Parallele Programmierung FS25

Exercise Session 11

Jonas Wetzel

Plan für heute

- Organisation
- Nachbesprechung Assignment 10
- Theory
- Intro Assignment 11
- Exam questions
- Kahoot

Organisation

- Mein Name ist Jonas Wetzel
- Meine Website (Materialien und Inhalt der Übungen): n.ethz.ch/~jwetzel
- Meine Email: jwetzel@ethz.ch
- Discord: @jonas.too

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Organisation

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- Falls ihr Feedback möchtet kommt bitte zu mir

Organisation

- Wo sind wir jetzt?

Reader Writer Lock
Lock granularity
Coarse-grained, Fine-grained, optimistic locking, lazy locking
Concurrent LinkedList

To come: lock free synchronization, lock free data structures, Linearizability, Consensus

Plan für heute

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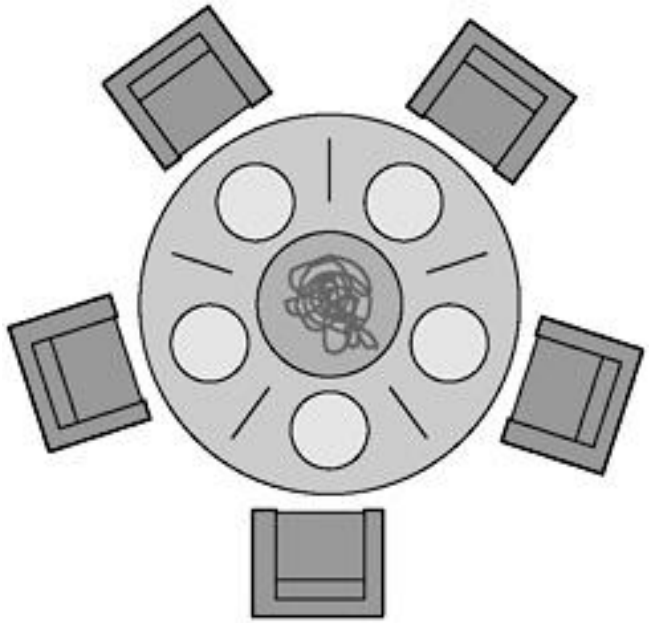
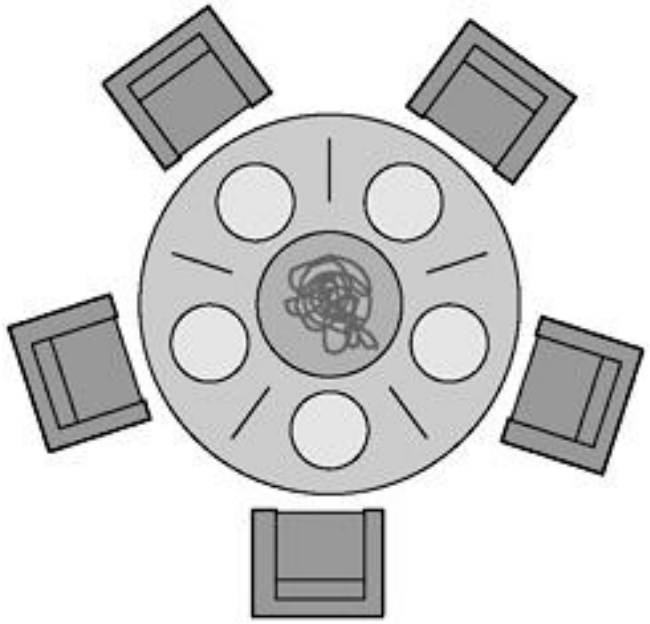
Task 1 - Dining Philosophers



Originally proposed by E. W. Dijkstra
Imagine five philosophers who spend their lives thinking and eating.
They sit around a circular table with five chairs with a big plate of spaghetti.
However, there are only five chopsticks available.

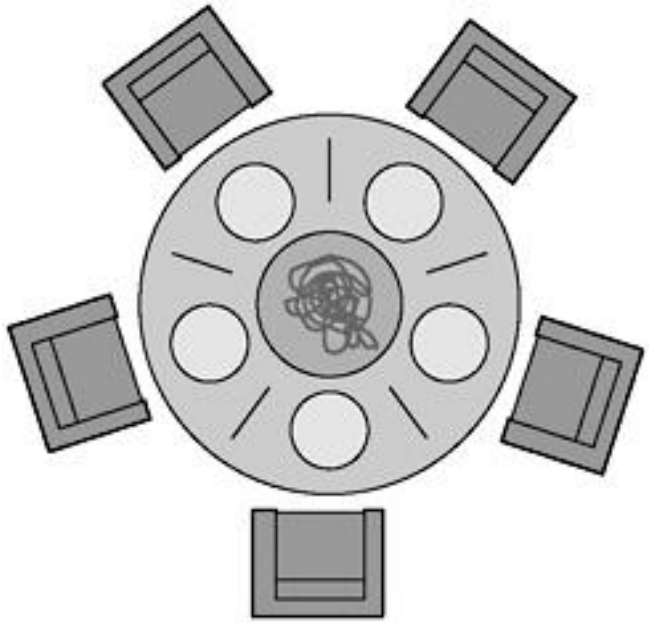
Task 1 - Dining Philosophers



Each philosopher thinks and when he gets hungry picks up the two chopsticks closest to him.

- If a philosopher can pick up BOTH chopsticks, he eats for a while.
- After a philosopher finishes eating, he puts down the chopsticks and starts to think again.

Find a solution that…



- Makes deadlocks impossible
- Has no starvation
- More than one parallel eating philosopher is possible

Assignment 10

Dining Philosophers:

```
while(true) {
    think();
    acquire_fork_on_left_side();
    acquire_fork_on_right_side();
    eat();
    release_fork_on_right_side();
    release_fork_on_left_side();
}
```

One philosophers left side is anothers right side!

But we take left first, then right. So we hold one fork, then wait – leads to cycle in dependency graph.

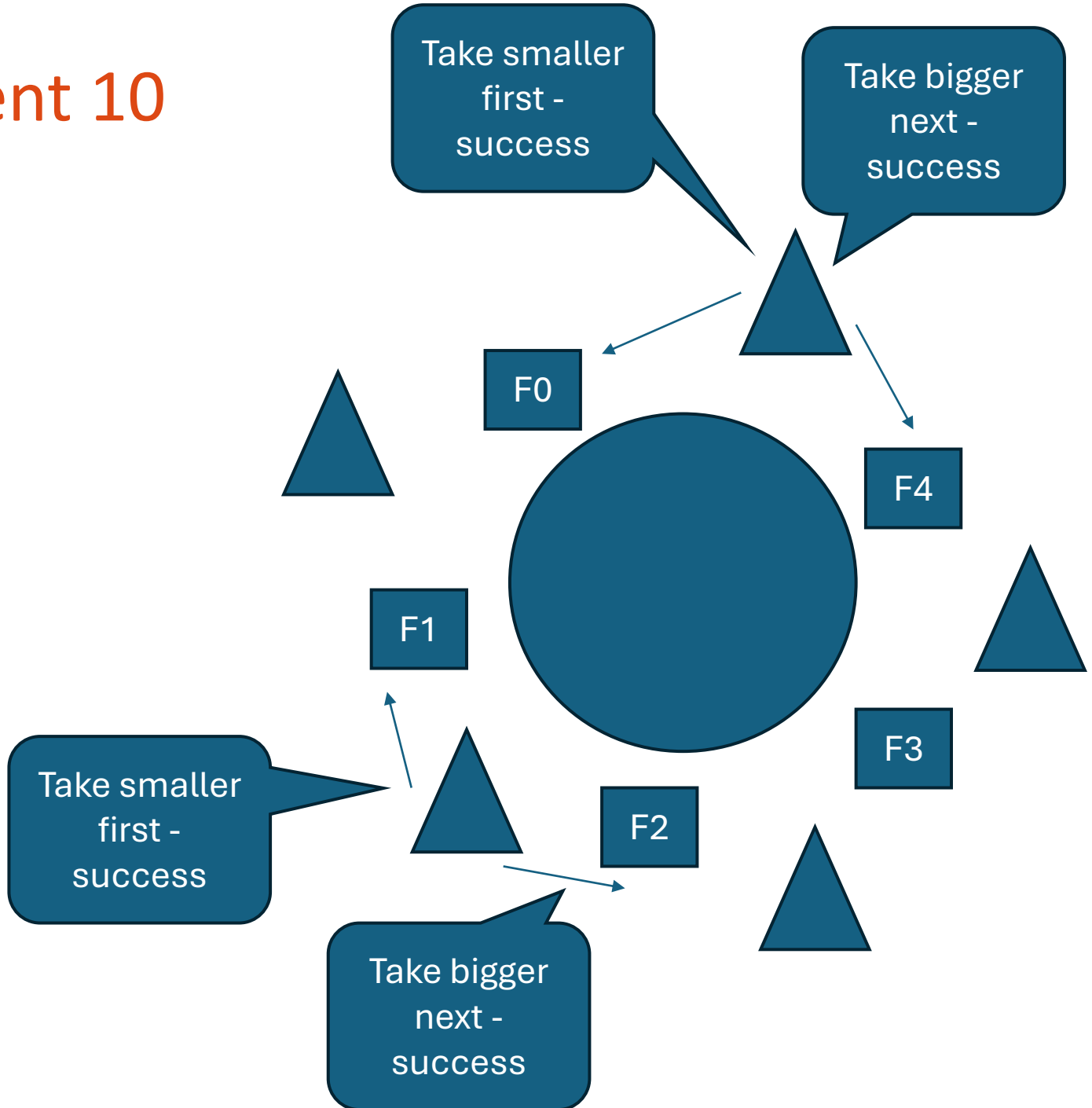
Assignment 10

Dining Philosophers:

- To avoid cyclic dependencies: Lock-ordering!

- Number all forks, take the one with smaller number first.
- Same principle we saw with bank-account already!

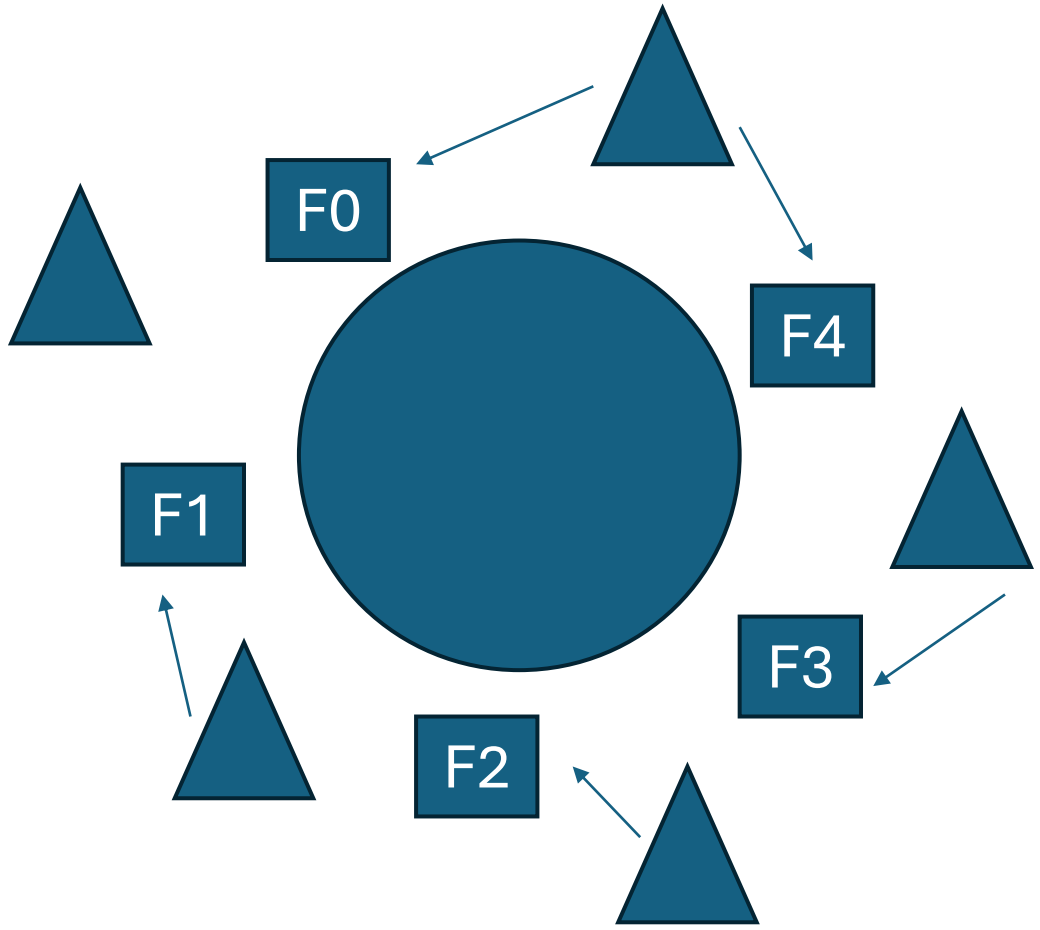
Assignment 10



Two can eat at the same time.

Three is impossible (would need six forks).

Assignment 10



Now only one is eating.

All others have to wait -
Not great, not terrible (no deadlock!)

Assignment 10

Dining Philosophers:

- The only way to ensure that two can always eat at the same time is to introduce additional elements (communication, a waiter, etc.)

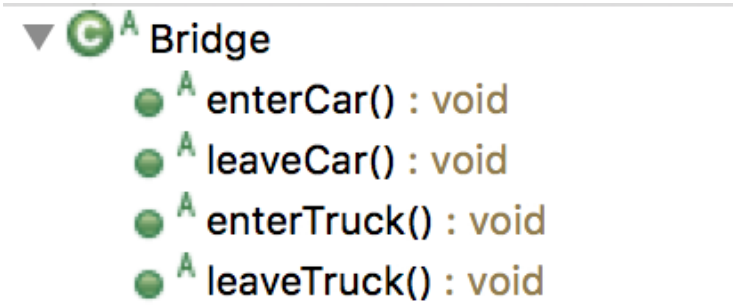
Now only one is eating.

All others have to wait -
Not great, not terrible (no deadlock!)

Task 2 – Monitors, Conditions and Bridges

Only either 3 cars or one truck may be on the bridge at each moment.

Implement Classes `BridgeMonitor` and `BridgeCondition`



How to Test my Implementation?
Implement method `invariant()` to check if the state is valid: at the end of a method there are never too many cars or trucks on the bridge

Assignment 10 – Bridge with monitor

```
public class BridgeMonitor extends Bridge {

    private int carCount = 0;
    private int truckCount = 0;
    private final Object monitor = new Object();

    public void enterCar() throws InterruptedException {
        synchronized(monitor)
        {
            while (carCount >= 3 || truckCount >= 1) {
                    monitor.wait();
            }
            carCount++;
        }
    }

    public void leaveCar() {
        synchronized (monitor) {
            carCount--;
            monitor.notifyAll();
        }
    }
```

Is this really needed?

Why notifyAll()?
We only want to wake up one car or maybe a truck (if carCount ==0)

Assignment 10 – Bridge with condition

```
public class BridgeCondition extends Bridge {

    final Lock bridgeLock = new ReentrantLock();
    Condition truckCanEnter = bridgeLock.newCondition();
    Condition carCanEnter = bridgeLock.newCondition();

    volatile private int carCount = 0;
    volatile private int truckCount = 0;
```

Make two separate groups of “waiters”

Assignment 10 – Bridge with condition

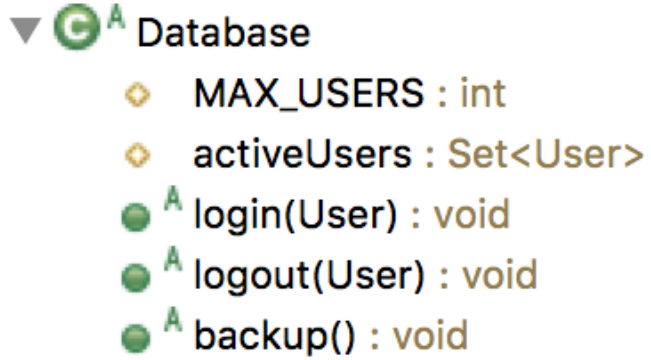
```
public void enterCar() throws InterruptedException {
    bridgeLock.lock();
    while (carCount >= 3 || truckCount >= 1) {
        carCanEnter.await();
    }
    carCount++;
    bridgeLock.unlock();
}

public void leaveCar() {
    bridgeLock.lock();
    carCount--;
    if (carCount == 0)
        truckCanEnter.signalAll();
    if (carCount < 3)
        carCanEnter.signalAll();
    bridgeLock.unlock();
}
```

Choose who to wake up based on conditions.

