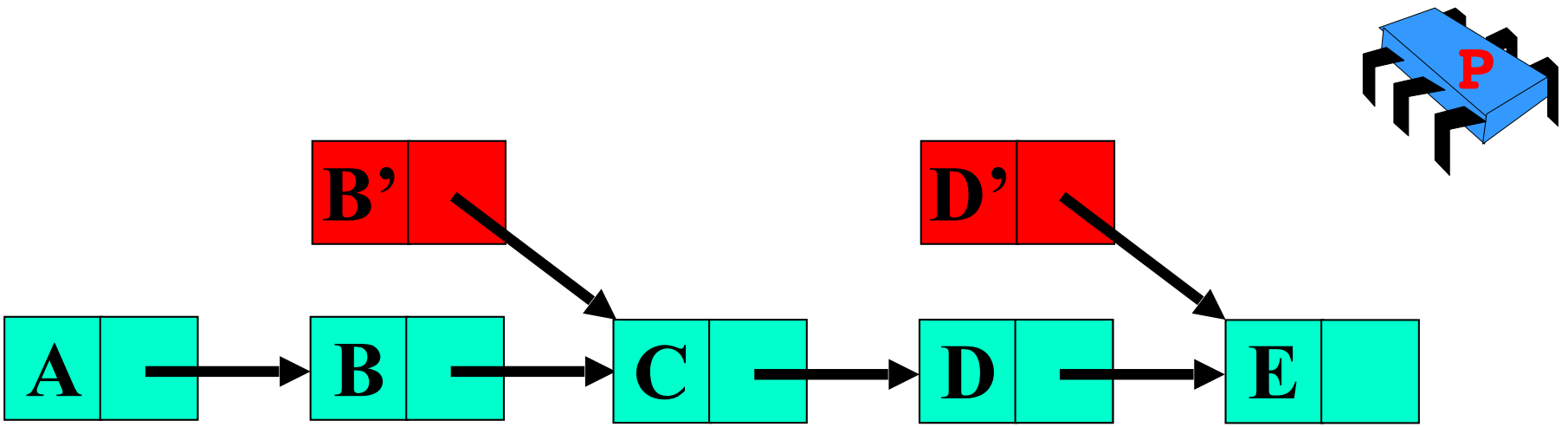

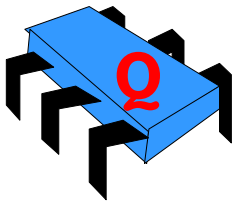

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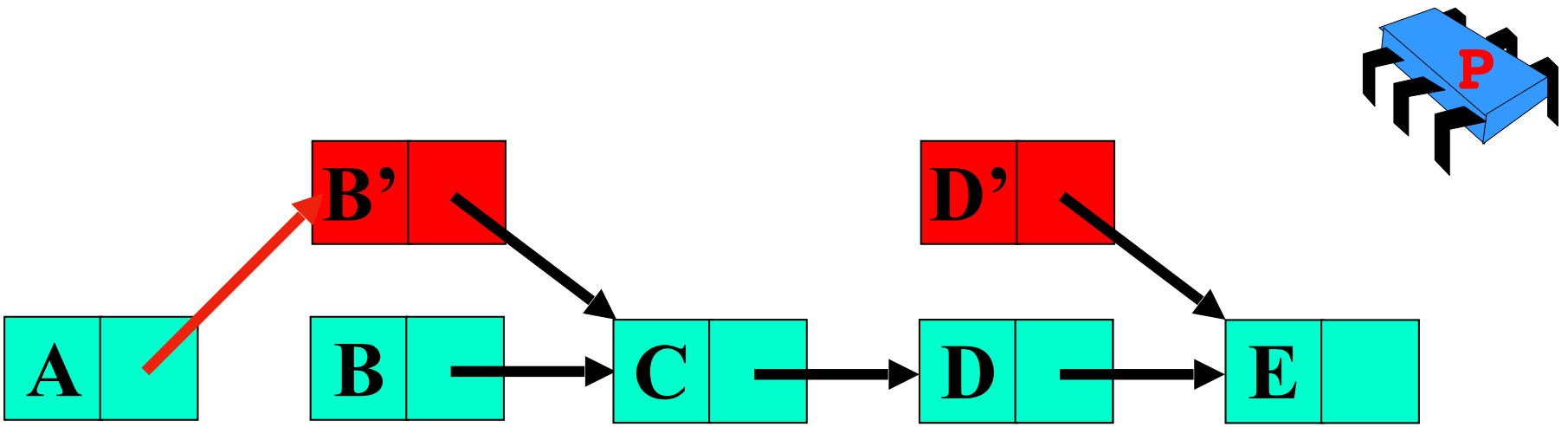

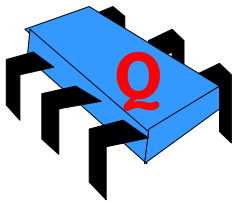

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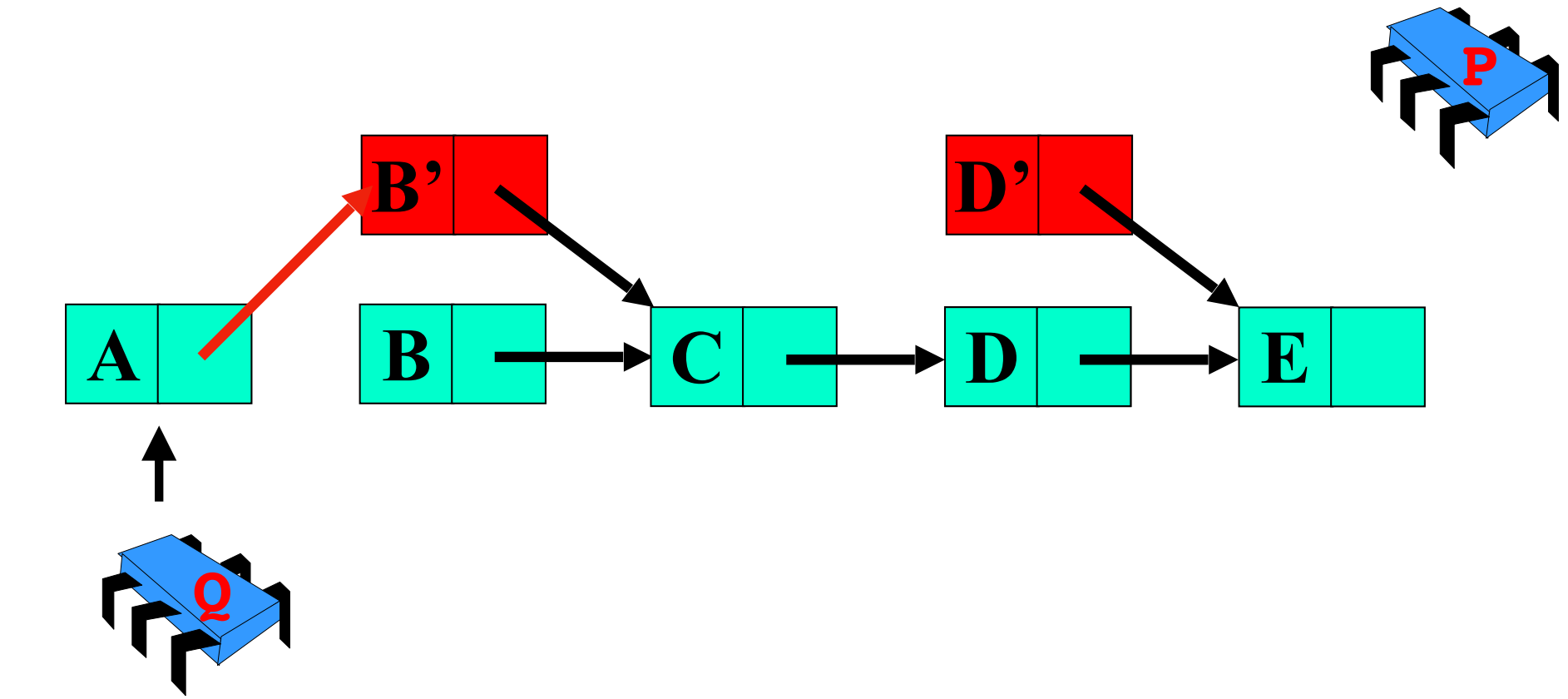

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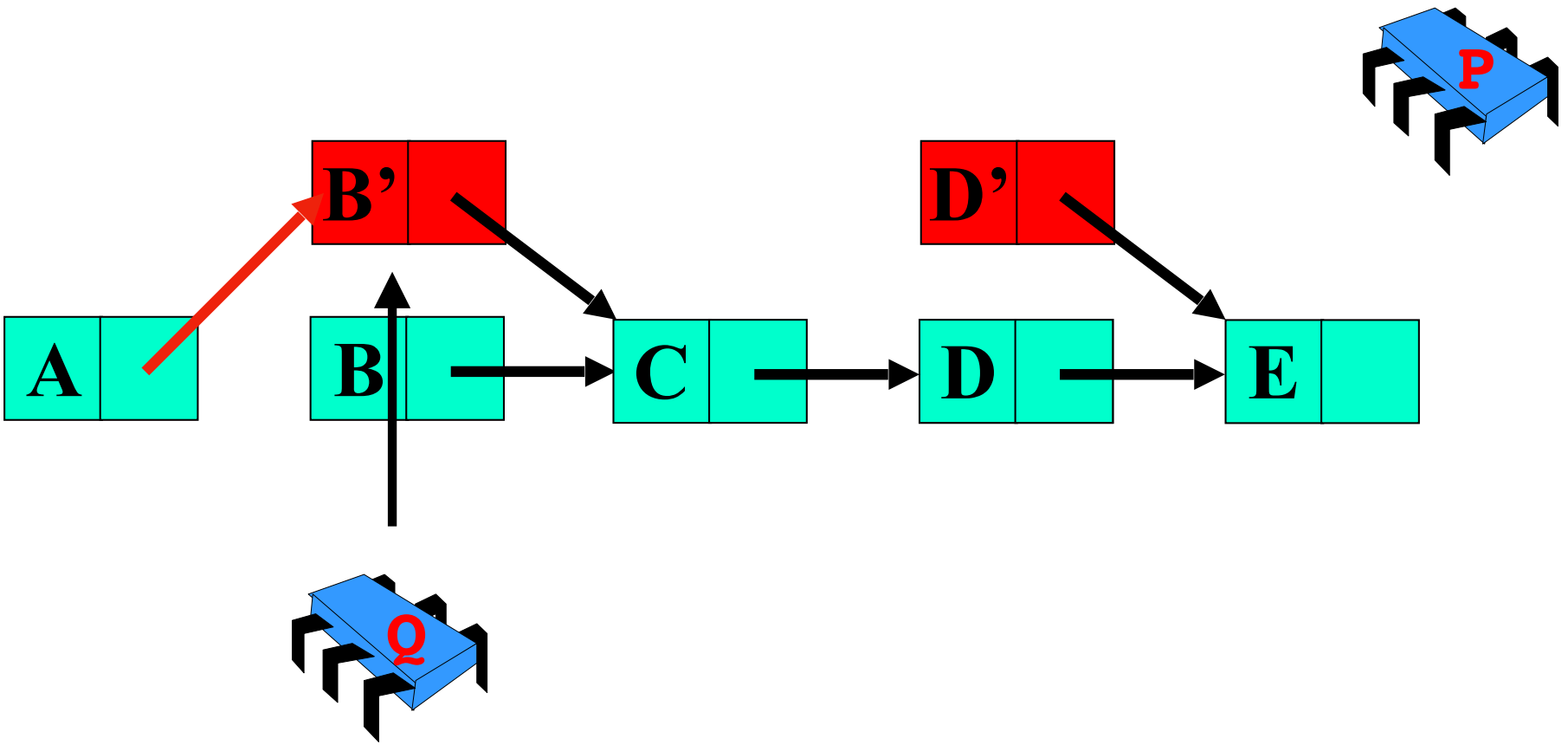