Task 3 – Semaphores and Databases

Use semaphores to implement login and logout database functionality that supports up to 10 concurrent users



Use barrier to implement 2-phase backup functionality.

Task 3 – Semaphores and Databases

Implement Classes MySemaphore and MyBarrier

Use monitors for both to avoid busy loop

- Put processes to sleep, when there is no entry into semaphore
- Wake up a waiting process when releasing a semaphore

```
acquire(S) {
        wait until S > 0
        dec(S)
}

release(S) {
        inc(S)
}
```

Assignment 10 – Semaphore implementation

```
public class MySemaphore {
    private volatile int count;

    public MySemaphore(int maxCount) {
        this.count = maxCount;
    }

    public void acquire() throws Inte
        synchronized (this) {
            while (count == 0) {this.wait();}
            count--;
        }
    }

    public void release() {
        synchronized (this) {
            count++;
            this.notifyAll();
        }
    }
}
```

Why a while loop here and not an if?

Does this have to be notifyAll()?

Note that we use “this” here – could also have created new object (see Bridge monitor)

Assignment 10 – Barrier implementation

```
synchronized void await() throws InterruptedException {
  while (draining) {
    wait();
  }
  ++i;
  while (i < n && !draining) {
    wait();
  }
  if (i-- == n) {
    draining = true;
    notifyAll();
  }
  if (i == 0) {
    draining = false;
    notifyAll();
  }
}
```

Why do we distinguish between draining and non-draining?

Two-Phase Barrier

init

barrier

```
mutex=1; barrier1=0; barrier2=1; count=0

acquire(mutex)
  count++;
  if (count==n)
     acquire(barrier2); release(barrier1)
release(mutex)

acquire(barrier1); release(barrier1);
// barrier1 = 1 for all processes, barrier2 = 0 for all processes
acquire(mutex)
  count--;
  if (count==0)
      acquire(barrier1); release(barrier2)
signal(mutex)

acquire(barrier2); release(barrier2)
// barrier2 = 1 for all processes, barrier1 = 0 for all processes
```

Plan für heute

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Assignment 11

- Implement SortedList with different lock strategies
- Exercise about effective use of locks
  - Coarse grained vs. fine grained locks
  - Tricks to avoid locking altogether for certain operations
- Measure the performance impact of your implementation choice

SortedListInterface

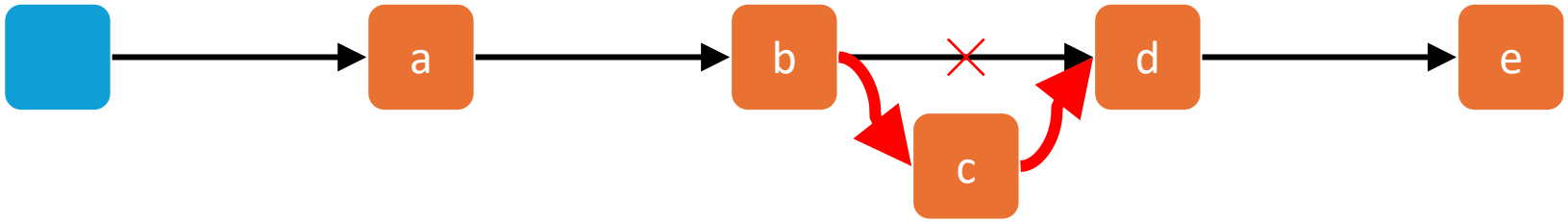
Add, Remove and Find unique elements in a **sorted linked list**.

```
add(c)
```

SortedListInterface

Add, Remove and Find unique elements in a **sorted linked list**.

`add(c)`



find b and d

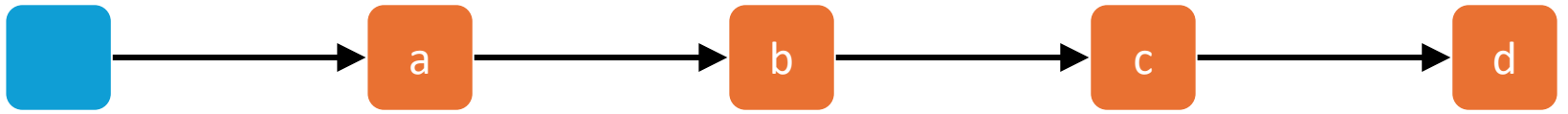
b.next=c

c.next=d

SortedListInterface

Add, Remove and Find unique elements in a **sorted linked list**.

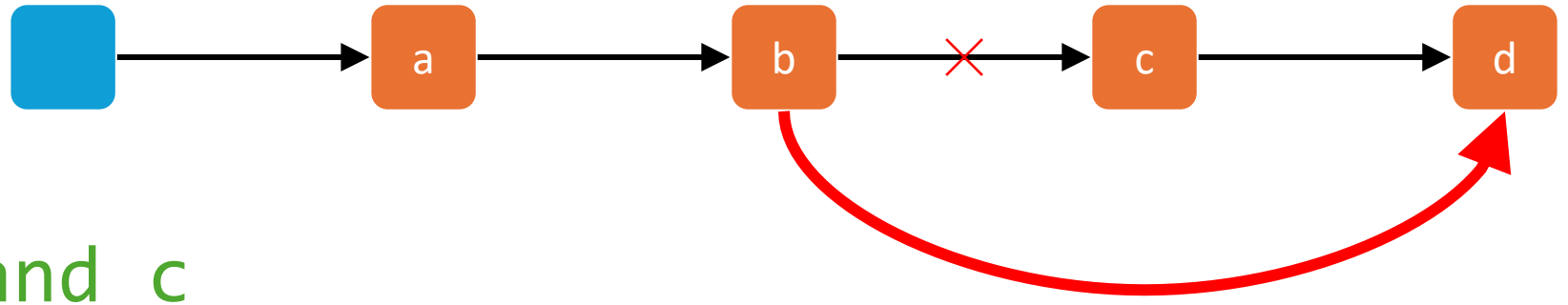
`remove(c)`



SortedListInterface

Add, Remove and Find unique elements in a **sorted linked list**.

`remove(c)`



`find b and c`

`b.next=c.next`

List and Node

```
public interface SortedListInterface<T extends Comparable<T>> {

      public boolean add (T item);
      public boolean remove (T item);
      public boolean contains (T item);

}
```

Make sure we can sort the entries in the list!

Implement those methods in a thread-safe way

Implementation tipps

- Keep an abstract Node to store list element:

```
private class Node {
        public Node next ;
        public T item;
}
```

- Code is simpler if we always have two **sentinel nodes** in the list:

```
public SequentialList() {
        first = new Node(Integer.MIN_VALUE);
        first.next = new Node(Integer.MAX_VALUE);
}
```

Coarse Grained Locking

```
public synchronized boolean add(T x) {...};
public synchronized boolean remove(T x) {...};
public synchronized boolean contains(T x) {...};
```

add(c)

Coarse Grained Locking

```
public synchronized boolean add(T x) {...};
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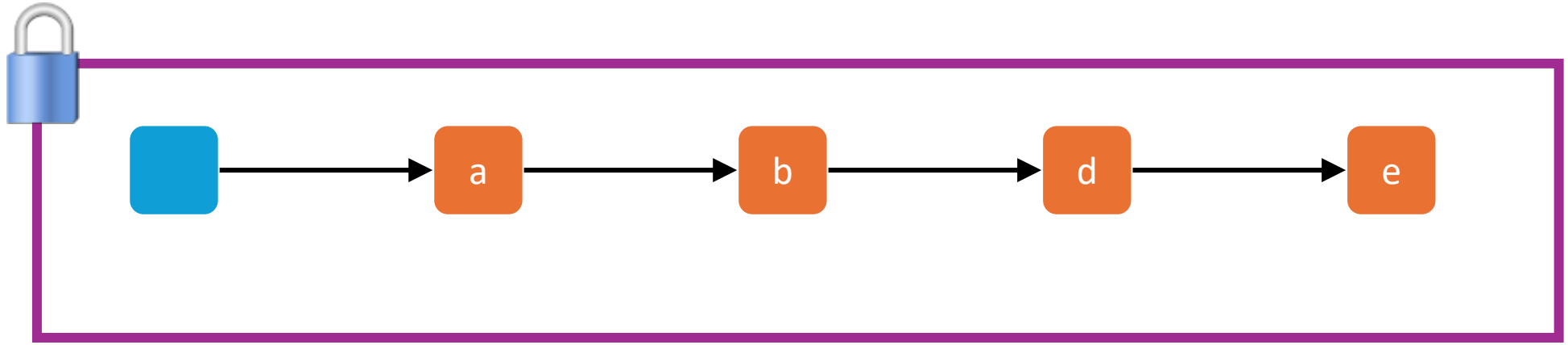

Coarse Grained Locking

```
public synchronized boolean add(T x) {...};
public synchronized boolean remove(T x) {...};
public synchronized boolean contains(T x) {...};
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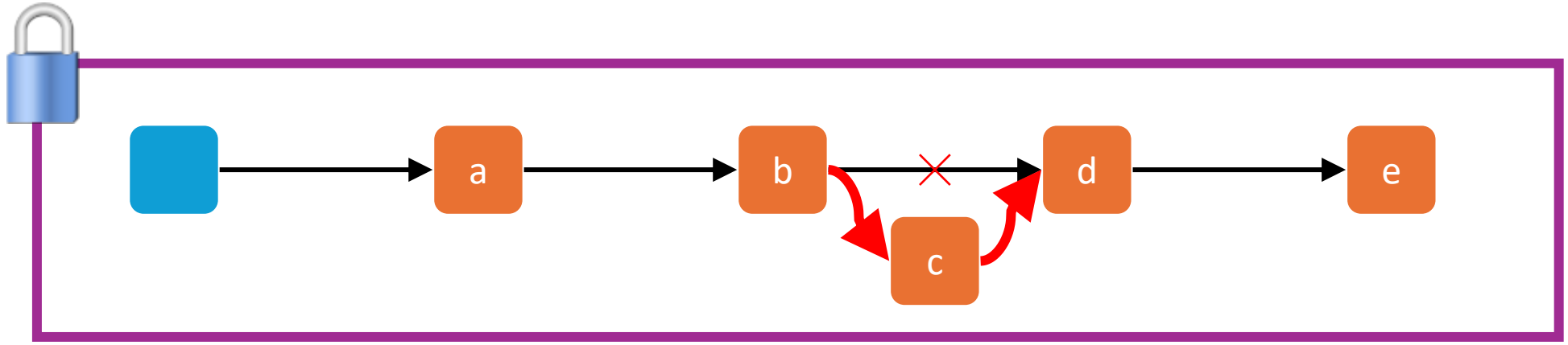


Simple, but a bottleneck for many threads, why?

Fine grained Locking

Often more intricate than visible at a first sight

- requires careful consideration of special cases

Idea: split object into pieces with separate locks

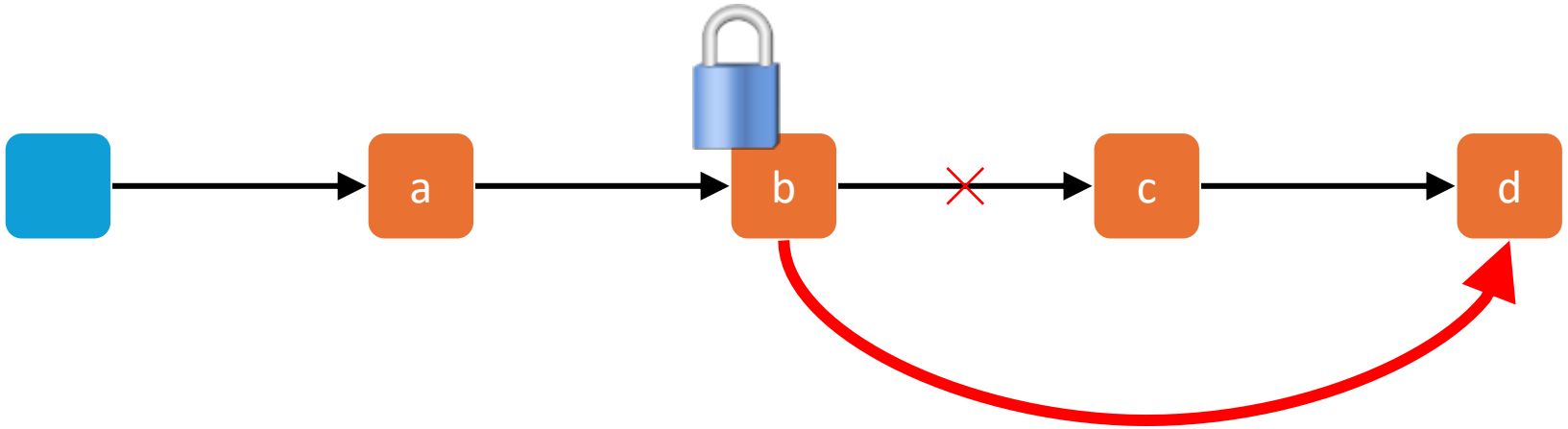
- no mutual exclusion for algorithms on disjoint pieces

Let's try this

`remove(c)`

Let's try this

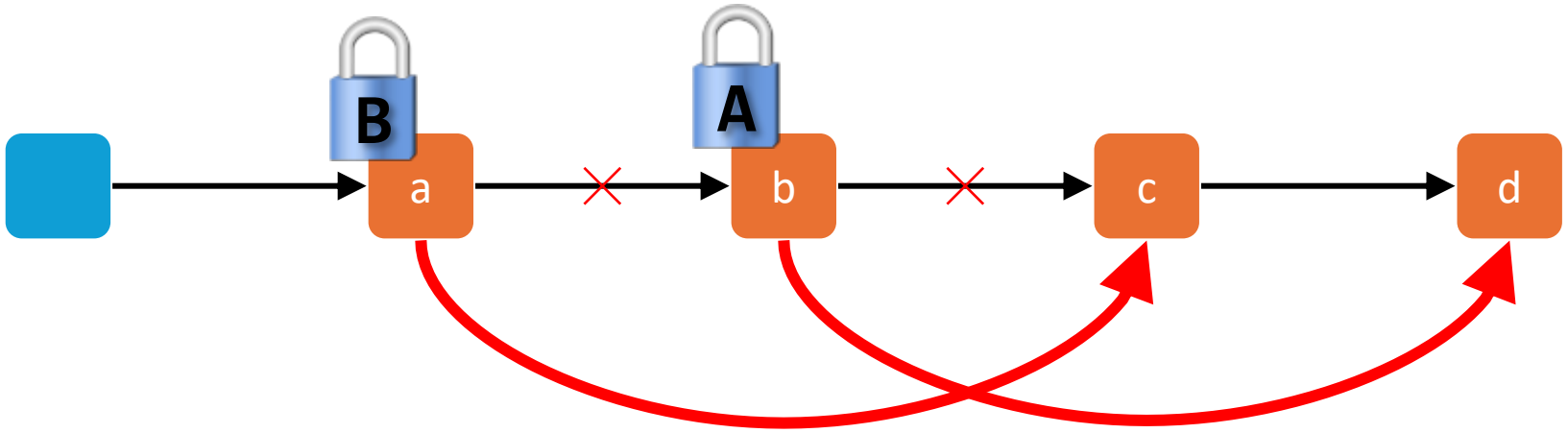
`remove(c)`



`Locking the predecessor is ok?`

Let's try this

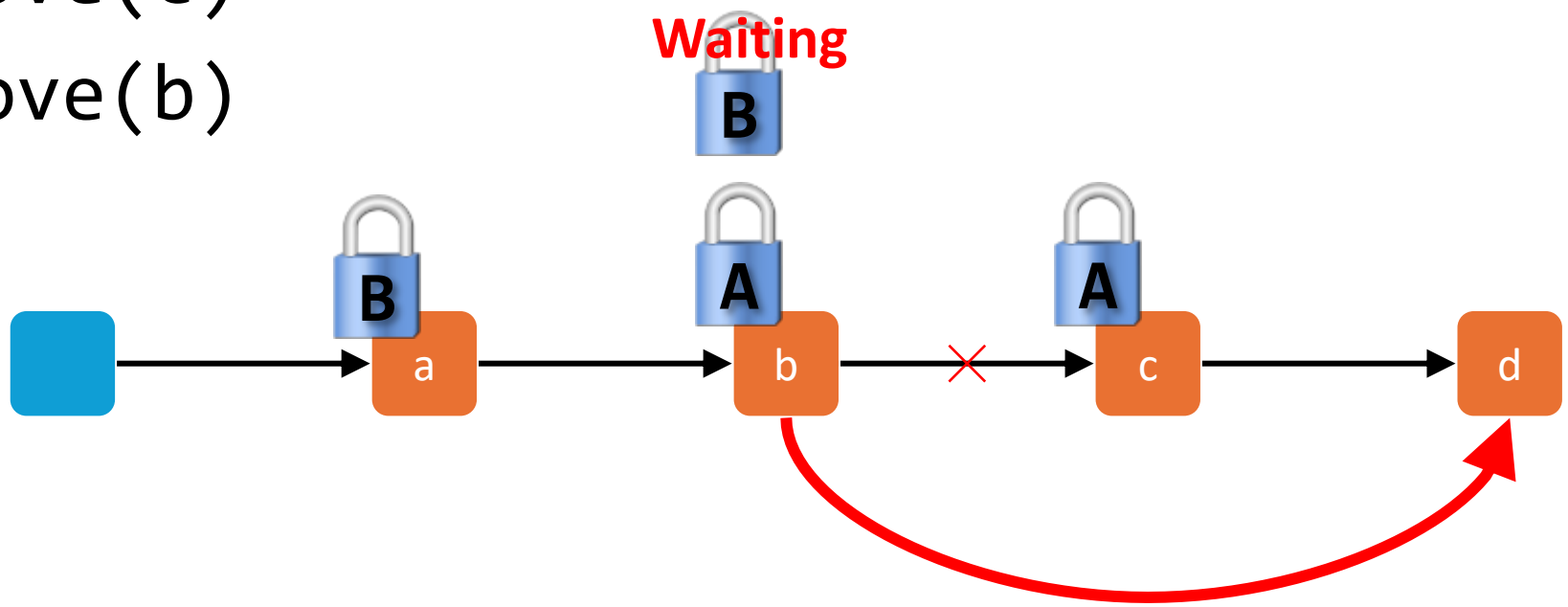
```
A: remove(c)
B: remove(b)
```



c not deleted!

Let's try this

```
A: remove(c)
B: remove(b)
```

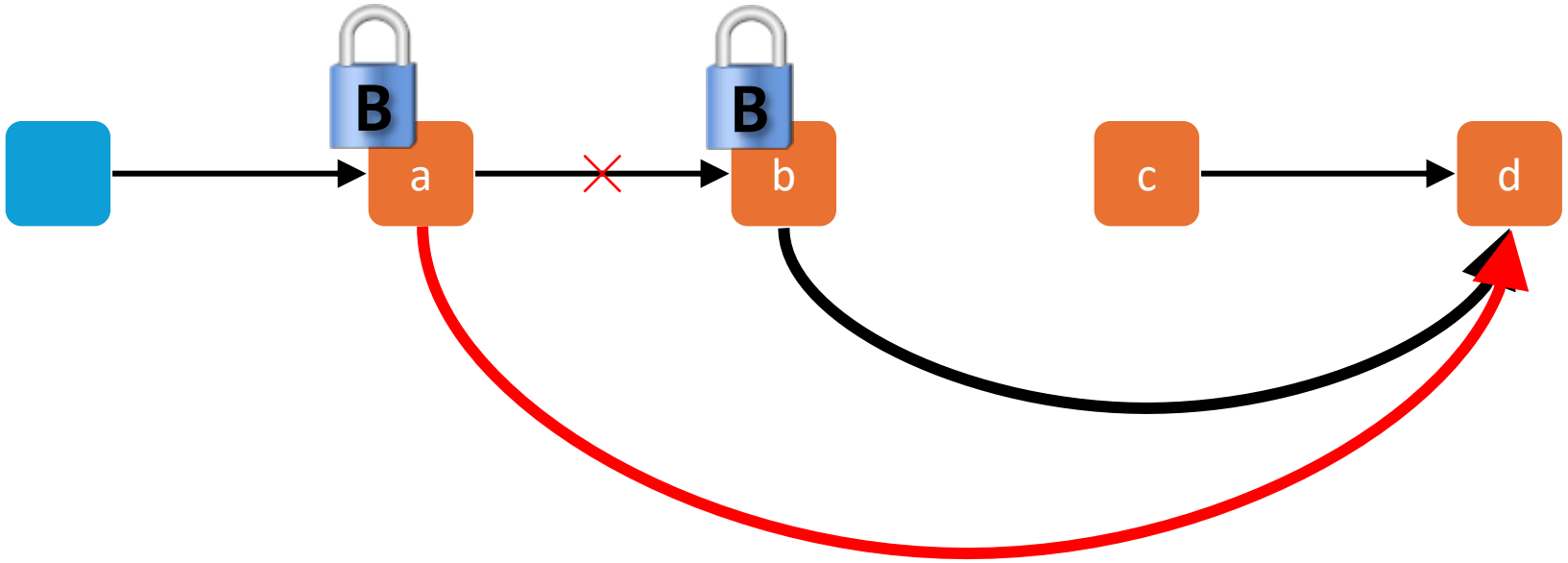


- c not deleted!

When removing, lock the **successor** defensively.

Let's try this

```
A: remove(c)
B: remove(b)
```



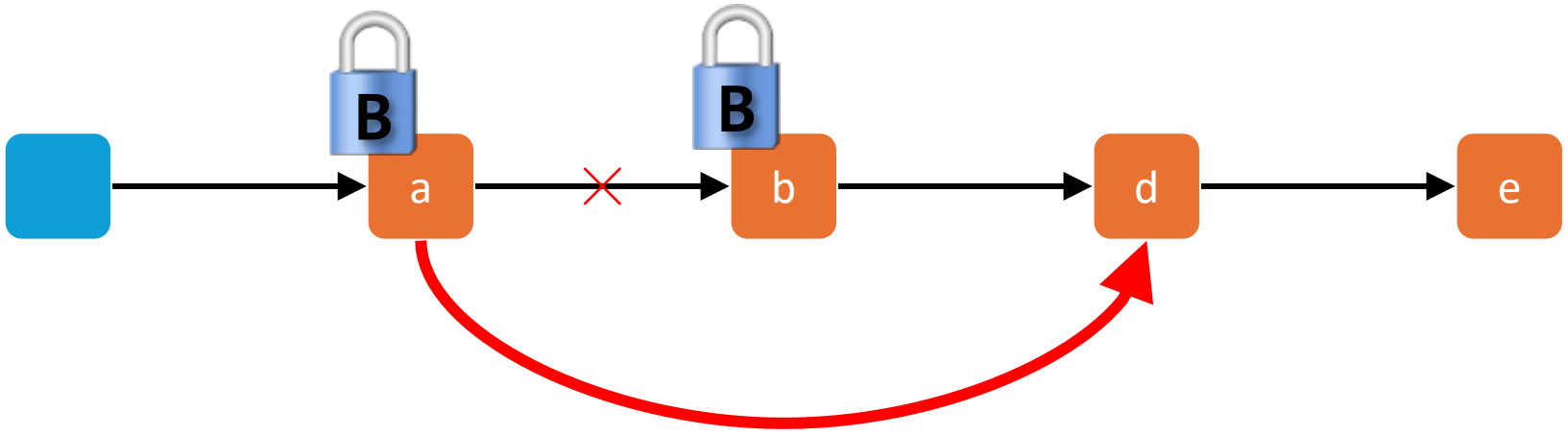
- c not deleted!

When removing, lock the **successor** defensively.

What's the problem?

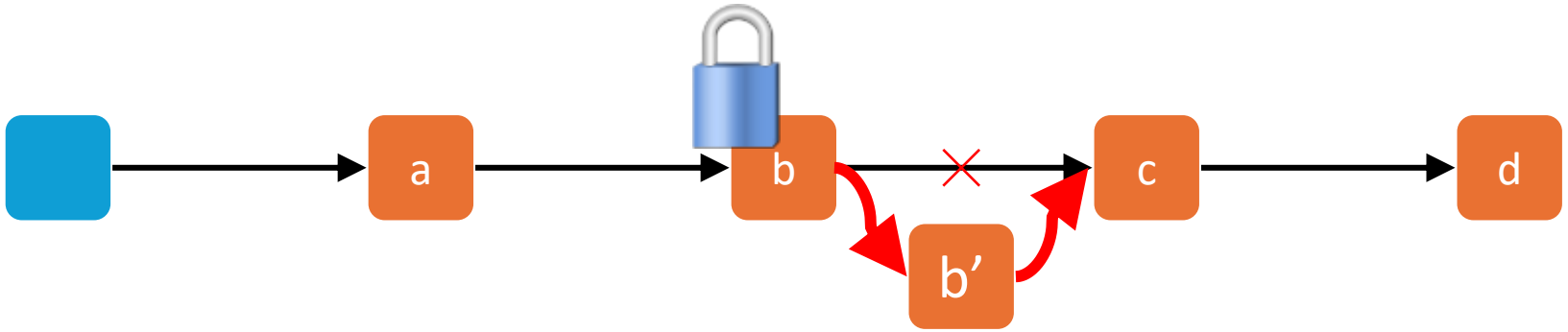
When deleting, the next field of next is read, i.e. next also has to be protected.

```
find a and b
a.next=b.next
```



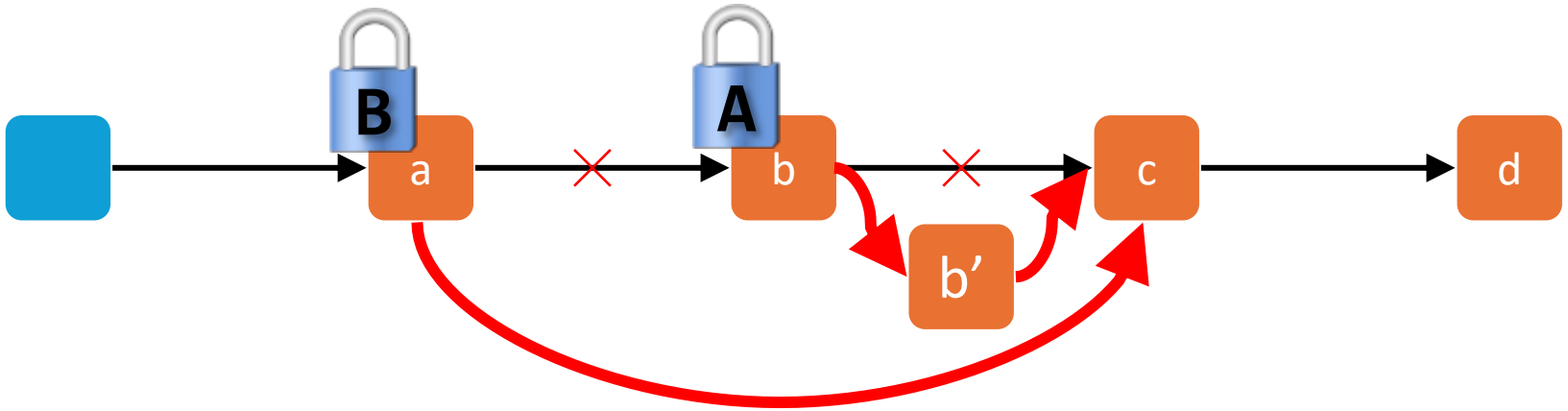
What about add?

```
add(b’)
```



What about add?

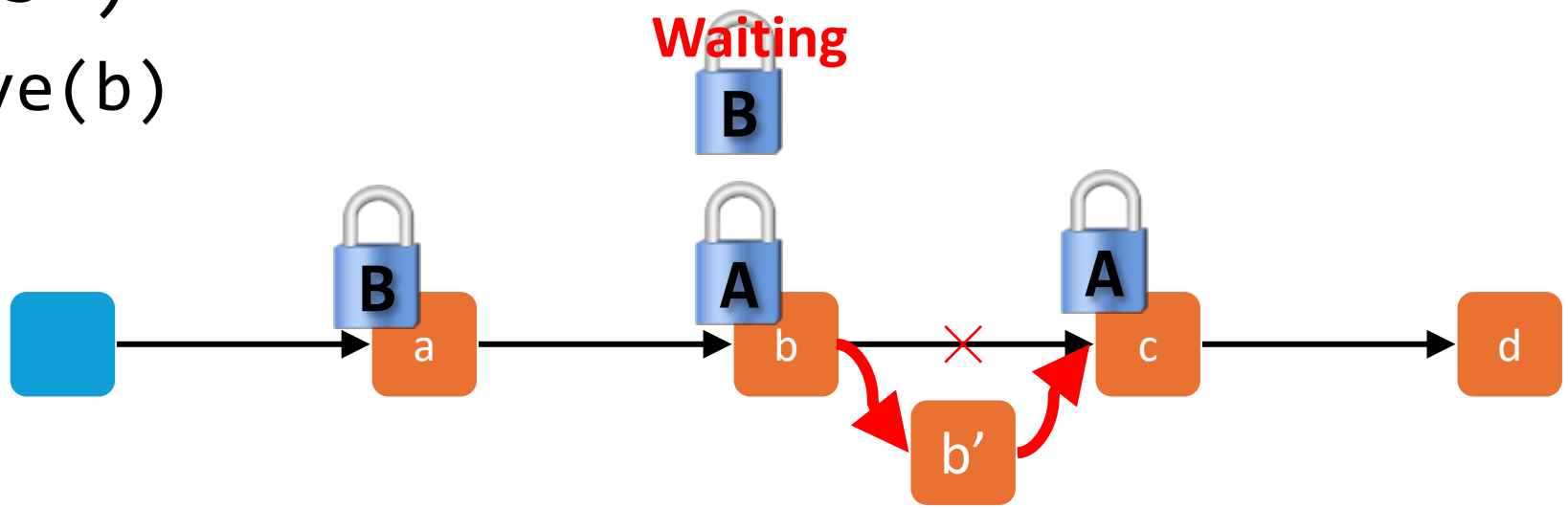
```
A: add(b’)
B: remove(b)
```



- b’ not added!

What about add?

```
A: add(b’)
B: remove(b)
```

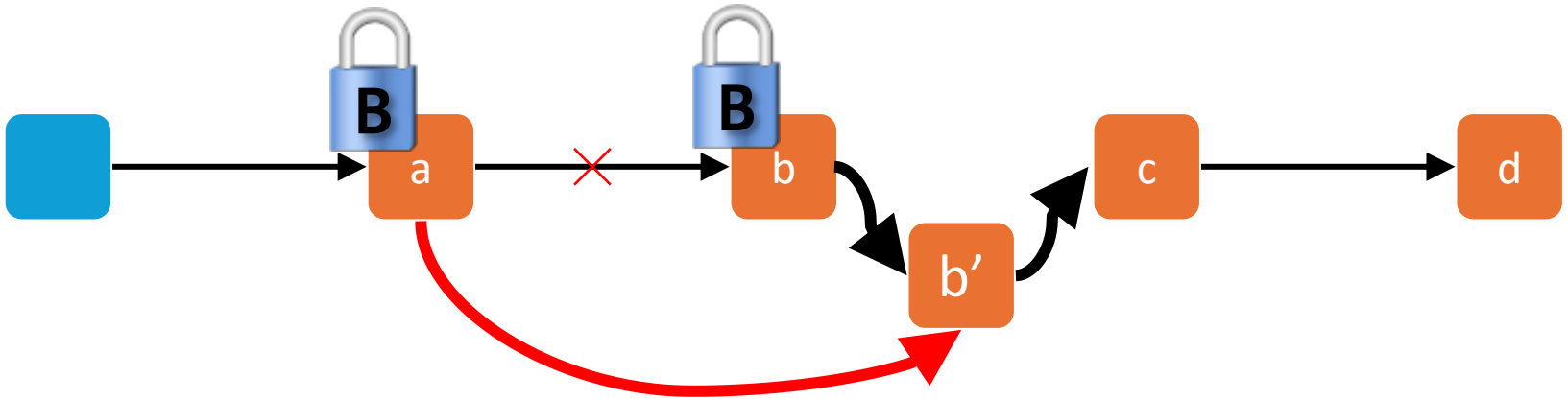


- b’ not added!