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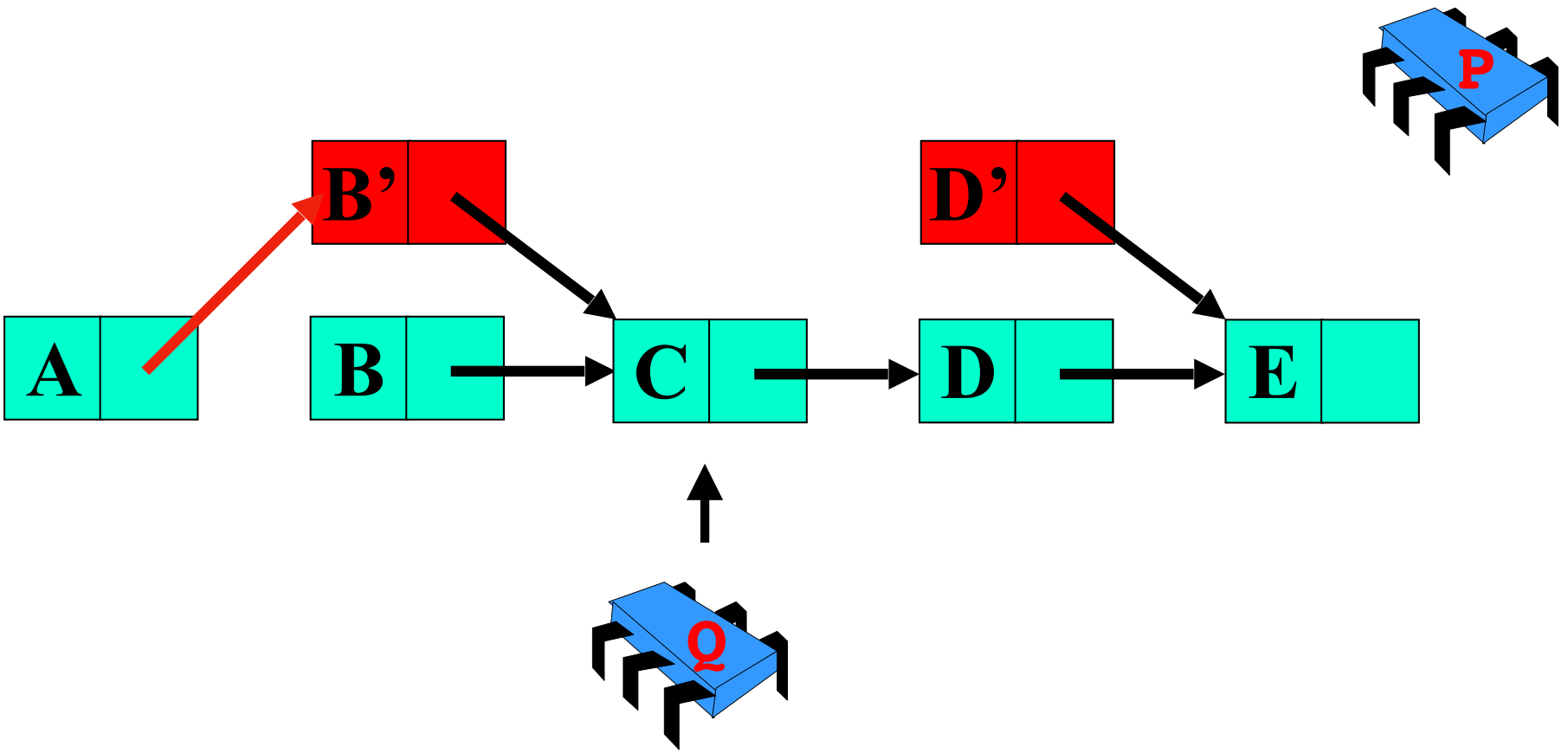

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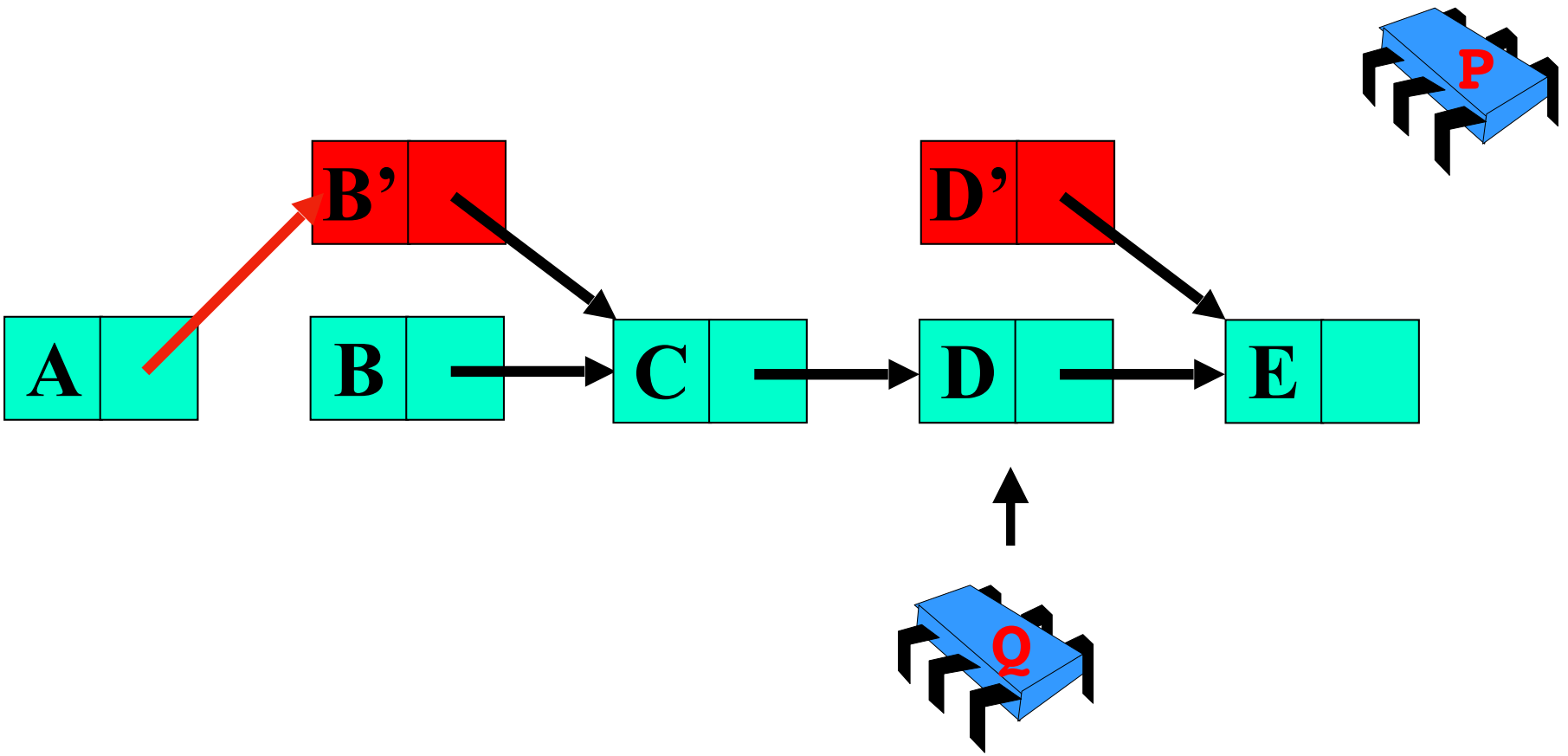

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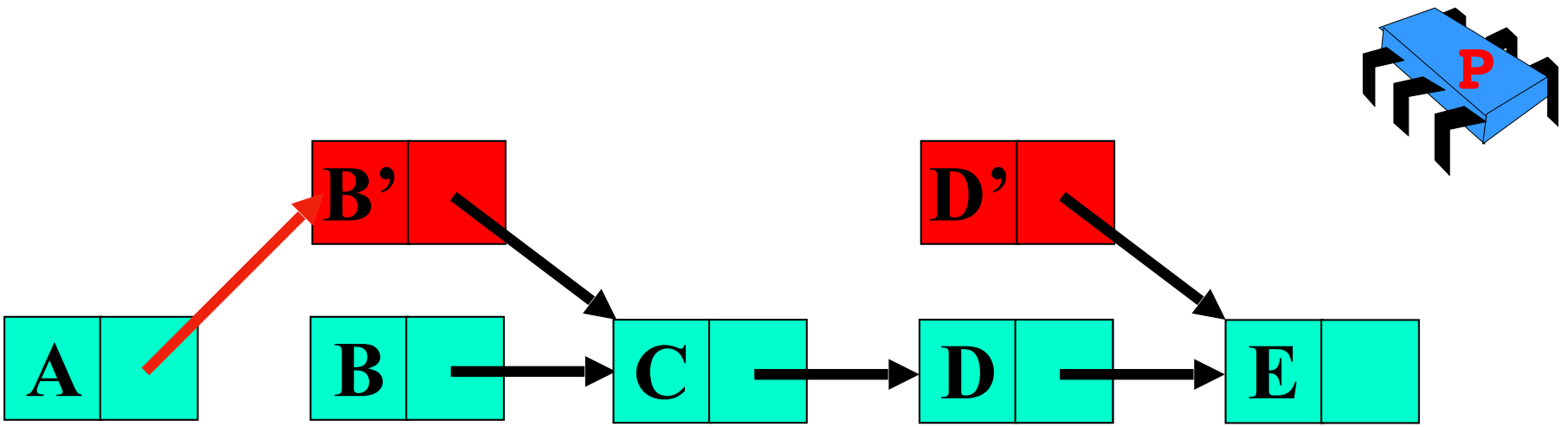
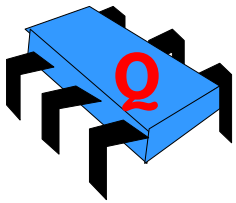