- To fix this lock the **successor** defensively as in the remove case

What about add?

```
A: add(b’)
B: remove(b)
```

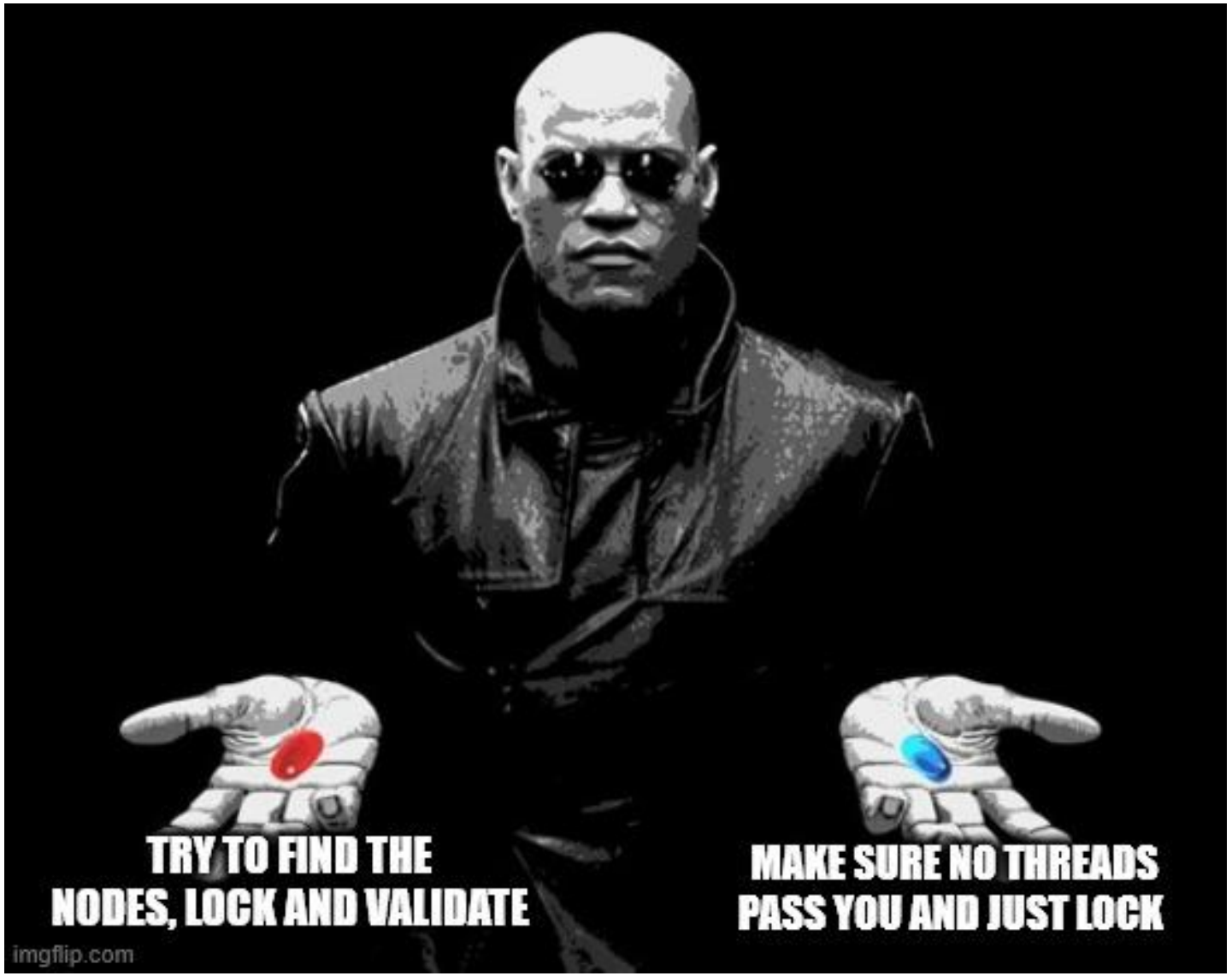


- b’ not added!

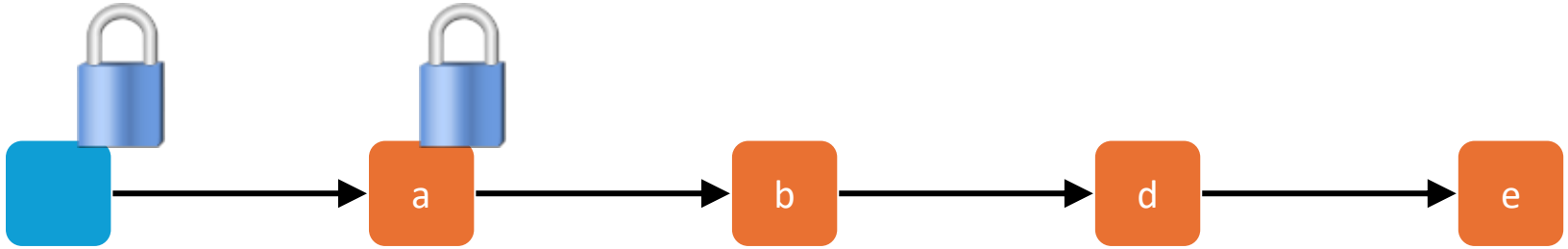
- Solution: lock the **successor** defensively.

The choice

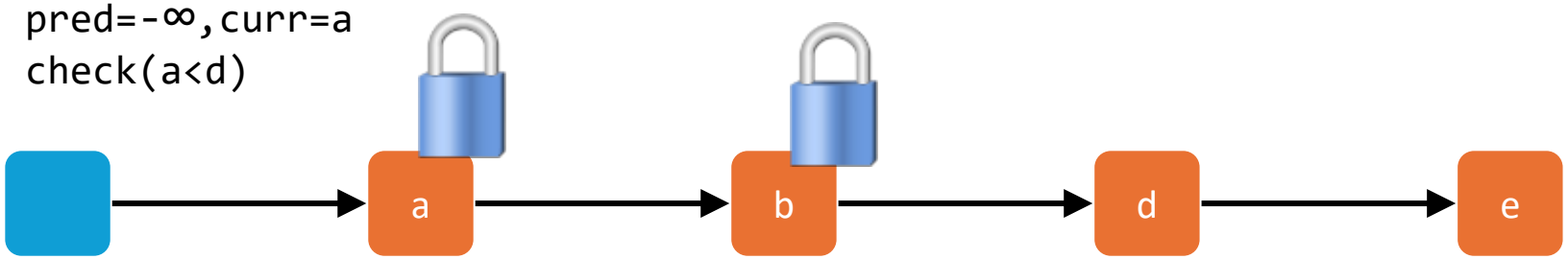
- How do we get to the data we need to work on?



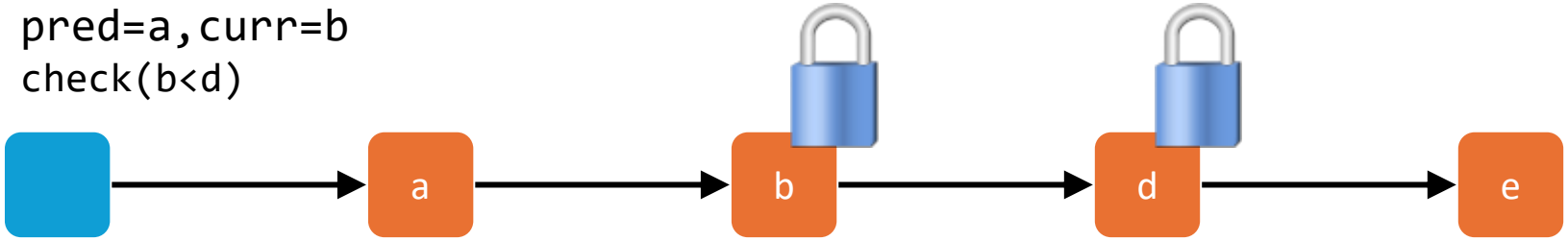
Hand-over-hand locking (remove d)



pred=-∞,curr=a
check(a<d)

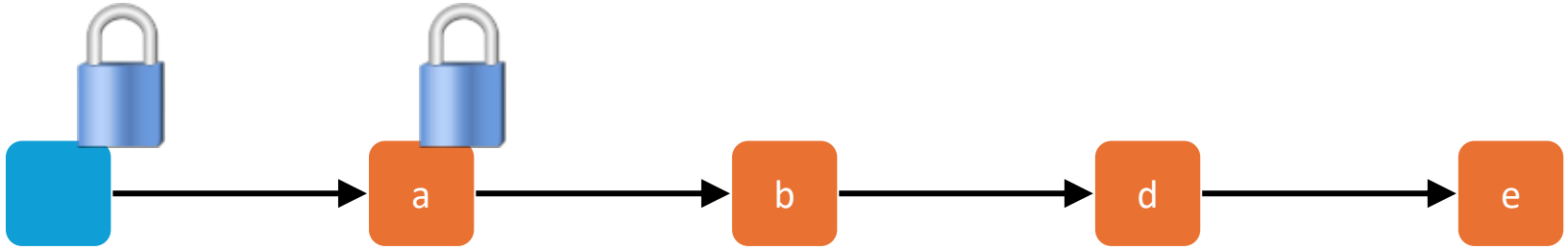


pred=a,curr=b
check(b<d)



pred=b,curr=d
check(d<d)
if(d==d)
  remove(d)

Hand-over-hand locking (remove d)



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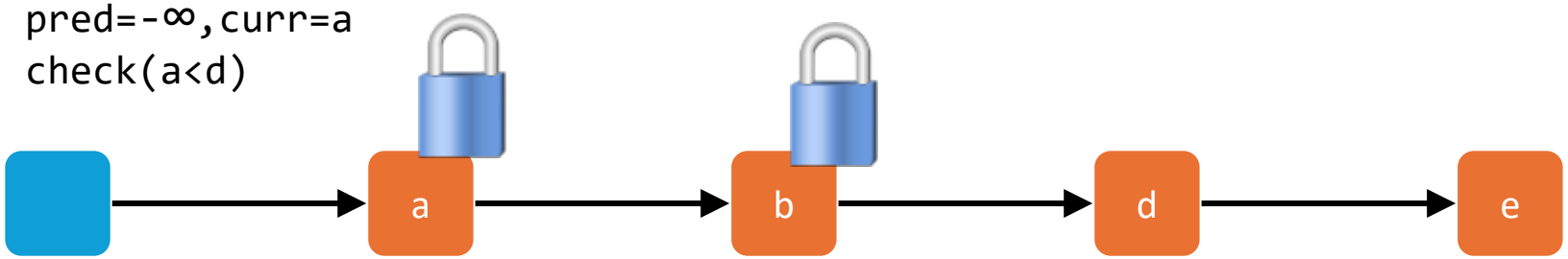

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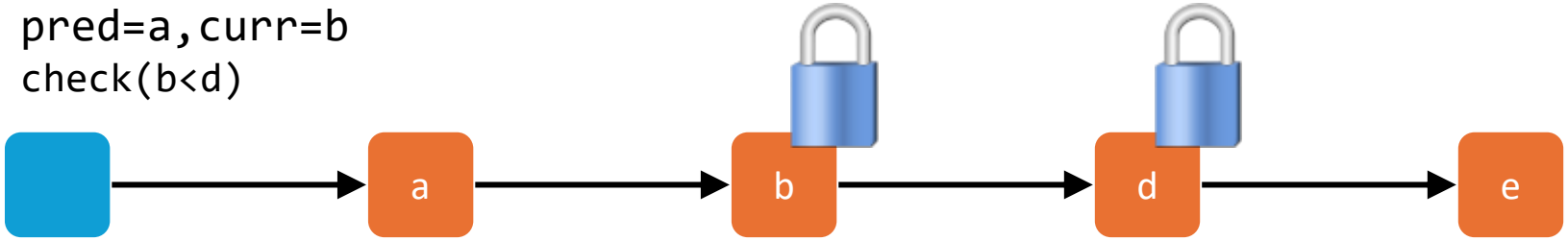


pred=b,curr=d
check(d<d)
if(d==d)
  remove(d)

What about add(c) and contains(e)?

Hand-over-hand locking

Benefits:

- Multiple readers and writers can be actively doing work in the same list.
- Readers and writers that are traversing the list in the same order will not pass each other.
- The locks taken on parts of the list won't deadlock with each other, because multiple locks are acquired **in the same order**.

Hand-over-hand locking

But what's bad?

- We can have "traffic jam", Threads can't overtake each other
- O(n) locks acquired/released => Big Overhead!