Read B' and D

Inconsistent



Lookup B & D

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  Double link list / Graph / Resizable hash table

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- RCU writers have to wait for all readers to complete

  Long epoch will **block** the writer

Introducing RLU

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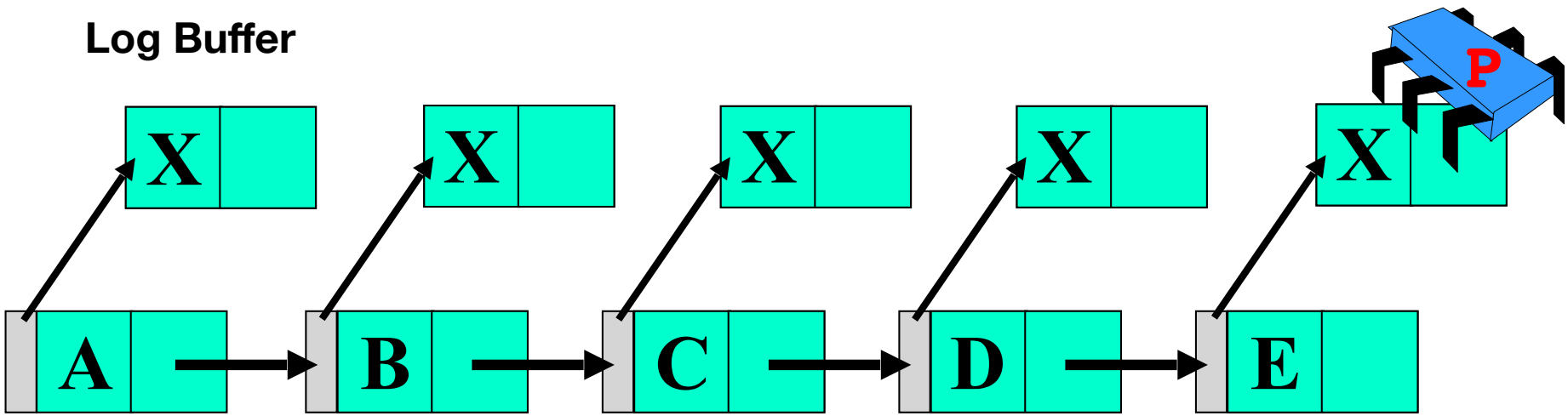
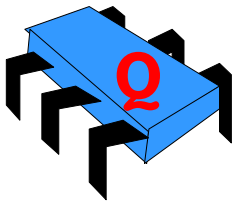
Read Log Update

Update B & D simultaneous



RLU header



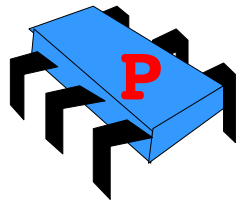
Lookup B & D

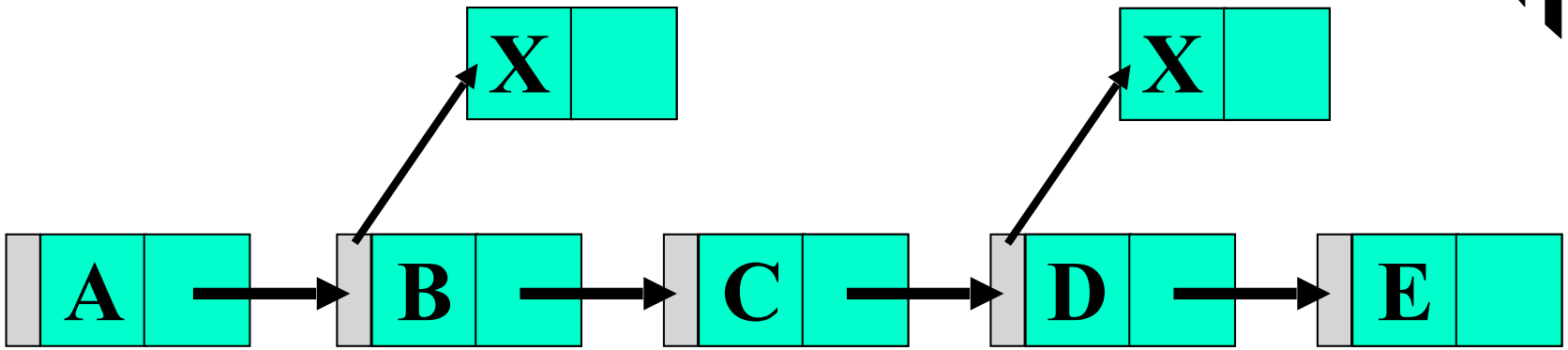
Read Log Update

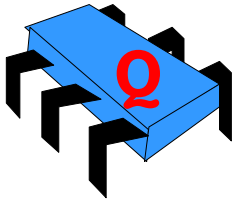
Update B & D simultaneous

Writer
Timestamp = ∞

Global
Timestamp = 22







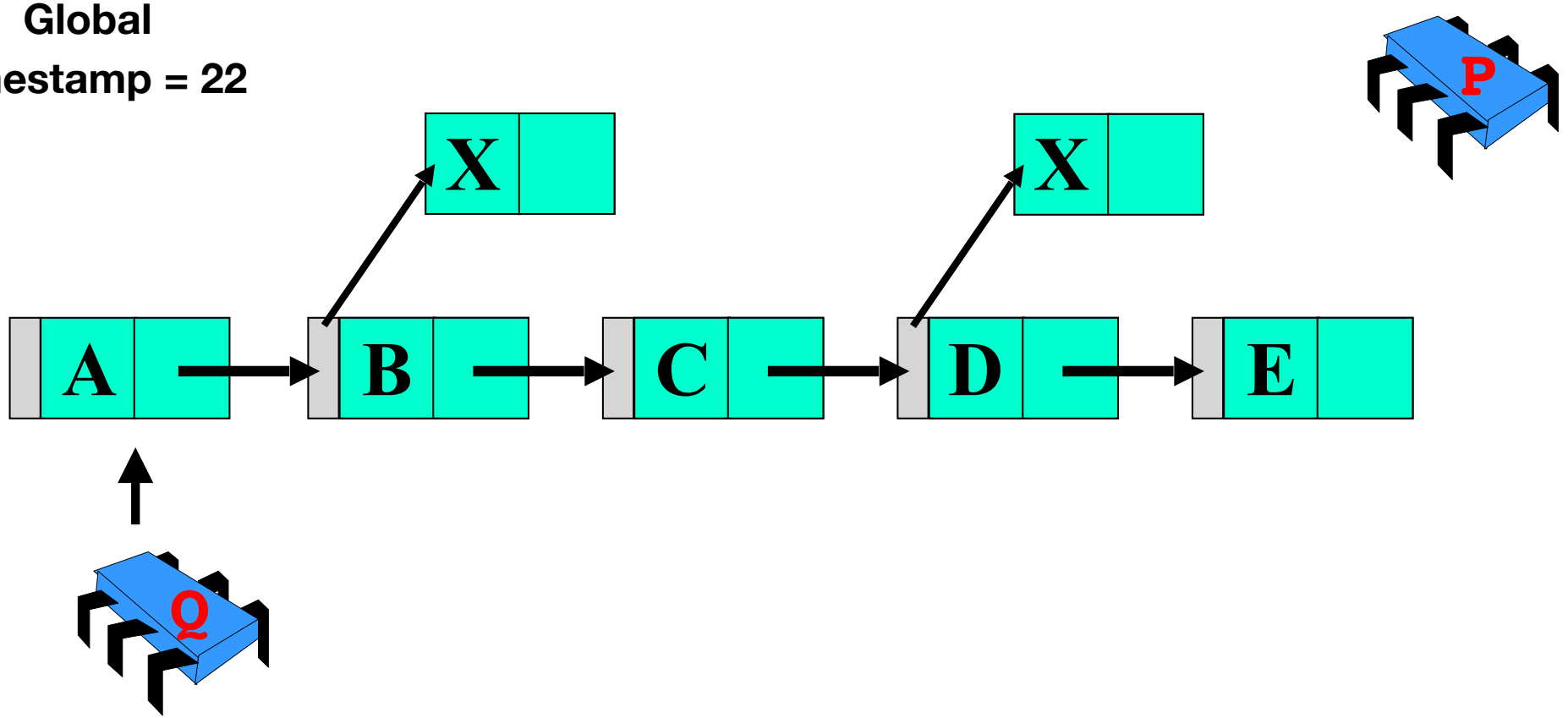
Lookup B & D

Read Log Update

Update B & D simultaneous

Writer
Timestamp = ∞

Global
Timestamp = 22



Lookup B & D

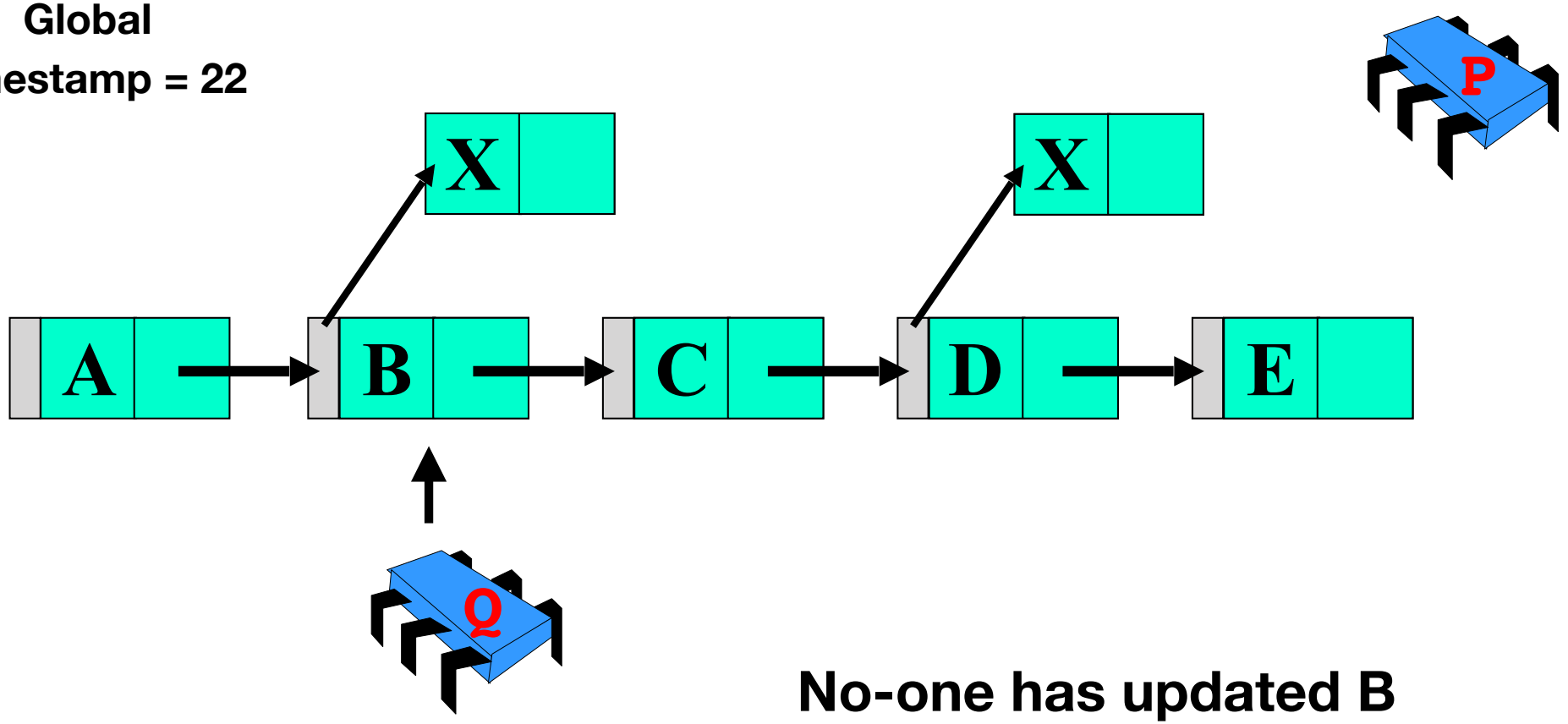
Local Timestamp = 22

Read Log Update

Update B & D simultaneous

Writer
Timestamp = ∞

Global
Timestamp = 22



No-one has updated B

Lookup B & D

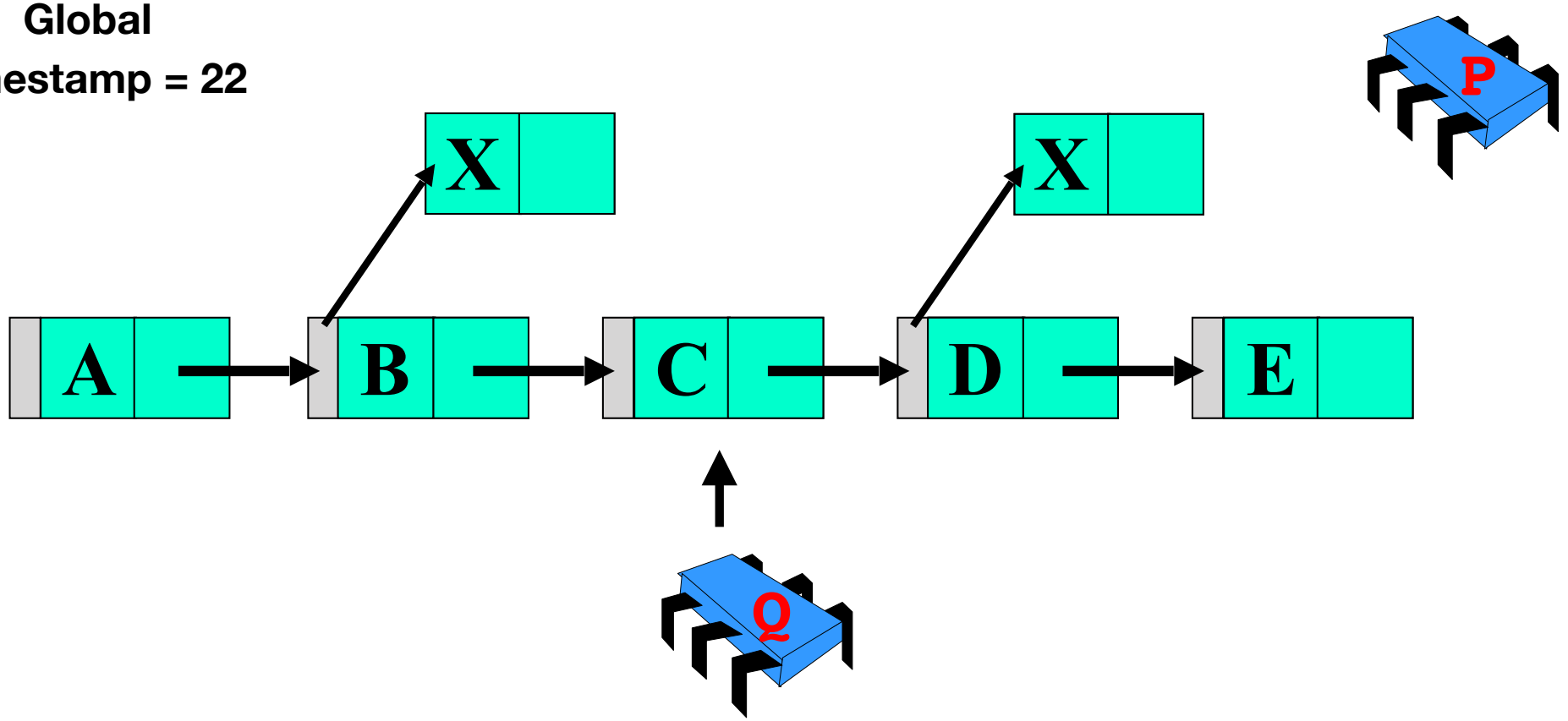
Local Timestamp = 22

Read Log Update

Update B & D simultaneous

Writer
Timestamp = ∞