Optimistic Synchronization

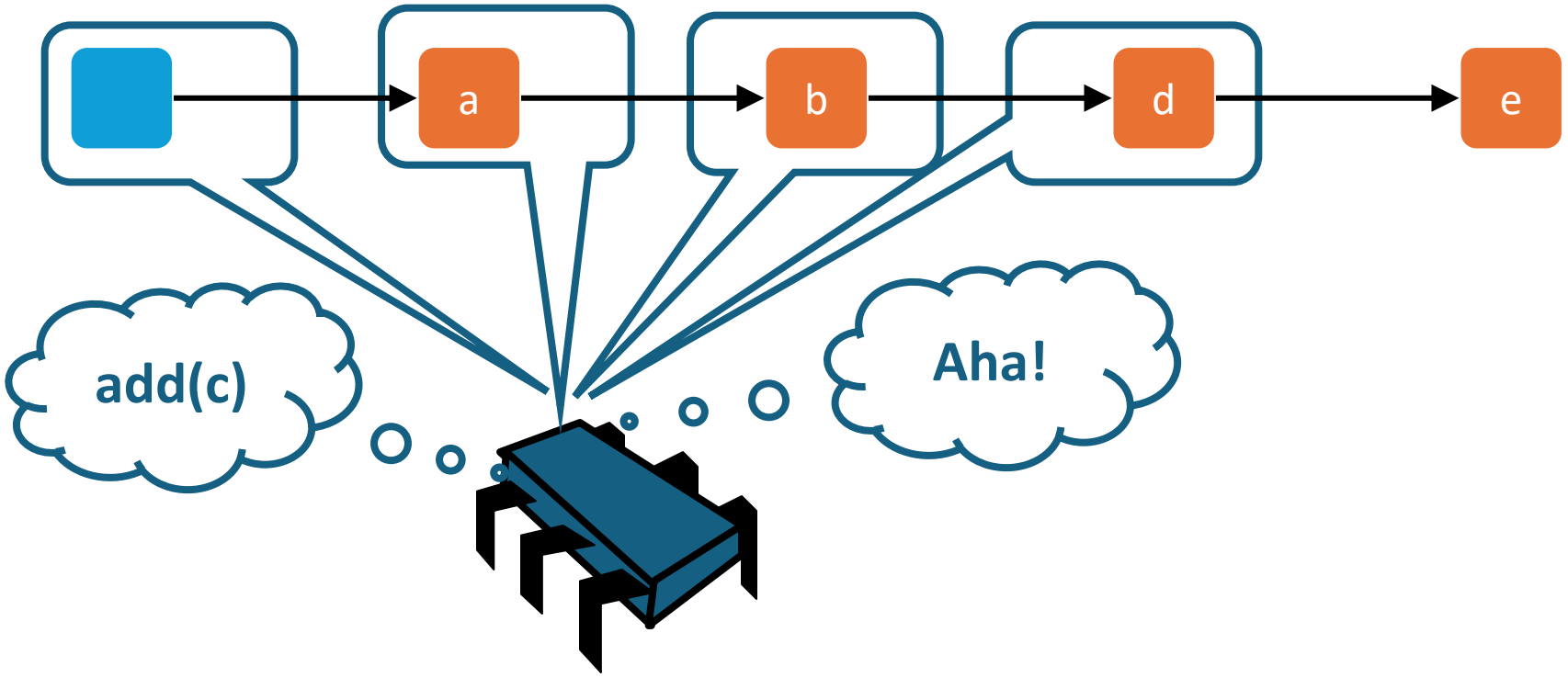
Idea

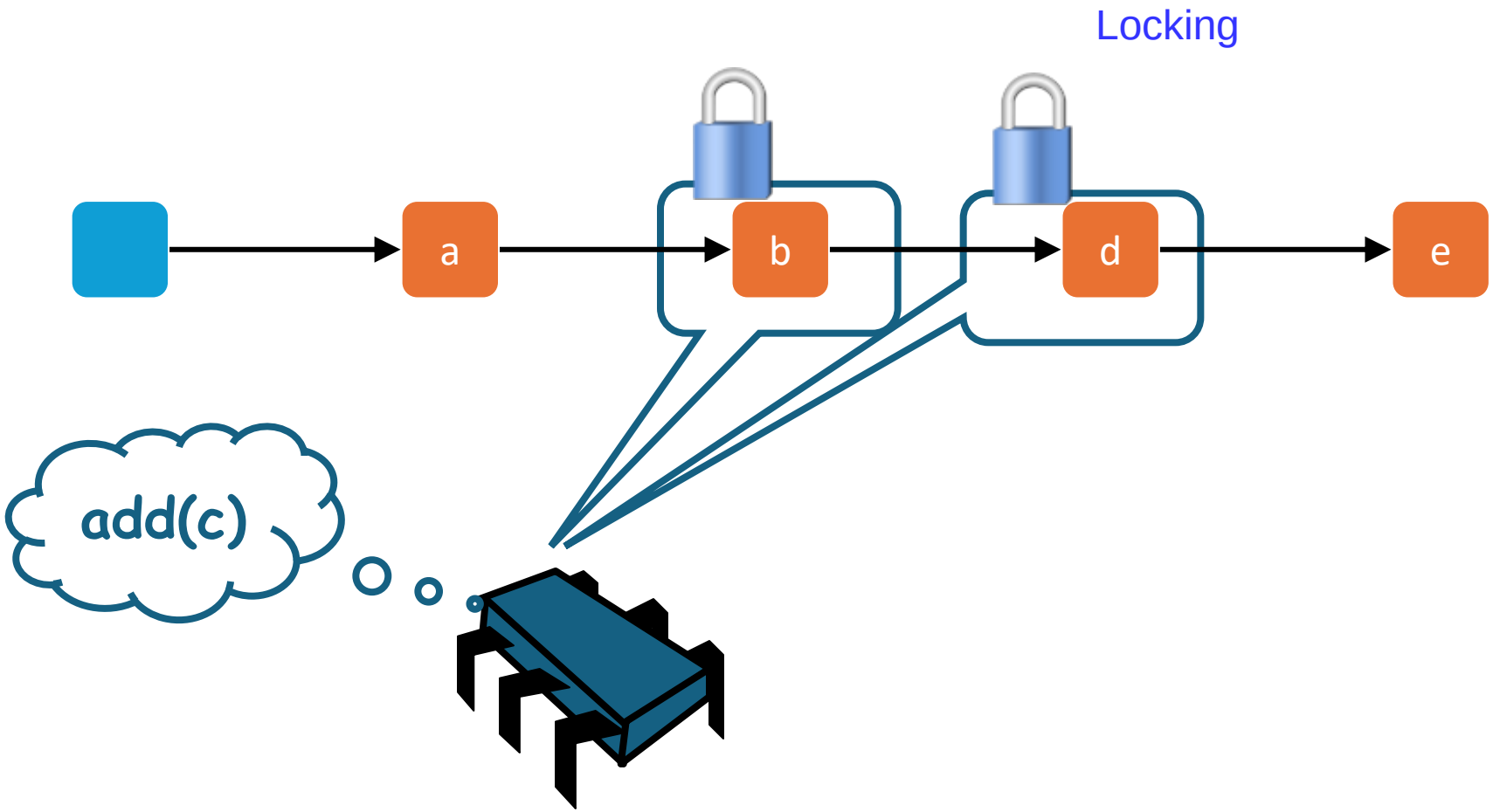
Algorithm:

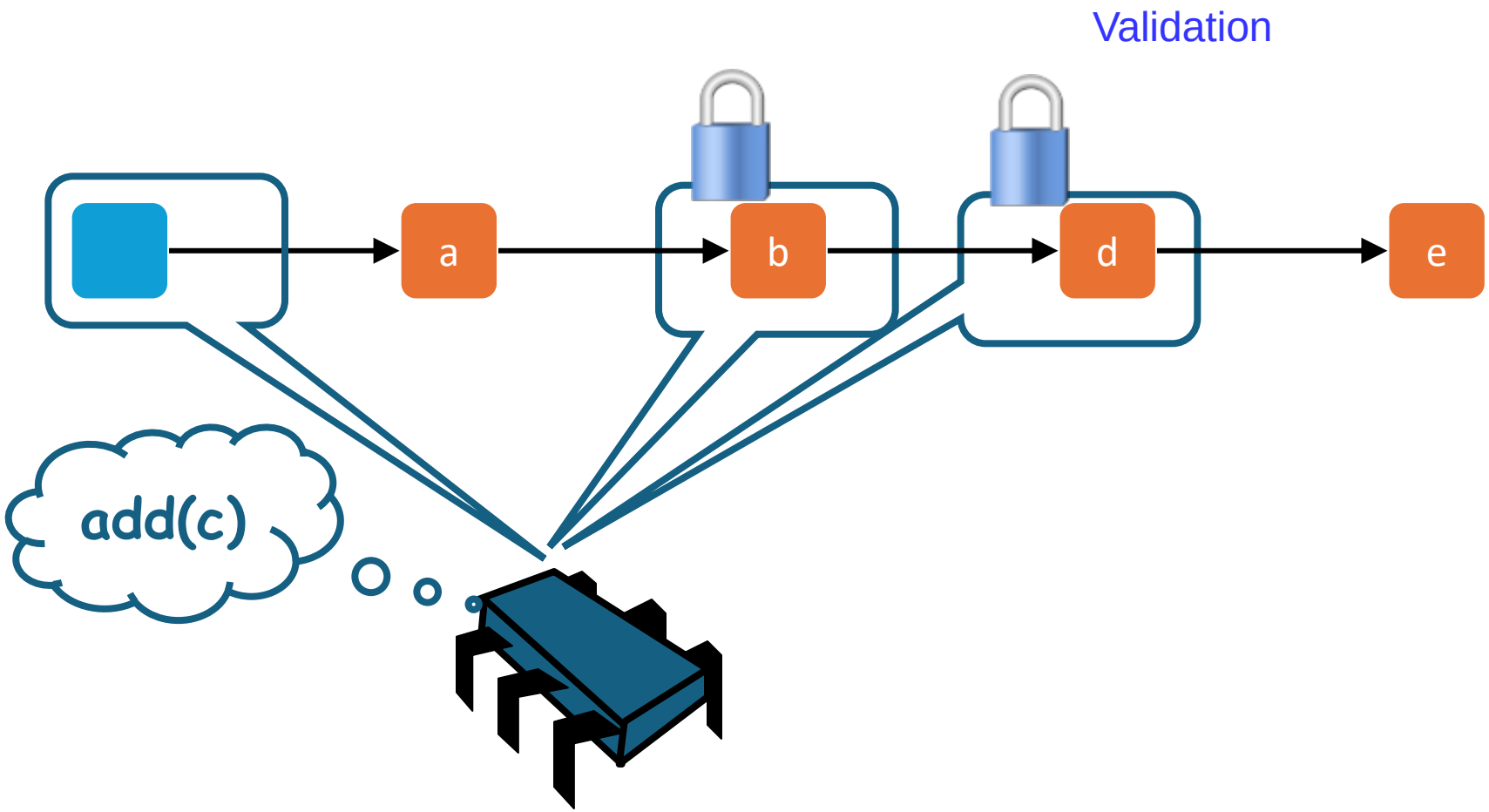
- find nodes without locking,
- then lock the two nodes and
- check that everything is ok (**validation**)
    - if so perform the operation (add, remove or contains) and return true
    - if not return false
- finally release the two locks