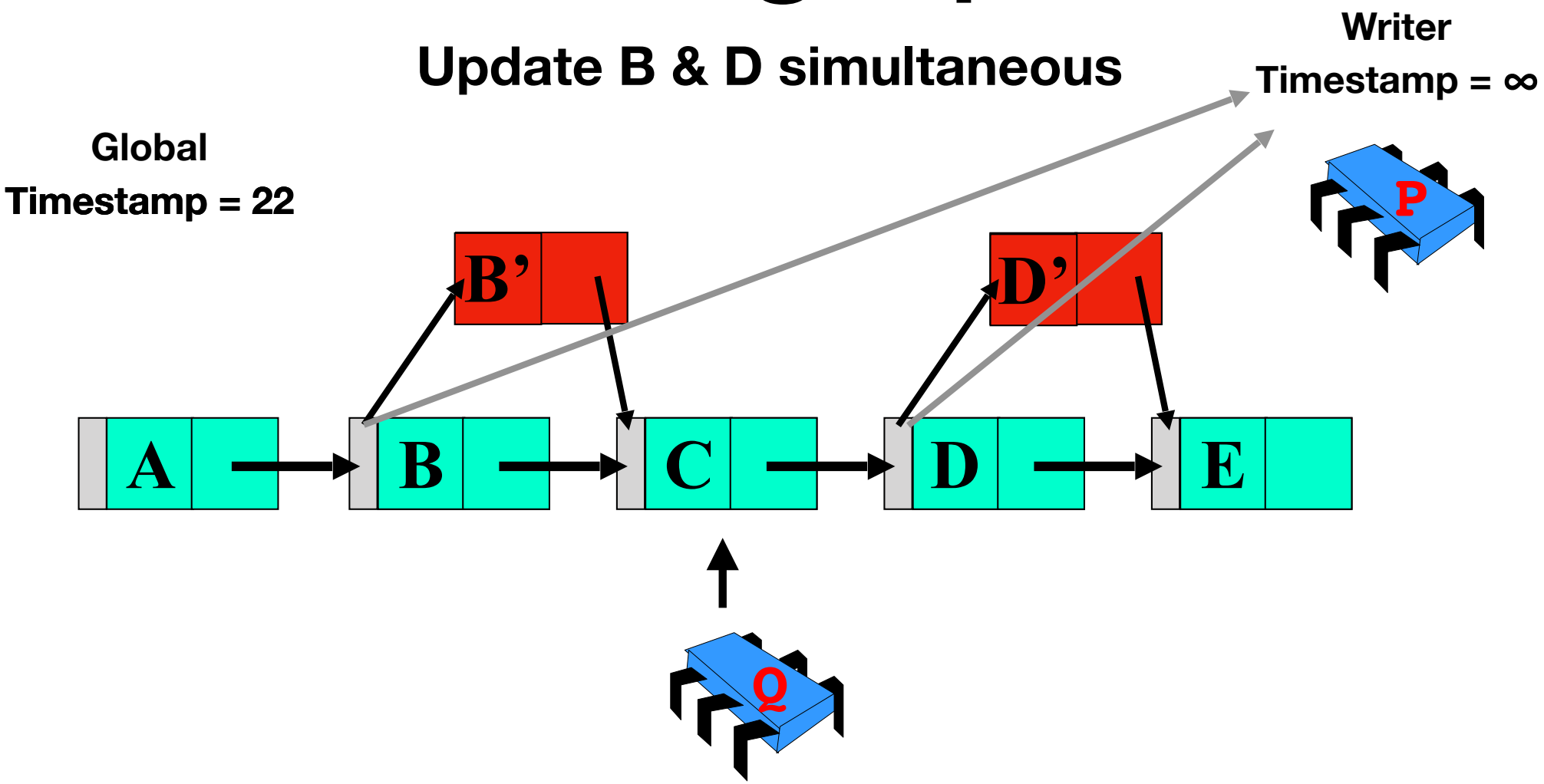
Global
Timestamp = 22



Lookup B & D

Local Timestamp = 22

Read Log Update



Read Log Update

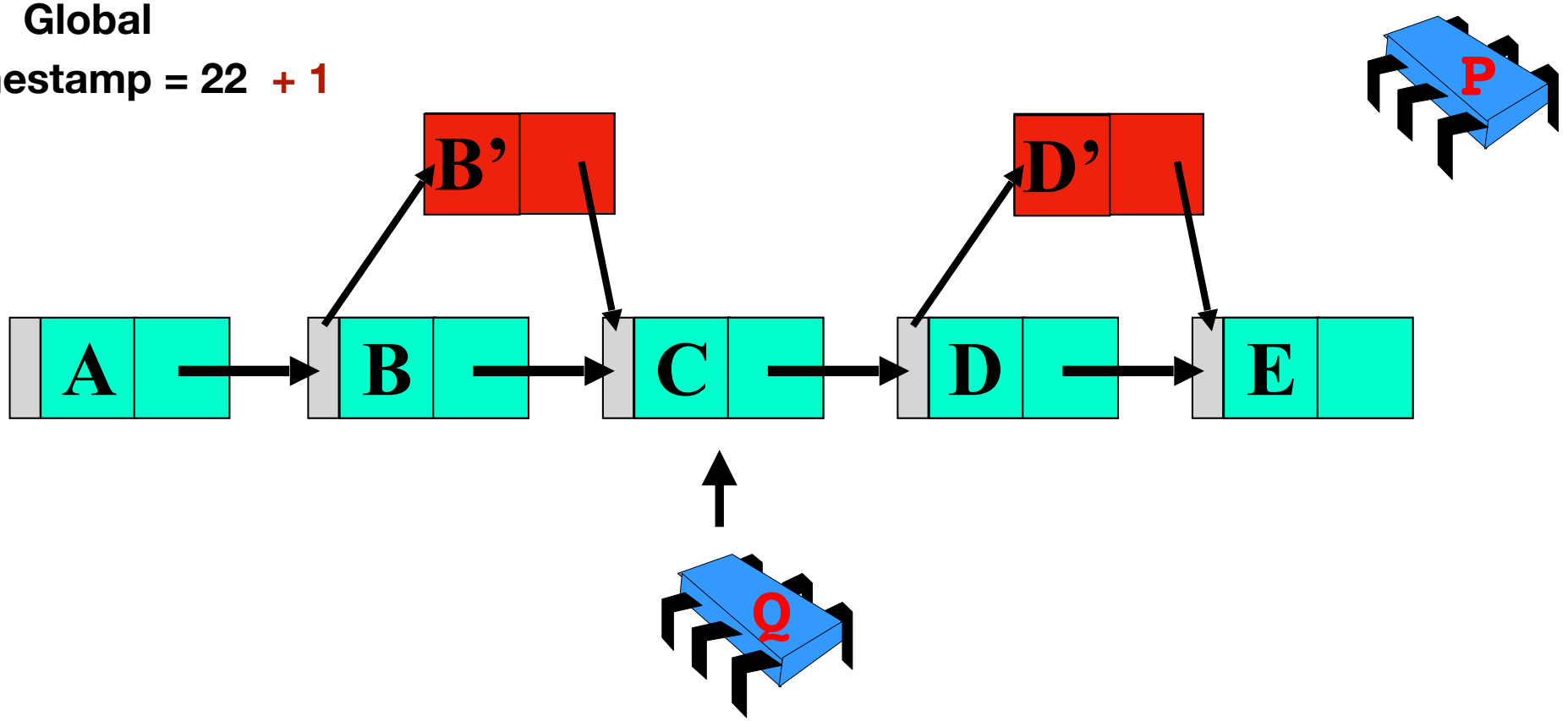
Update B & D simultaneous

Writer

Timestamp = 22 + 1

Global

Timestamp = 22 + 1



Lookup B & D

Local Timestamp = 22

Read Log Update

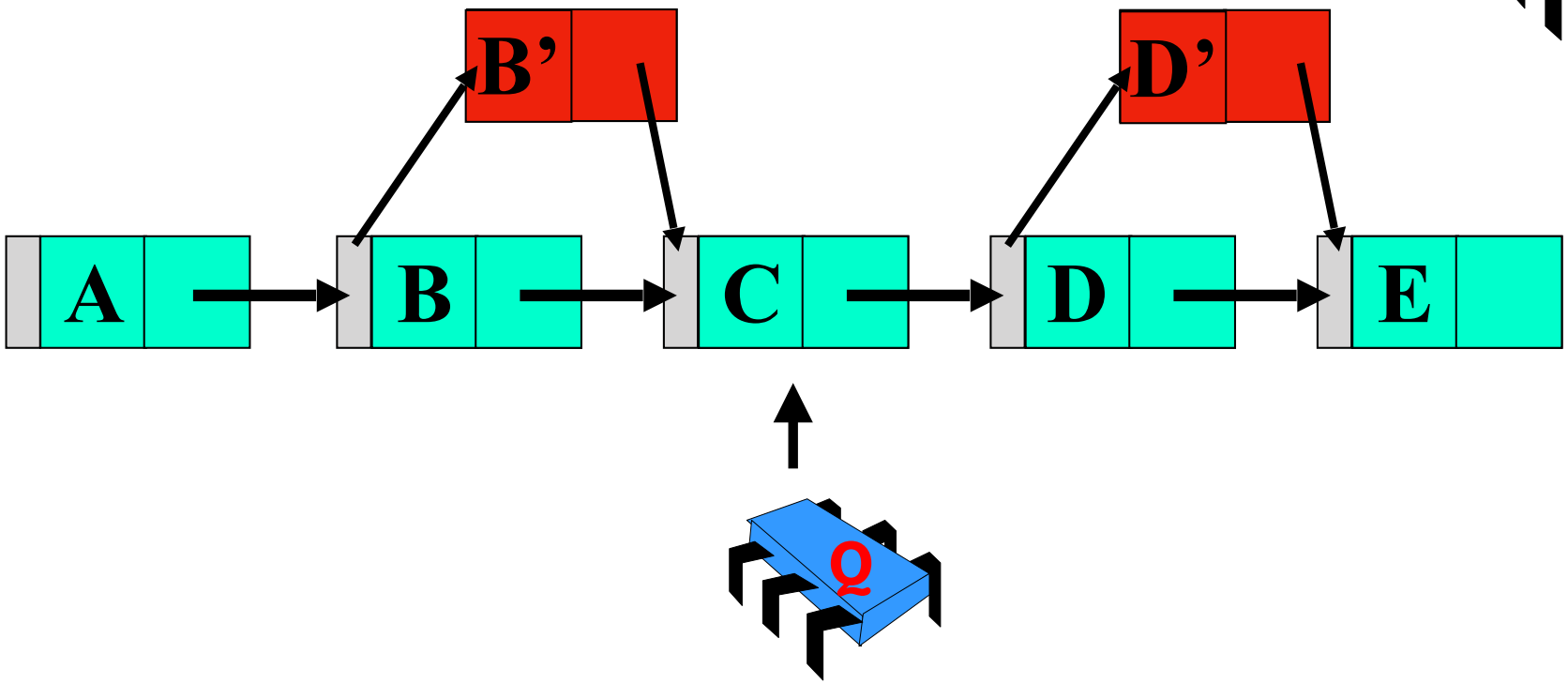
Update B & D simultaneous

Writer

Timestamp = 23

Global

Timestamp = 23



Lookup B & D

Local Timestamp = 22

Read Log Update

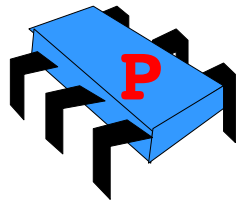
Update B & D simultaneous

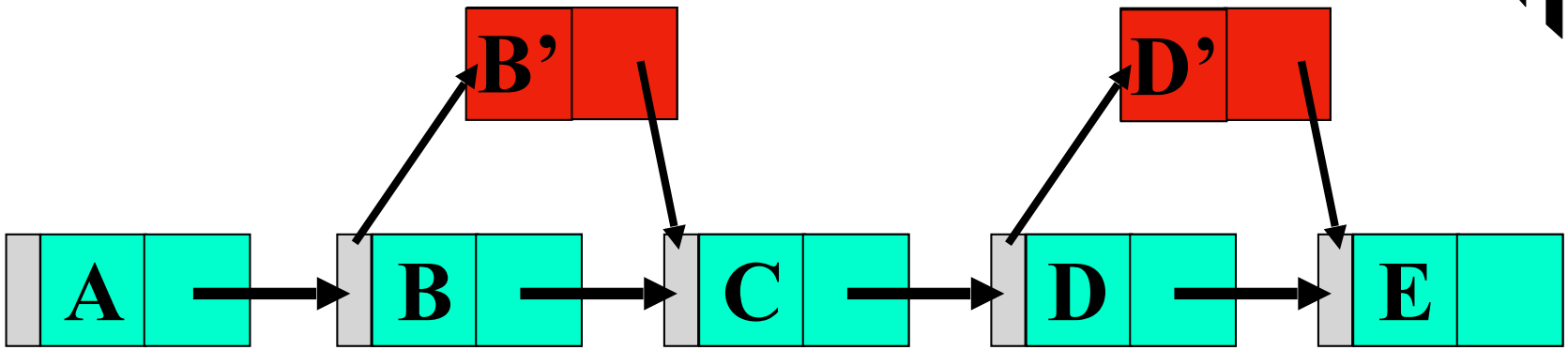
Writer

Timestamp = 23

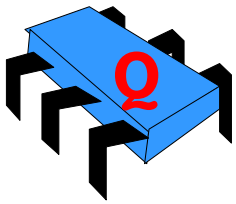
Global

Timestamp = 23





Anyone update D ?



Equal or smaller timestamp?

Lookup B & D

Local Timestamp = 22

Read Log Update

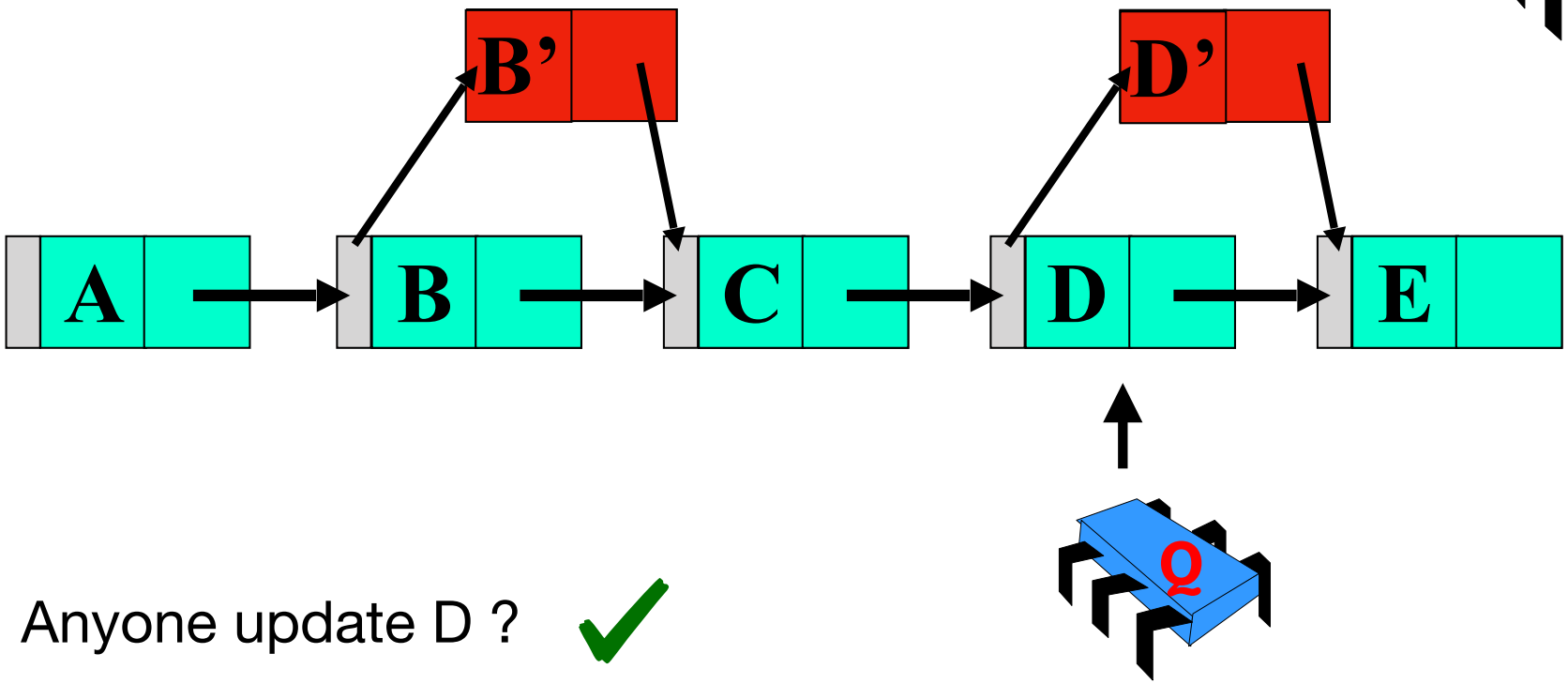
Update B & D simultaneous

Writer

Timestamp = 23

Global

Timestamp = 23



Anyone update D ? ✓

Equal or smaller timestamp? ✗

Lookup B & D

Local Timestamp = 22

Read Log Update

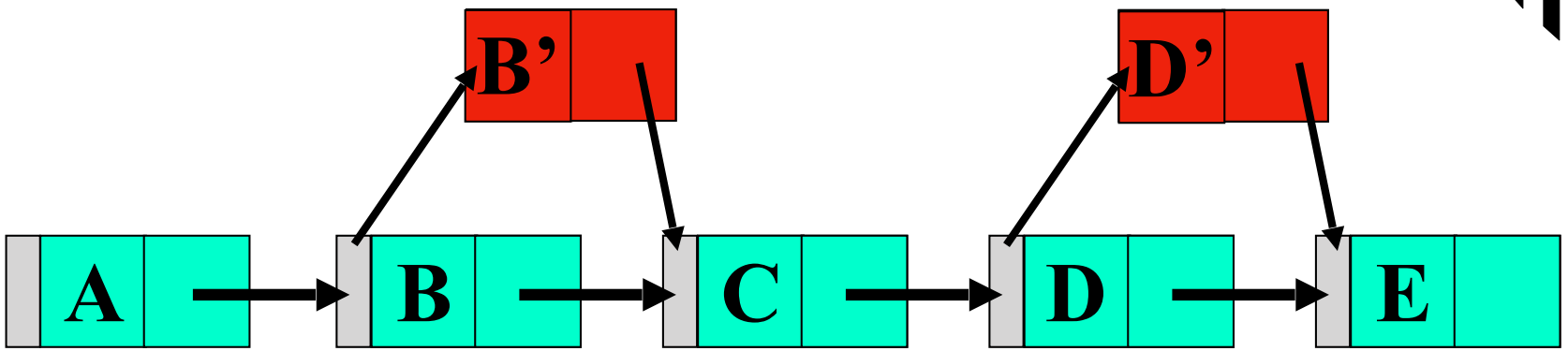
Update B & D simultaneous

Writer

Timestamp = 23

Global

Timestamp = 23



Read Log Update

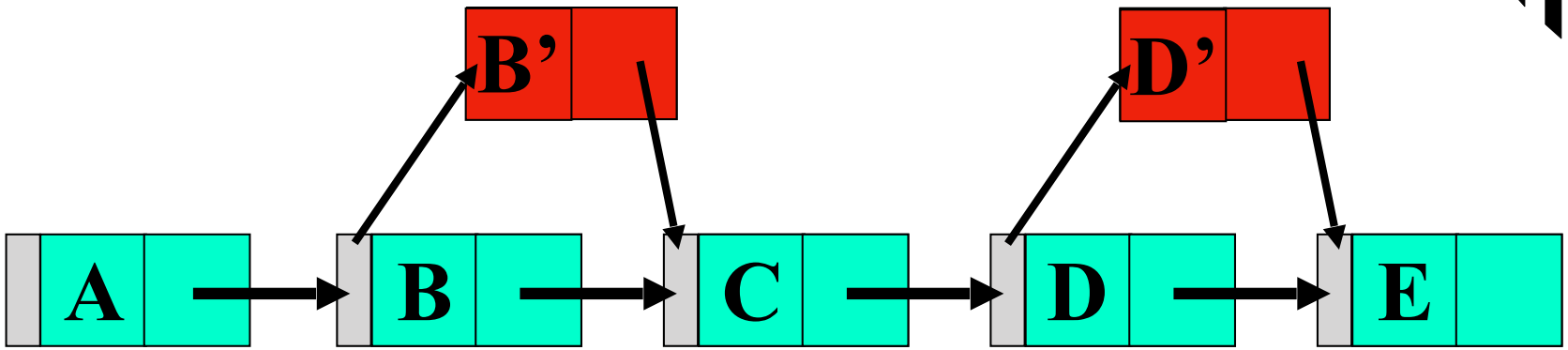
Update B & D simultaneous

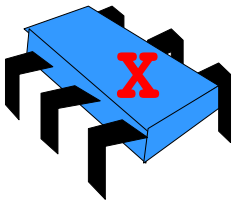
Writer

Timestamp = 23

Global

Timestamp = 23





Lookup B & D

Timestamp = 23

Anyone update B ? ✓

Equal or smaller timestamp? ✓

Read Log Update

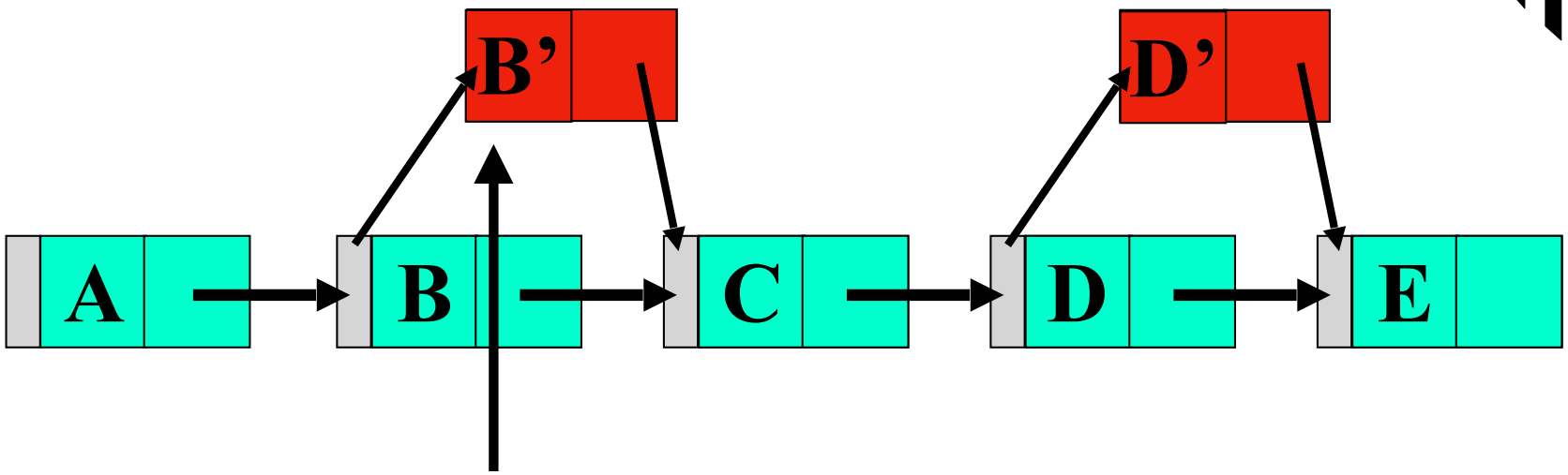
Update B & D simultaneous

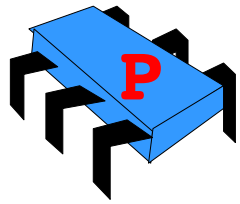
Writer

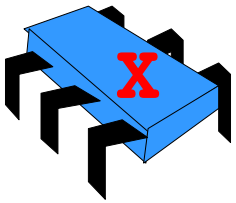
Timestamp = 23

Global