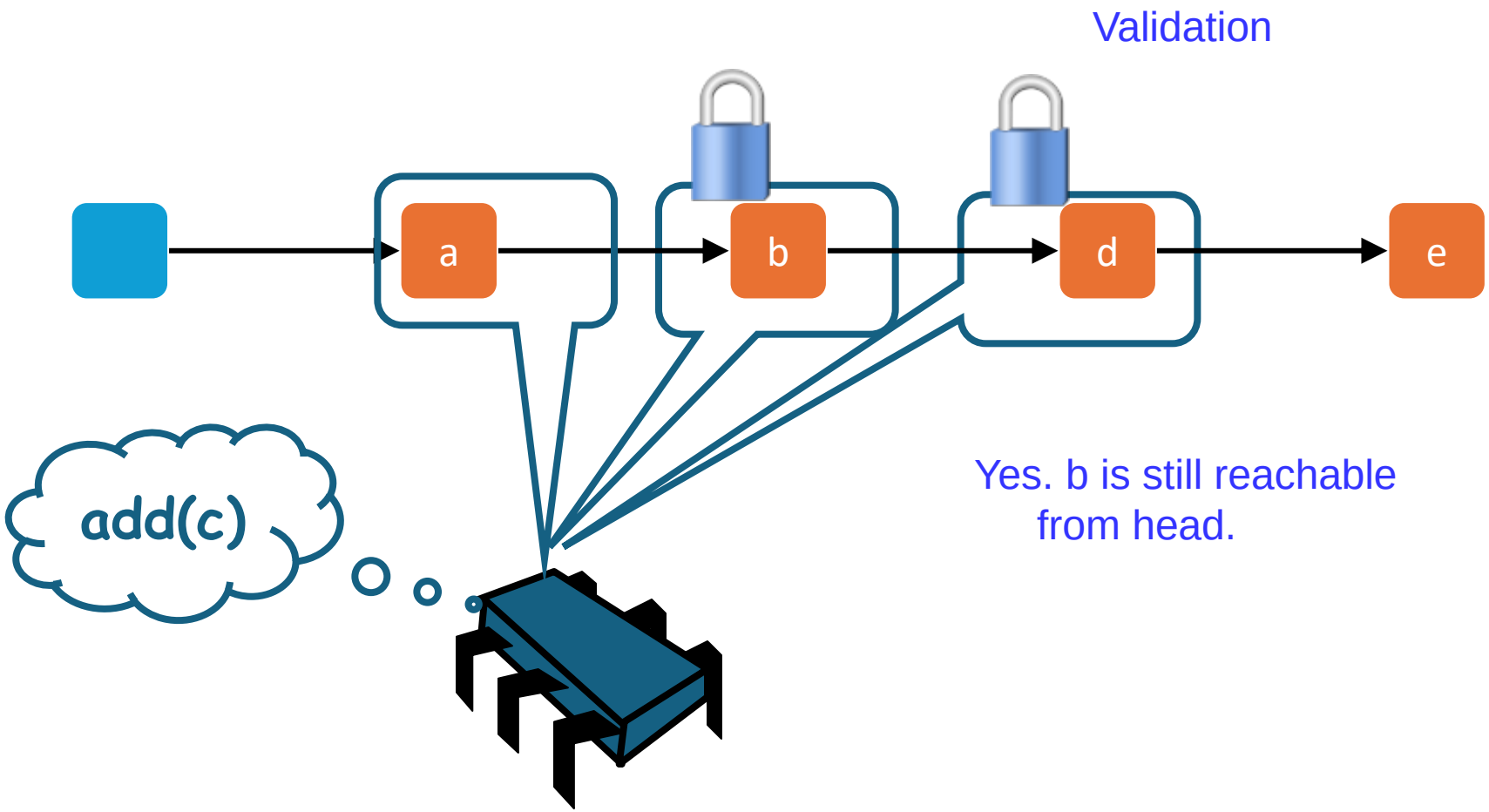
`e.g. add(c)`

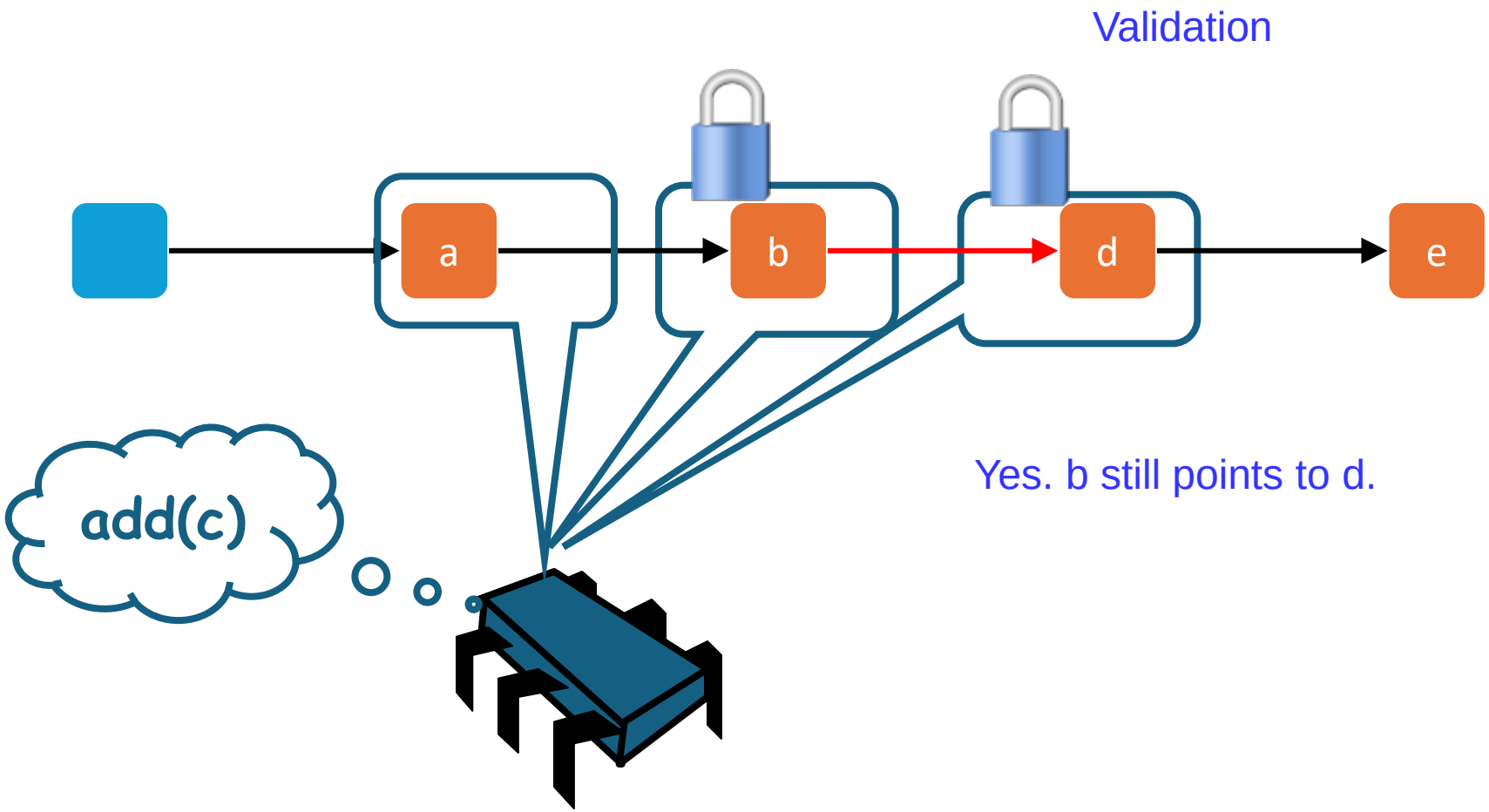
Finding without locking

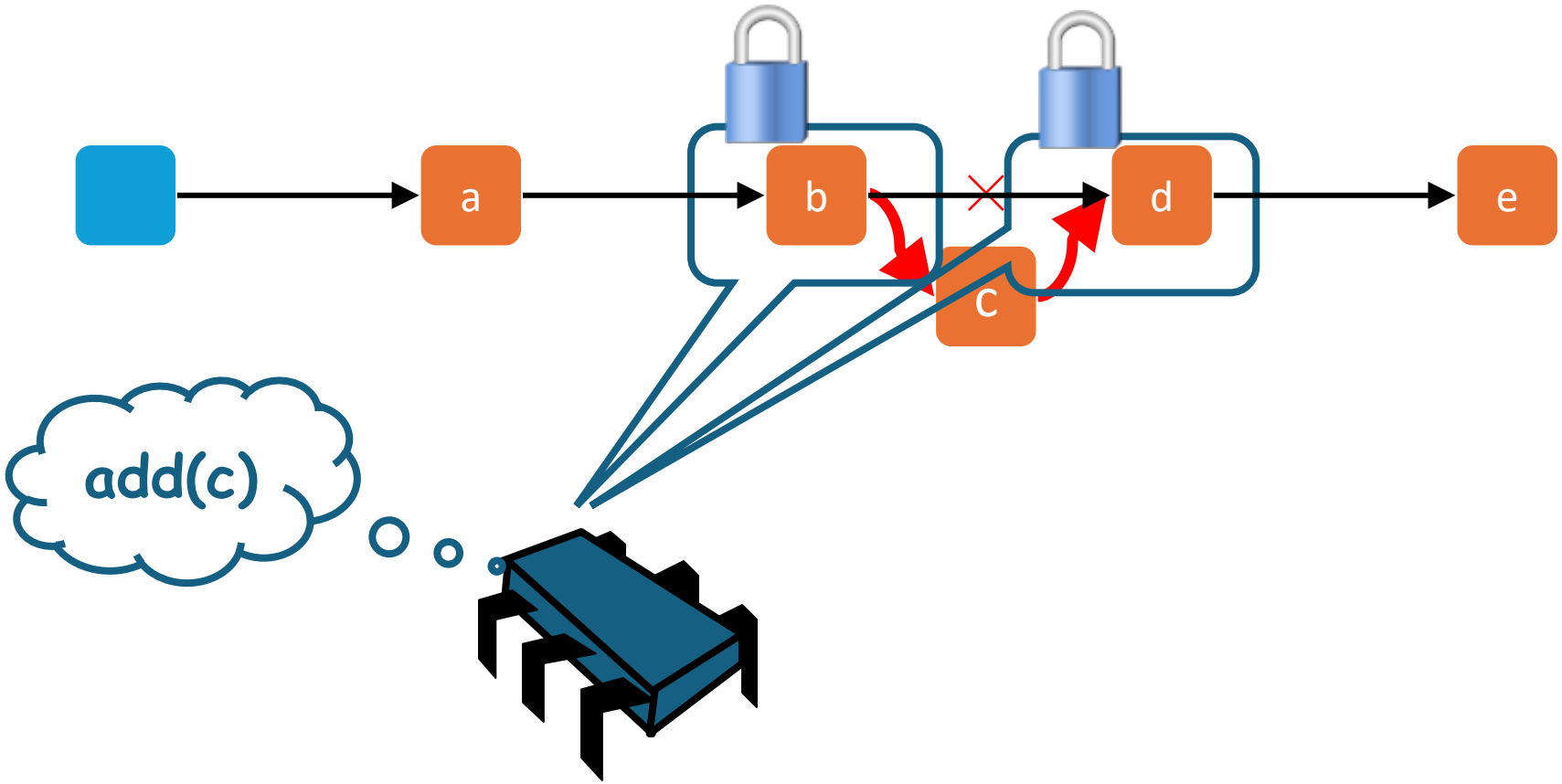


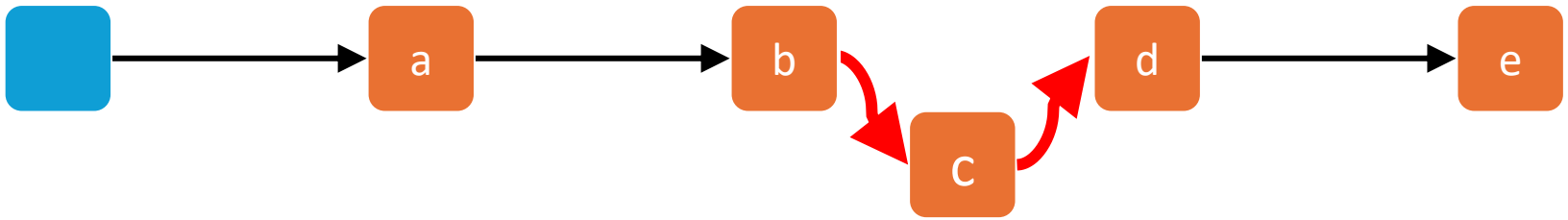

Locking
a
b
d
e
add(c)

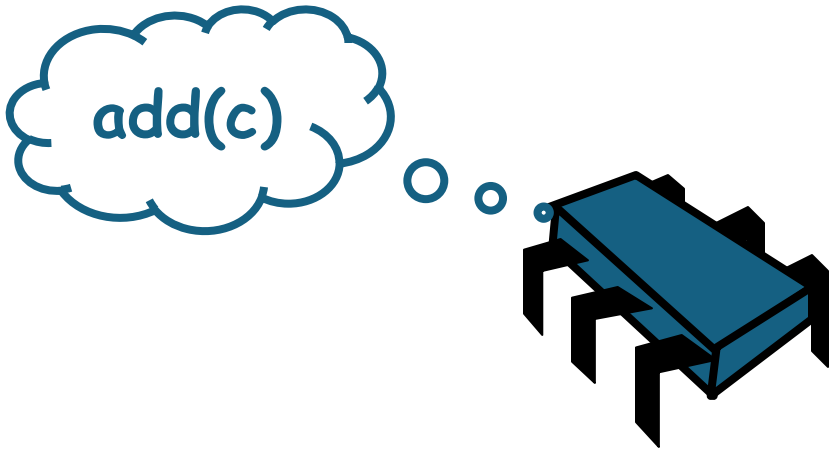

Validation
a
b
d
e
add(c)


Validation
a
b
d
e
add(c)
Yes. b is still reachable
from head.


Validation
a
b
d
e
add(c)
Yes. b still points to d.


a
b
c
d
e
add(c)


a
b
c
d
e

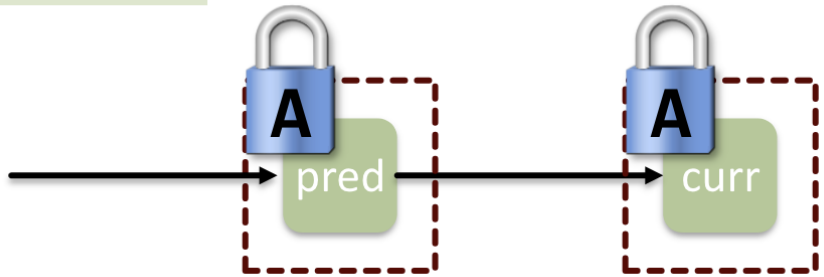

add(c)

Validation: what can go wrong?

Why do we even need validation?

Validate - summary

```
private Boolean validate(Node pred, Node curr) {
   Node node = head;
   while (node.key <= pred.key) { // reachable?
       if (node == pred)
             return pred.next == curr; // connected?
       node = node.next;
   }
   return false;
}
```



Validation: what can go wrong?

Remove case

A: add(c)

A: find insertion point

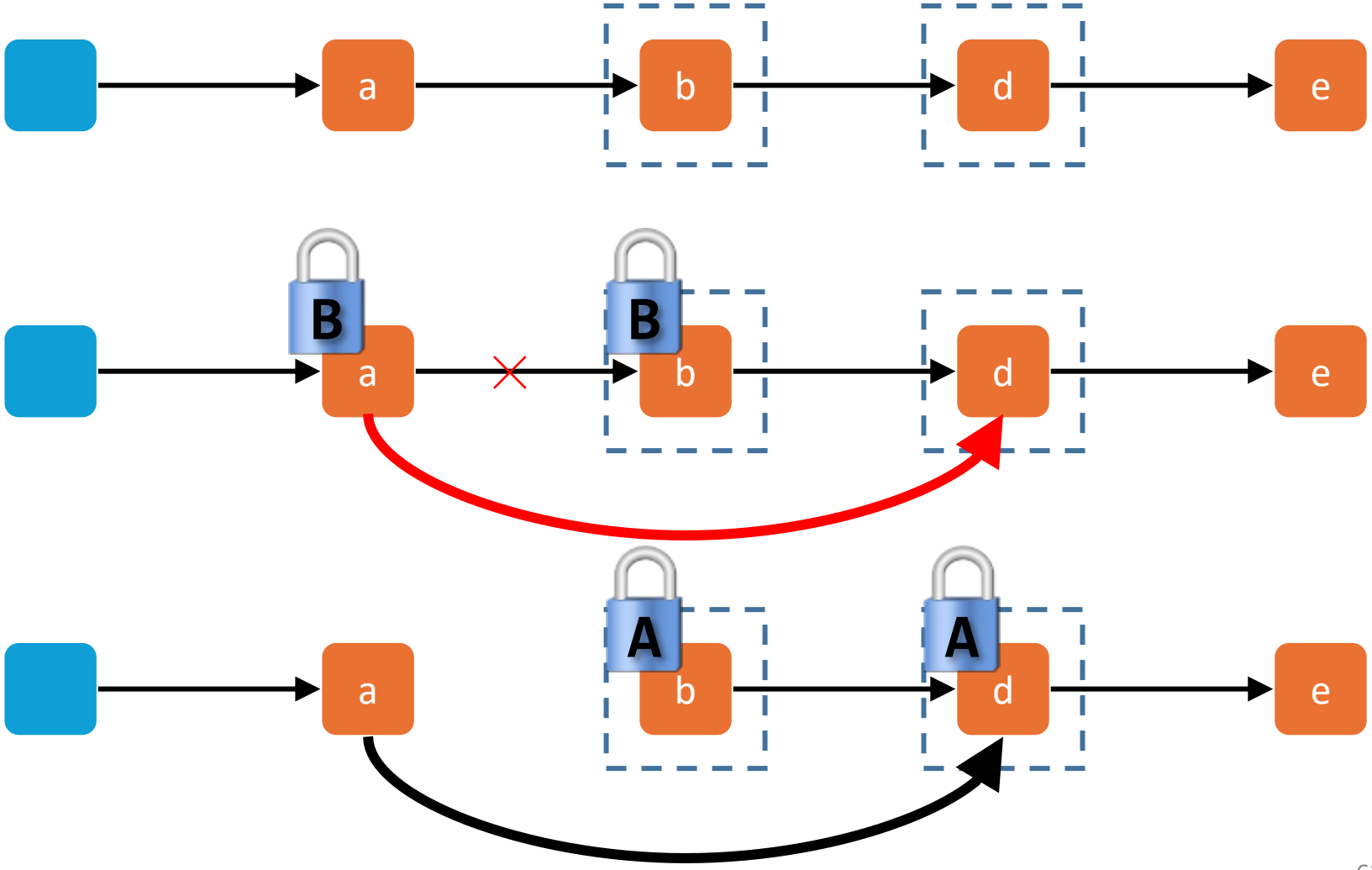
B: remove(b)

A: lock

A: validate: rescan

A: b not reachable

→return false

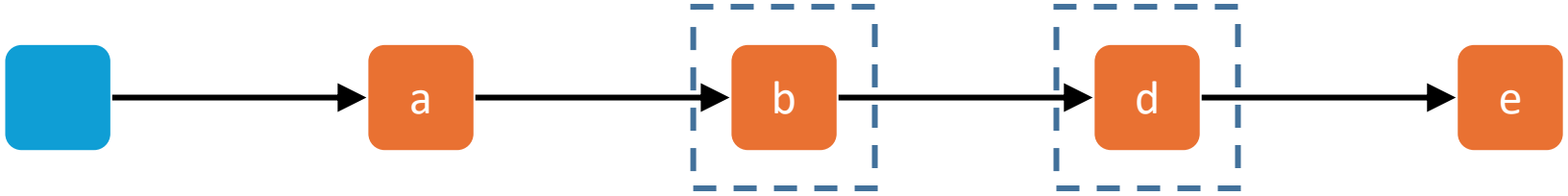


Validation: what can go wrong?

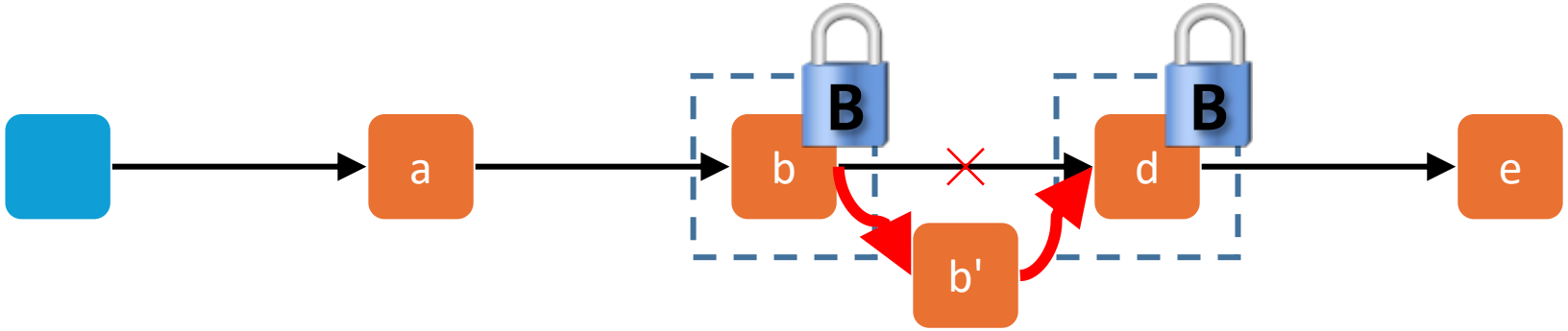
Insert case

A: add(c)

A: find insertion point



B: insert(b')

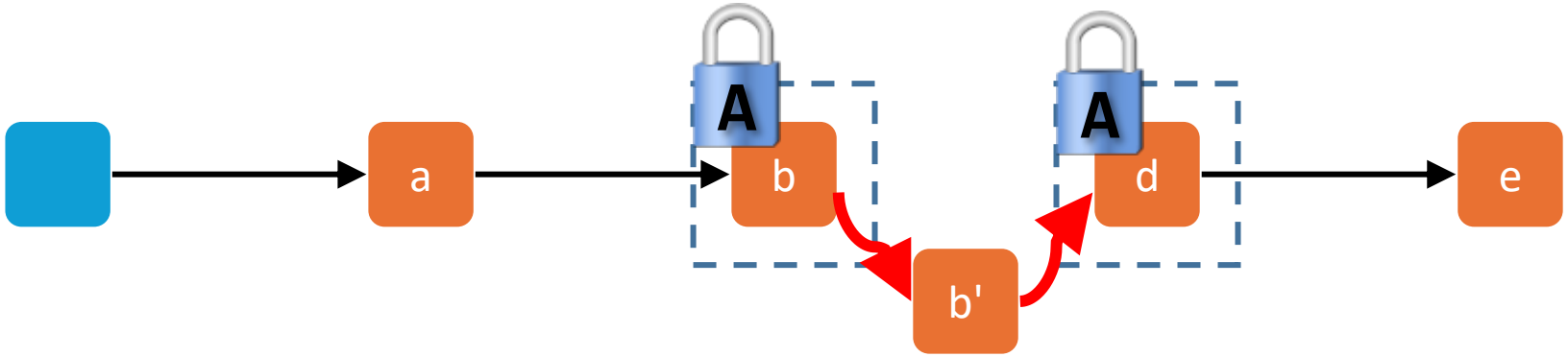


A: lock

A: validate: rescan

A: d != succ(b)

→return false



Optimistic Locking

```
@Override
public boolean add(T item) {
    int key = item.hashCode();
    while (true) {
        Node pred = this.head;
        Node curr = pred.next;
        while (curr.key < key) {
            pred = curr;
            curr = curr.next;
        }
        pred.lock();
        curr.lock();
        try {
            if (validate(pred, curr)) {
                if (curr.key == key) { // present
                    return false;
                } else { // not present
                    Node entry = new Node(item);
                    entry.next = curr;
                    pred.next = entry;
                    return true;
                }
            }
        } finally {
            pred.unlock();
            curr.unlock();
        }
    }
}
```

```
@Override
public boolean remove(T item) {
    int key = item.hashCode();
    while (true) {
        Node pred = this.head;
        Node curr = pred.next;
        while (curr.key < key) {
            pred = curr;
            curr = curr.next;
        }
        pred.lock();
        curr.lock();
        try {
            if (validate(pred, curr)) {
                if (curr.key == key) {
                    pred.next = curr.next;
                    return true;
                } else {
                    return false;
                }
            }
        } finally {
            pred.unlock();
            curr.unlock();
        }
    }
}
```

```
@Override
public boolean contains(T item) {
    int key = item.hashCode();
    while (true) {
        Node pred = this.head;
        Node curr = pred.next;
        while (curr.key < key) {
            pred = curr;
            curr = curr.next;
        }
        try {
            pred.lock();
            //curr.lock();
            if (validate(pred, curr)) {
                return (curr.key == key);
            }
        } finally {
            pred.unlock();
            //curr.unlock();
        }
    }
}
```

```
private boolean validate(Node pred, Node curr) {
    Node entry = head;
    while (entry.key <= pred.key) {
        if (entry == pred)
            return pred.next == curr;
        entry = entry.next;
    }
    return false;
}
```

Optimistic List

Good:

No contention on traversals.

Traversals are wait-free.

Less lock acquisitions.

Bad:

Need to traverse list twice (find + validate)

contains() method needs to acquire locks

Teaching Awards

- Ich wäre dankbar, wenn ihr für mich abstimmen könntet!

Lazy Synchronisation

Lazy List

Like optimistic list but

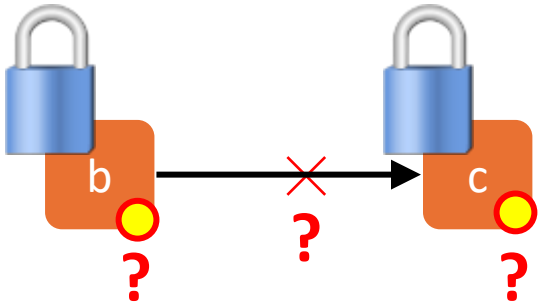
- scan only once
- contains() never locks

How?

- Removing nodes causes trouble
- do it "lazily”
- add a special **”removed?” flag** to the nodes

New Validate

- Given two locked nodes
- Pred is not marked
- Curr is not marked
- Pred points to Curr



Lazy List: Remove

Find nodes to remove (as before)

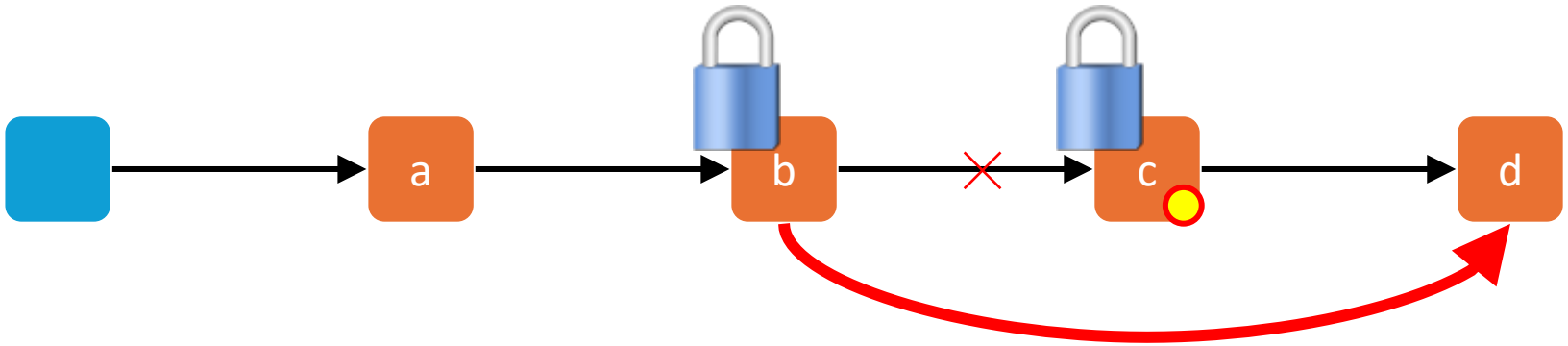
Lock predecessor and current (as before)

Validate (new validation)

Logical delete: mark current node as removed

Physical delete: redirect predecessor's next

e.g. remove(c)



Lazy List: Remove

Find nodes to remove (as before)

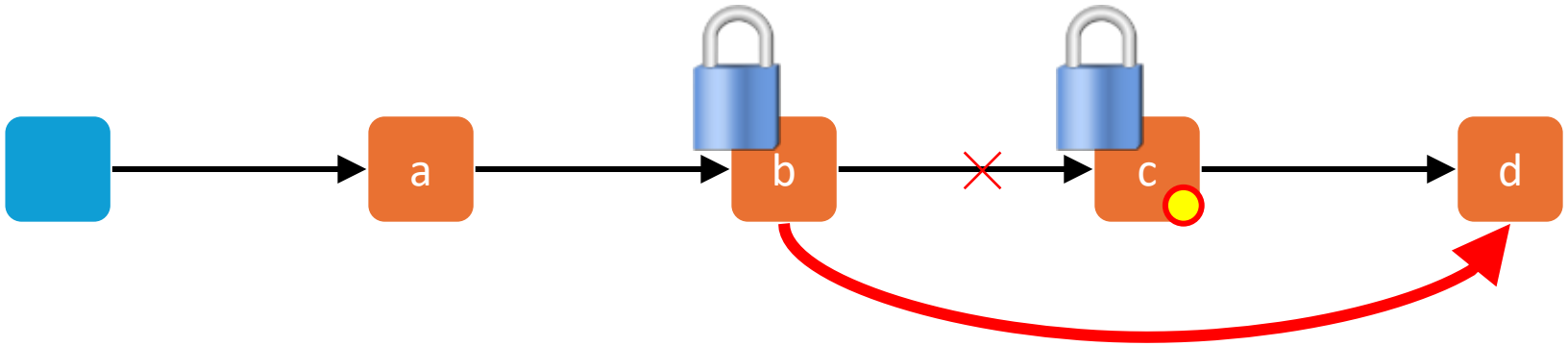
Lock predecessor and current (as before)

Validate (new validation)

Logical delete: mark current node as removed volatile?

Physical delete: redirect predecessor's next

e.g. remove(c)



Invariant

If a node is not marked then

- it is reachable from head
- and reachable from its predecessor

Only check if nodes are adjacent. Why?

A: remove(c)

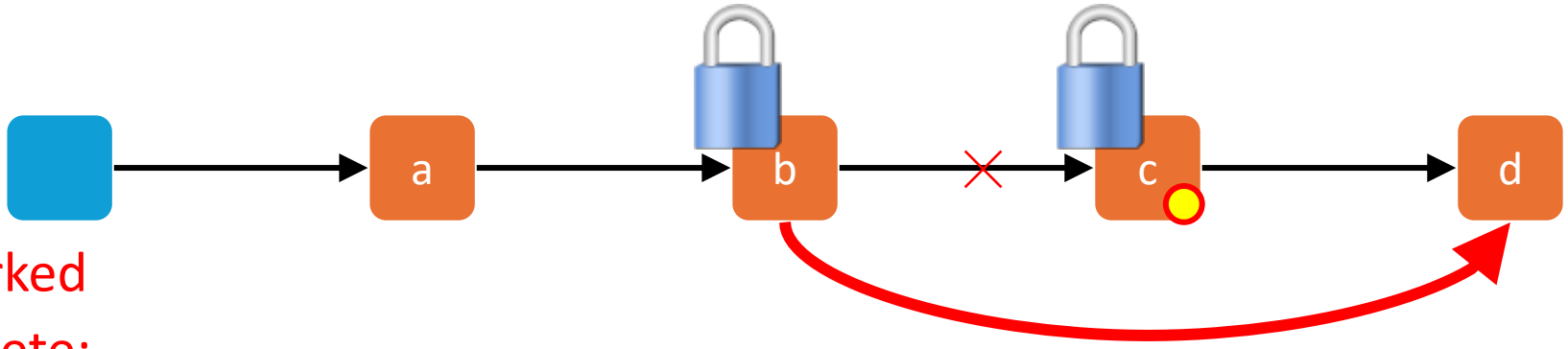
lock

check if b or c are marked

not marked? ok to delete:

mark c

delete c



Remove method

```
public boolean remove(T item) {
  int key = item.hashCode();
  while (true) { // optimistic, retry
    Node pred = this.head;
    Node curr = head.next;
    while (curr.key < key) {
      pred = curr;
      curr = curr.next;
    }
    pred.lock();
    try {
      curr.lock();
      try {
        // remove or not
      } finally { curr.unlock(); }
    } finally { pred.unlock(); }
  }
}
```

What is validate() now?

Remove method

```
public boolean remove(T item) {
  int key = item.hashCode();
  while (true) { // optimistic, retry
    Node pred = this.head;
    Node curr = head.next;
    while (curr.key < key) {
      pred = curr;
      curr = curr.next;
    }
    pred.lock();
    try {
      curr.lock();
      try {
        // remove or not
      } finally { curr.unlock(); }
    } finally { pred.unlock(); }
  }
}
```

```
if (!pred.marked && !curr.marked &&
      pred.next == curr) {
    if (curr.key != key)
       return false;
    else {
       curr.marked = true;    // logically remove
       pred.next = curr.next; // physically remove
       return true;
    }
}
```

Lazy List: Add

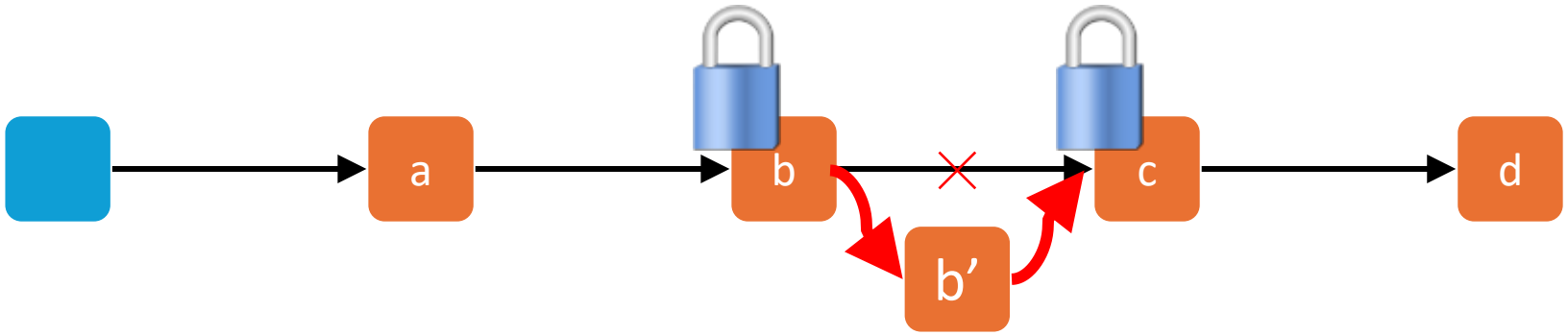
- Find nodes to where to add (as before)

Lock predecessor and current (as before)

Validate (new validation)

Physical add: change predecessor's next

e.g. add(b’)

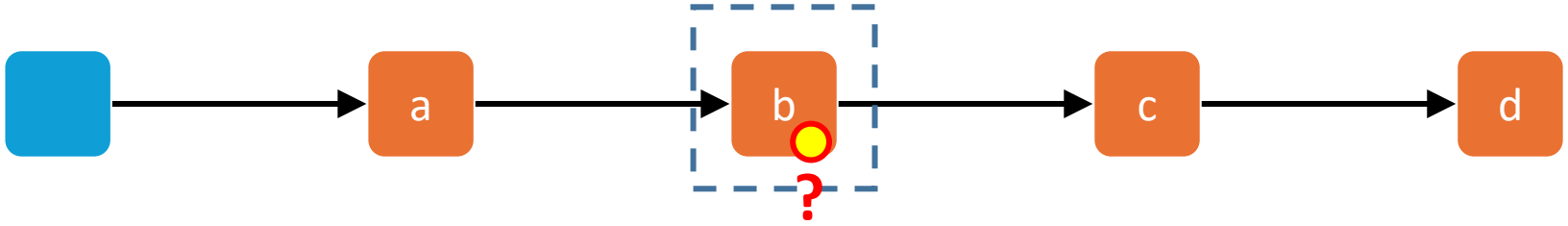


Lazy List: Contains

- Find nodes to return without locking

Return true if node is not marked

e.g. contains(b)



New Validation: What can go wrong?

A: add(c)

A: find insertion point

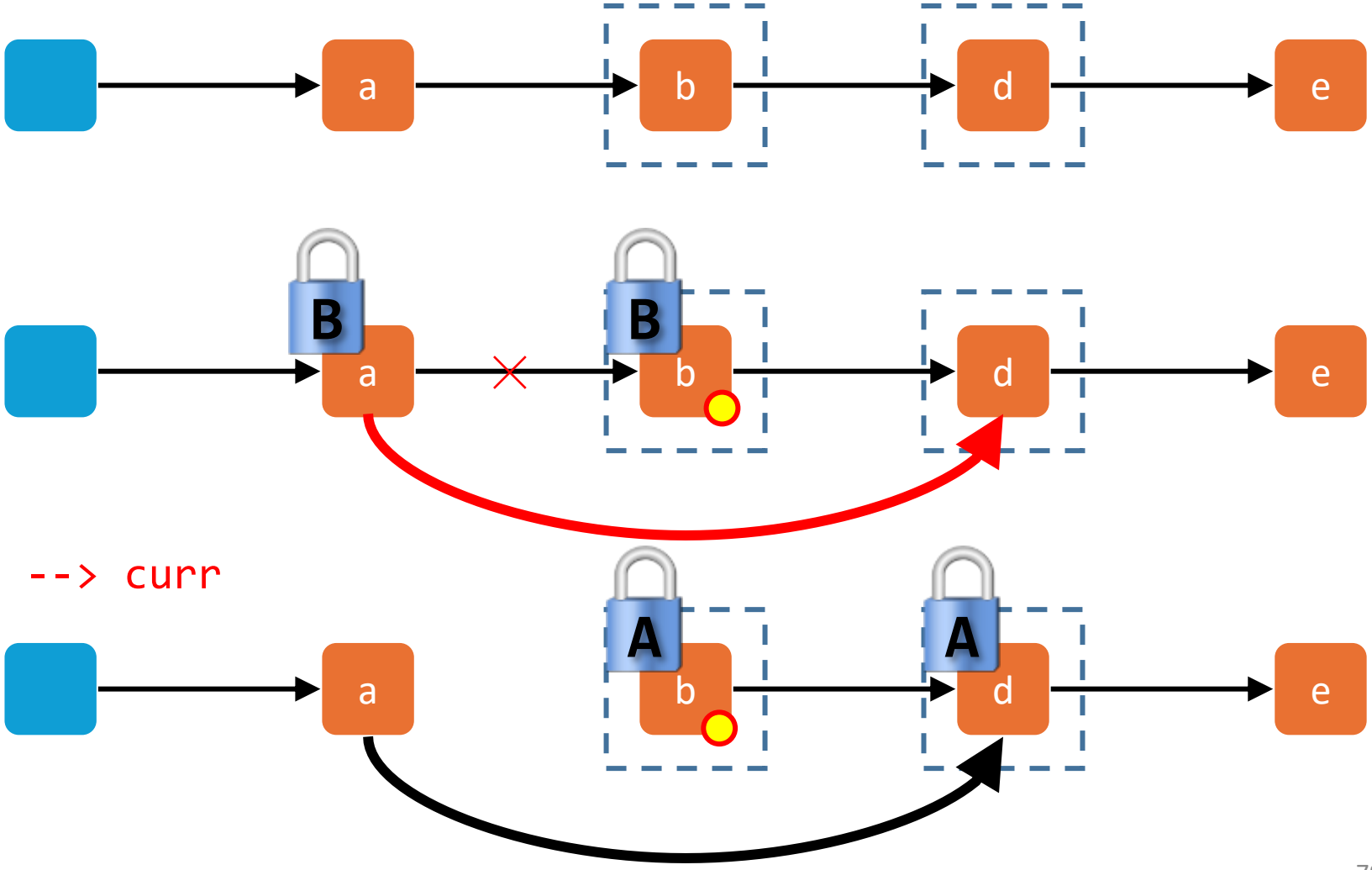
B: remove(b)