Timestamp = 23







Anyone update B ? ✓

Equal or smaller timestamp? ✓

Lookup B & D

Timestamp = 23

Read Log Update

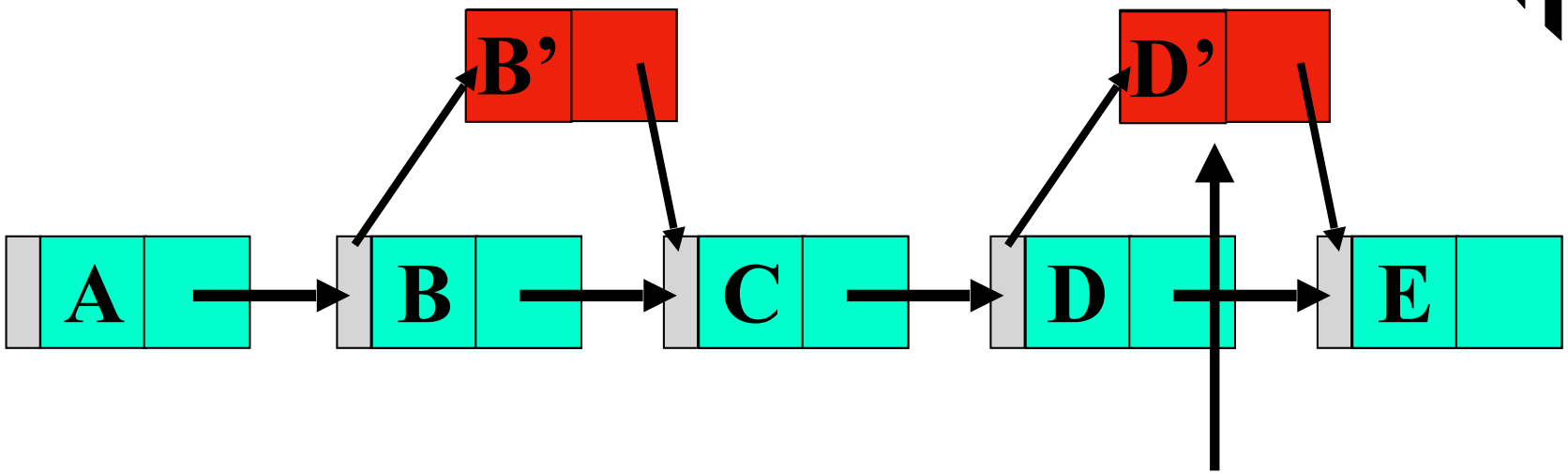
Update B & D simultaneous

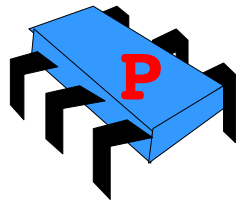
Writer

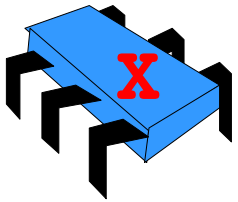
Timestamp = 23

Global

Timestamp = 23







Anyone update D ? ✓

Equal or smaller timestamp? ✓

Lookup B & D

Timestamp = 23

Read Log Update

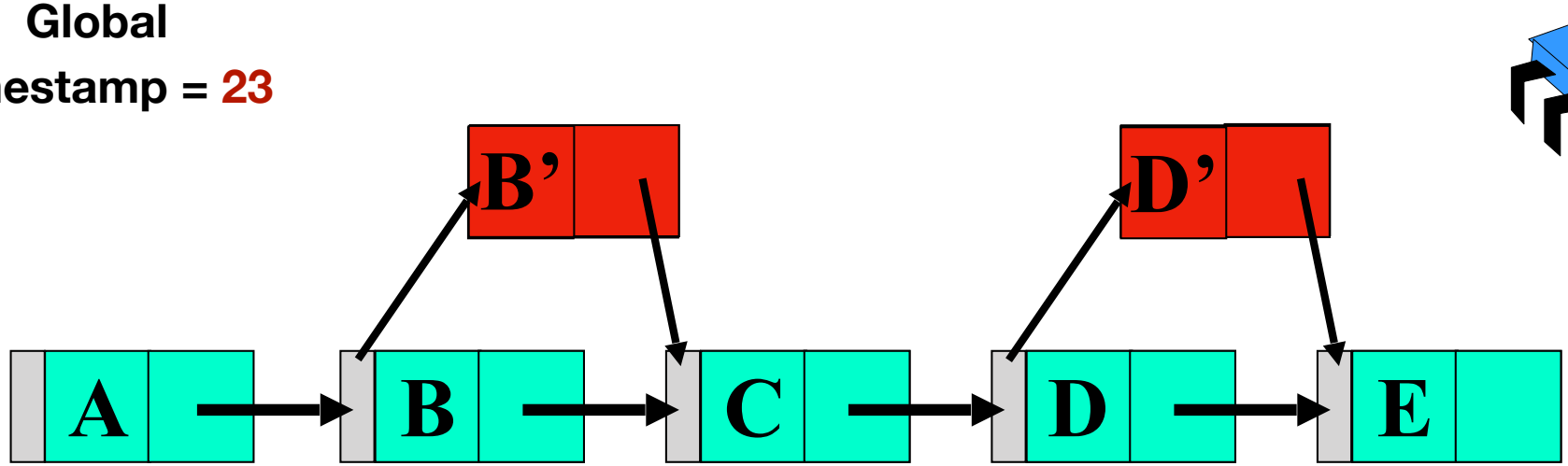
Update B & D simultaneous

Writer

Timestamp = 23

Global

Timestamp = 23



Wait until all previous readers finish their jobs

```
Readers' timestamp < Current writers’
```

Read Log Update

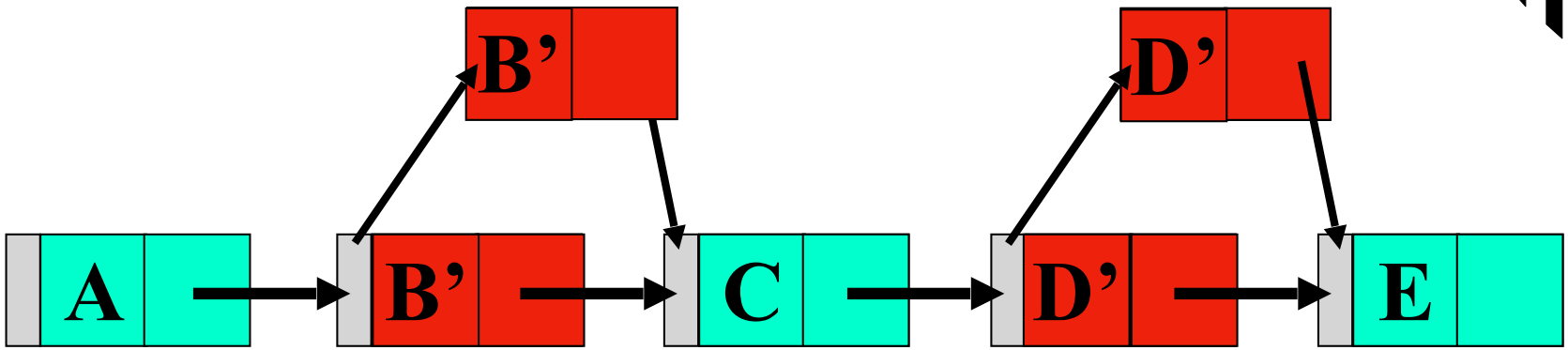
Update B & D simultaneous

Writer

Timestamp = 23

Global

Timestamp = 23



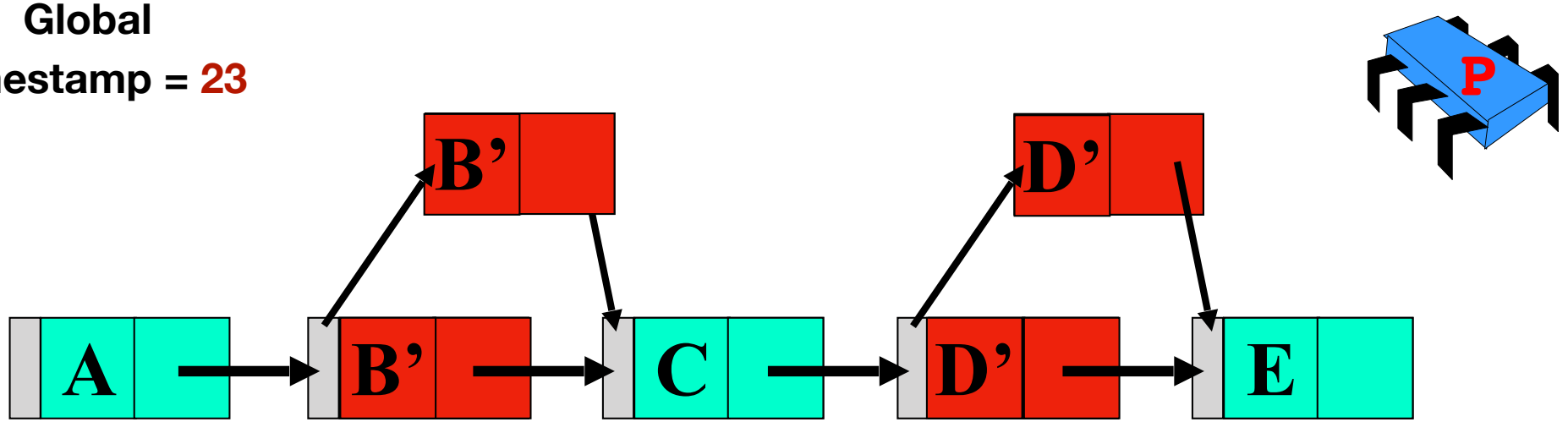
Write back logs when previous readers finish their jobs

Read Log Update

Update B & D simultaneous

Timestamp = ∞

Global Timestamp = 23

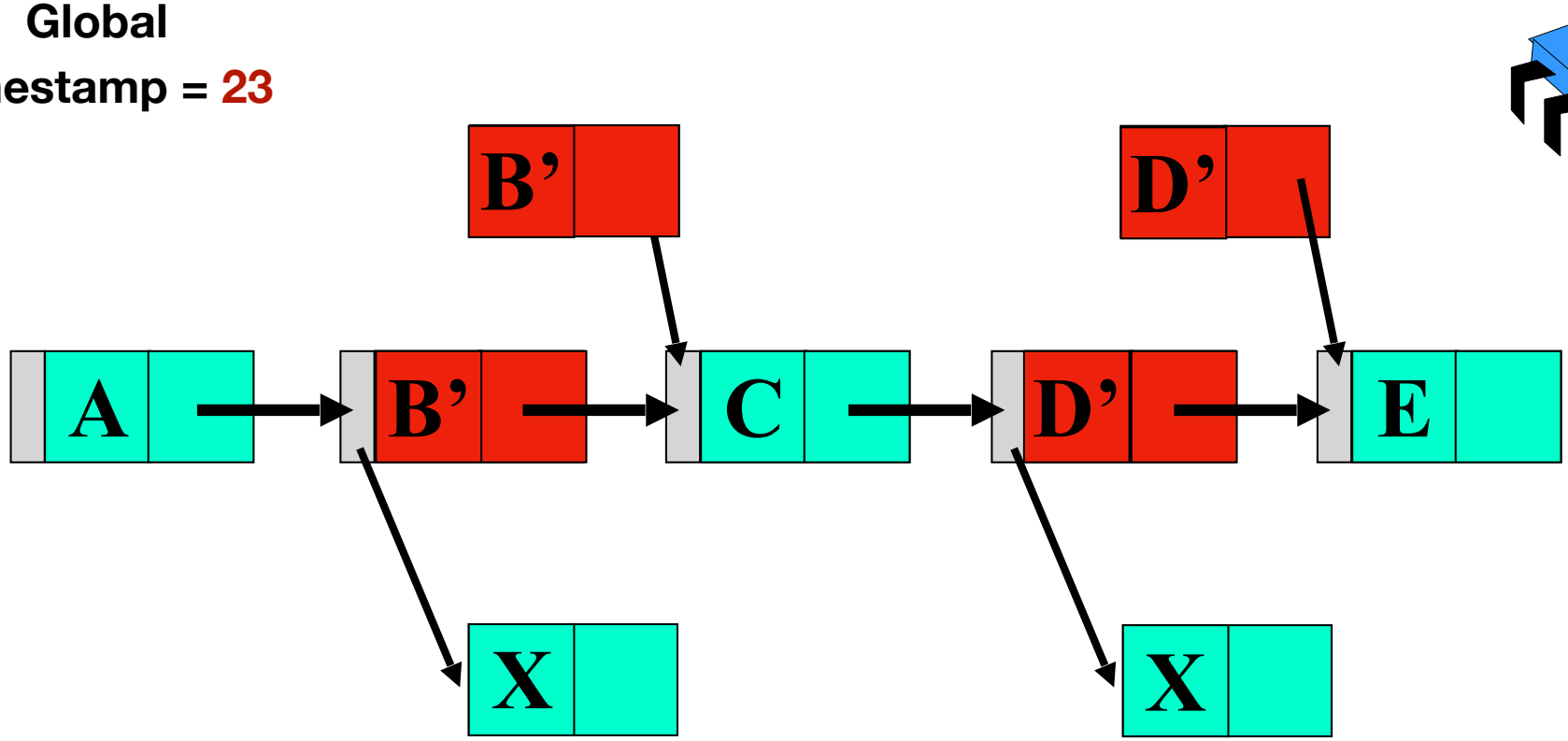


Reset write timestamp

Read Log Update

Update B & D simultaneous

Global
Timestamp = 23



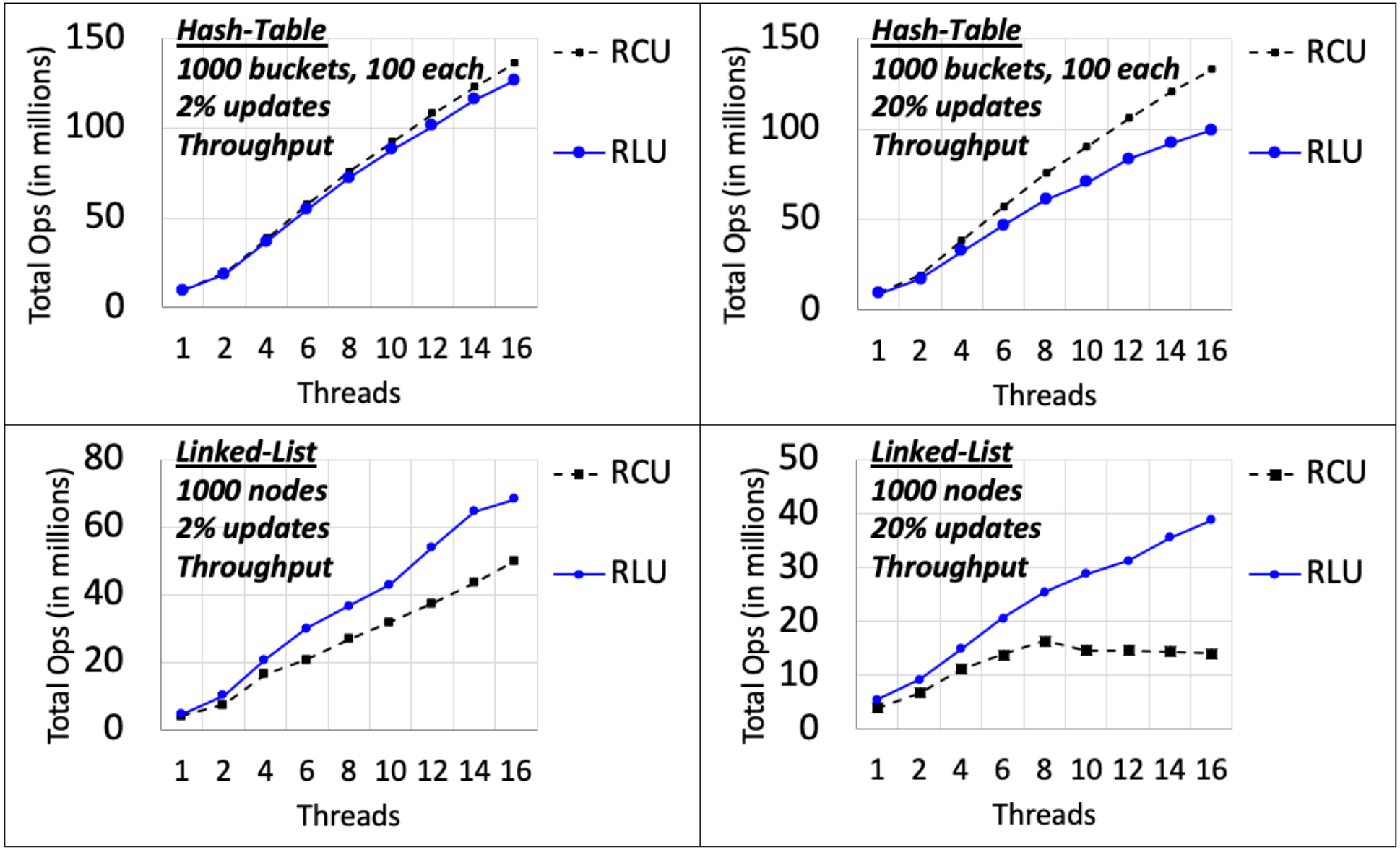
Swap to another log buffer

Most exciting part in RLU

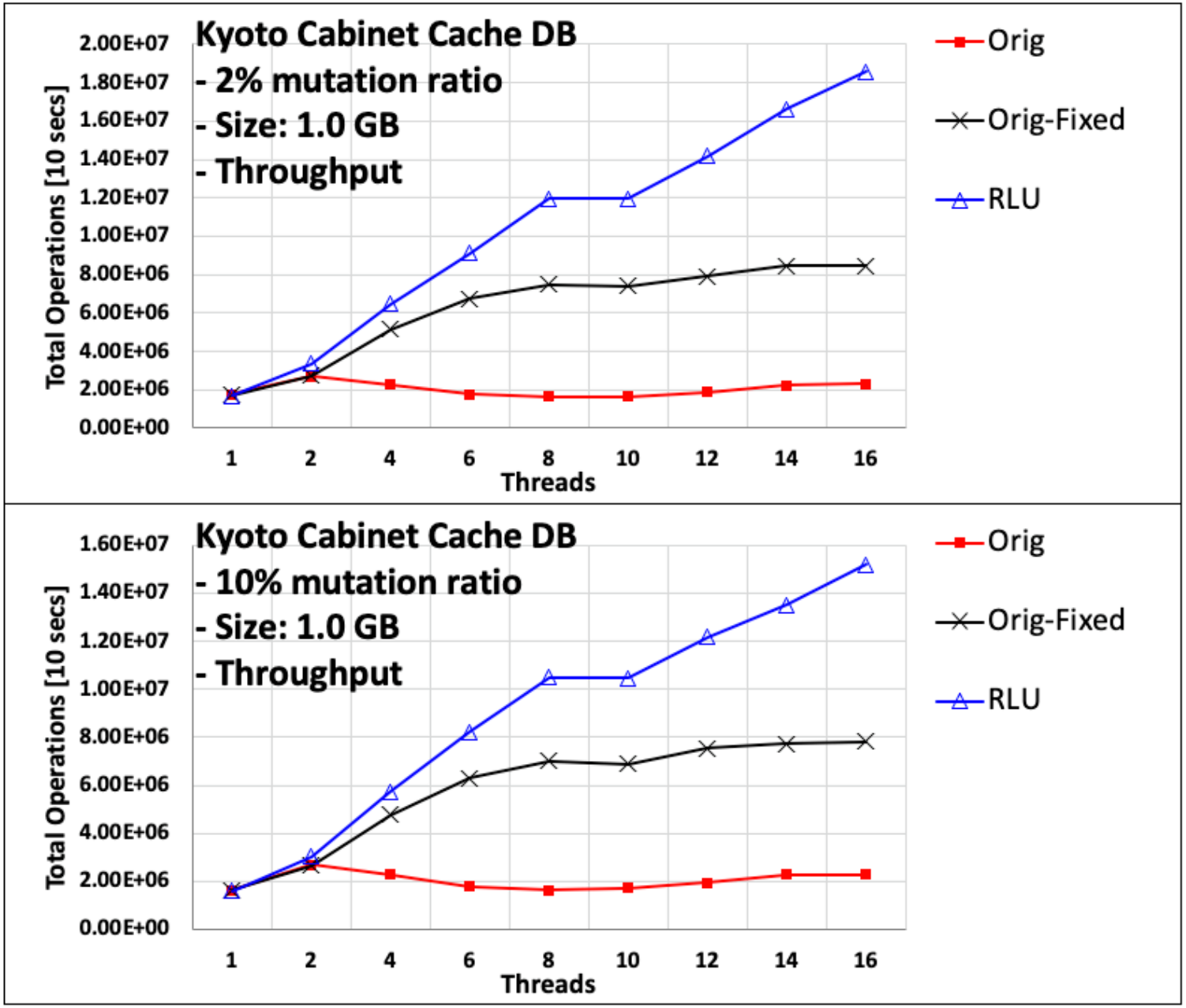
- 2 key concerns for concurrent data structure:
  - **Unsynchronized** traversals ✓
  - **Multi-location** atomic updates ✓
- Easier to be used in complicated applications
  - Double link list
  - Kyoto Cabinet

Evaluation

Microbenchmarks



Kyoto Cabinet



Conclusion

- Single pointer update => Global clock update
- Stronger semantic compared to RCU
- Significantly lower intellectual cost to the programmer
- No extra overhead on reader’s critical path
- Achieve similar (even better) performance with RCU

Thanks
Q & A