A: lock

A: validate: marks + pred --> curr

A: b marked

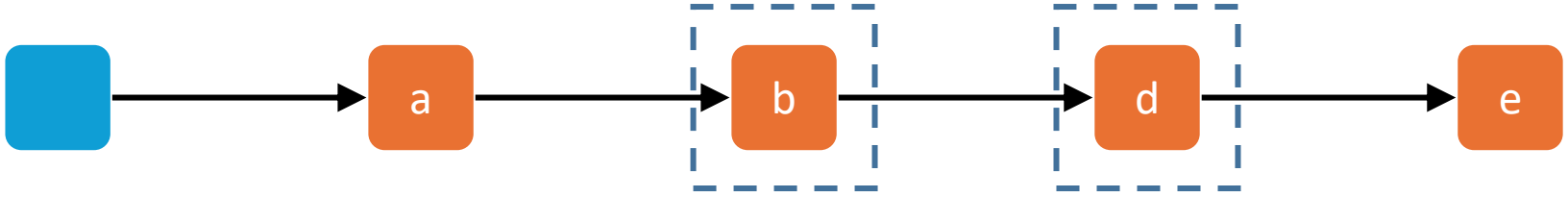
→return false



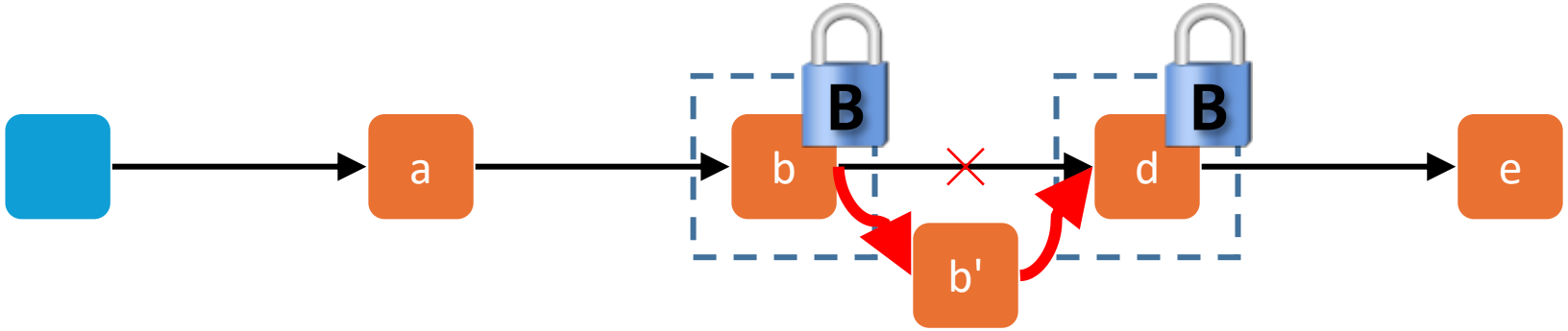
New Validation: What can go wrong?

A: add(c)

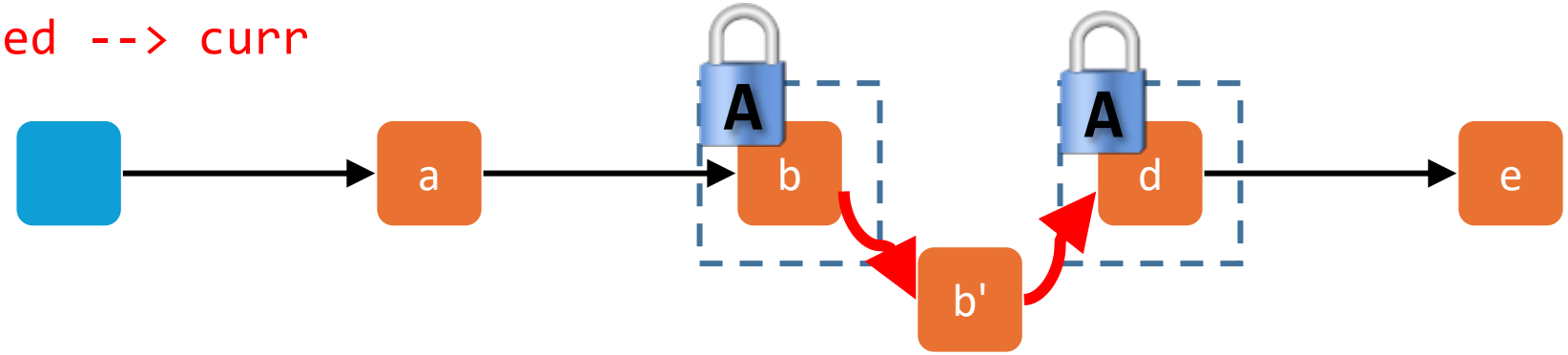
A: find insertion point



B: insert(b')

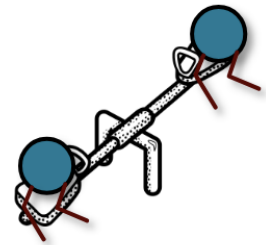


- A: lock
- A: validate: marks + pred --> curr
- A: pred –x-> curr
- →return false

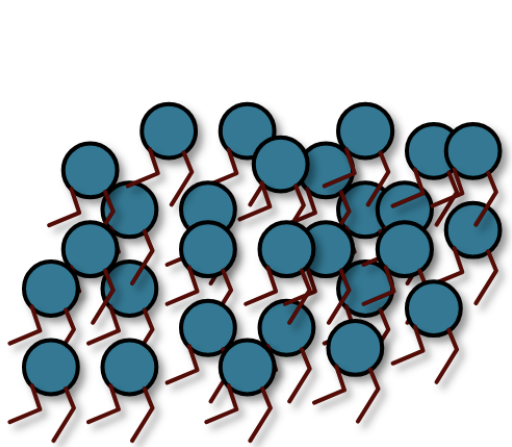


Lock free data structures

Locks performance



- **Uncontended case**
  - when threads do not compete for the lock
  - lock implementations try to have minimal overhead
  - typically "just" the cost of an atomic operation



- **Contended case**
  - when threads do compete for the lock
  - can lead to significant performance degradation
  - also, starvation
  - there exist lock implementations that try to address these issues

Disadvantages of locking

Locks are pessimistic by design

- Assume the worst and enforce mutual exclusion

Performance issues

- Overhead for each lock taken even in uncontended case
- Contended case leads to significant performance degradation
- Amdahl's law!

Blocking semantics (wait until acquire lock)

- If a thread is delayed (e.g., scheduler) when in a critical section → all threads suffer
- What if a thread dies in the critical section
- Prone to deadlocks (and also livelocks)
- Without precautions, locks cannot be used in interrupt handlers

So how do we build lock free data structures?

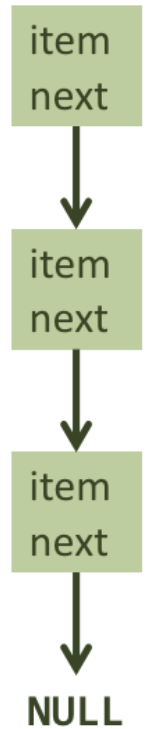
Stack Node

```
public static class Node {
   public final Long item;
   public Node next;

   public Node(Long item) {
       this.item = item;
   }

   public Node(Long item, Node n) {
       this.item = item;
       next = n;
   }

}
```

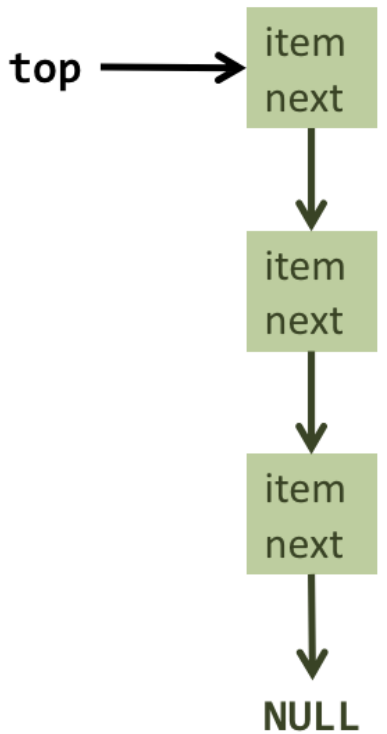


Blocking Stack

```
public class BlockingStack {
   Node top = null;

   synchronized public void push(Long item) {
      top = new Node(item, top);
   }

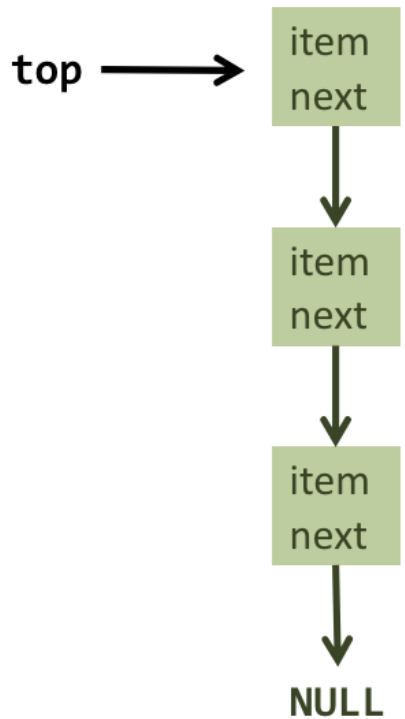
   synchronized public Long pop() {
      if (top == null)
         return null;
      Long item = top.item;
      top = top.next;
      return item;
   }
}
```



Non-blocking Stack

```
public class ConcurrentStack {
   AtomicReference<Node> top = new AtomicReference<Node>();

   public void push(Long item) { … }
   public Long pop() { … }
}
```



pop

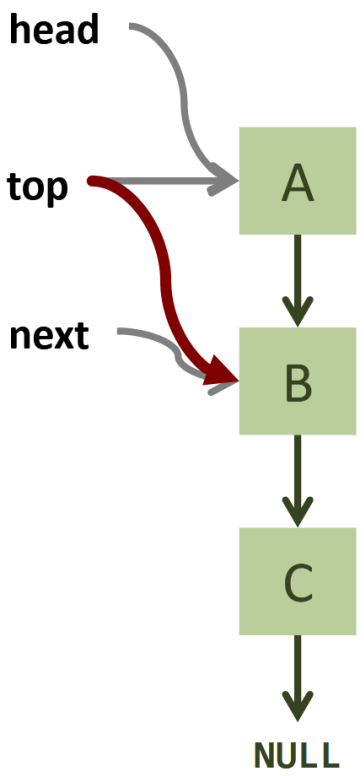
```
public Long pop() {
  Node head, next;

  do {
    head = top.get();
    if (head == null) return null;
    next = head.next;
  } while (!top.compareAndSet(head, next));

  return head.item;
}
```

Memorize "current stack state" in local variable head

Action is taken only if "the stack state" did not change



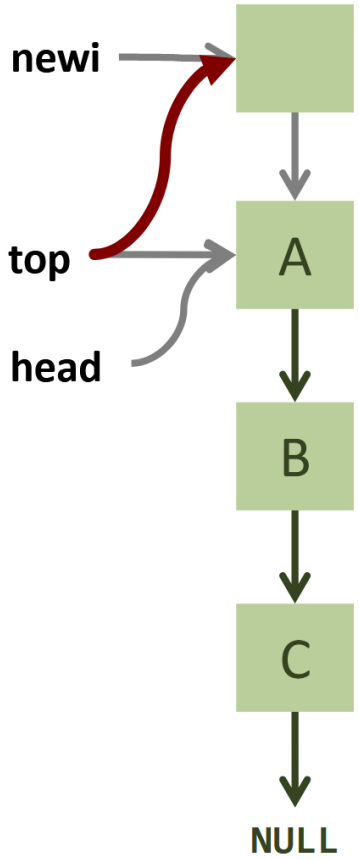
push

```
public void push(Long item) {
      Node newi = new Node(item);
      Node head;

      do {
            head = top.get();
            newi.next = head;
      } while (!top.compareAndSet(head, newi));
}
```

Memorize "current stack state" in local variable head

Action is taken only if "the stack state" did not change



What's the benefit?

Lock-free programs are deadlock-free by design.

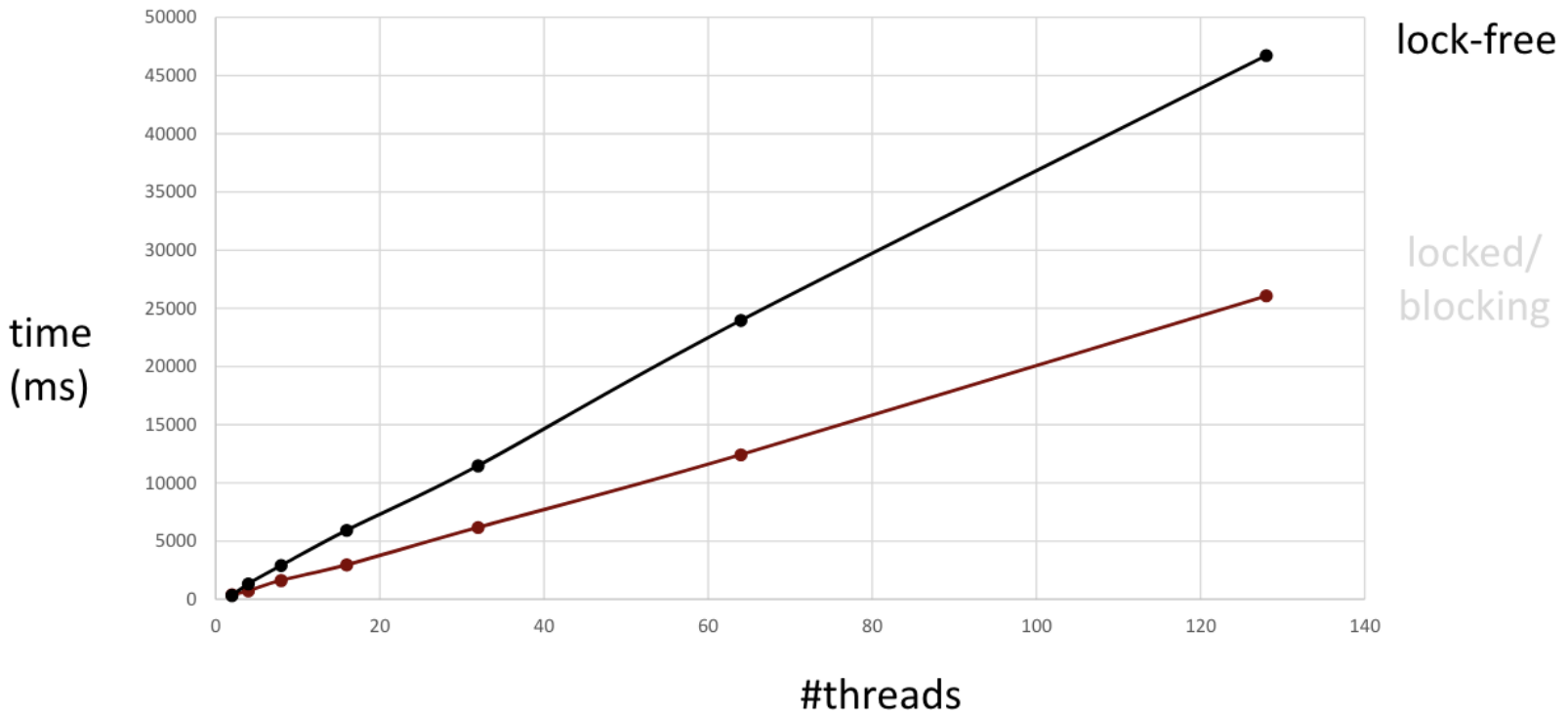
How about performance?

```
public void push(Long item) {
        Node newi = new Node(item);
        Node head;
        do {
                head = top.get();
                newi.next = head;
        } while (!top.compareAndSet(head, newi));
}
```

n threads

100,000 push/pop operations

10 times

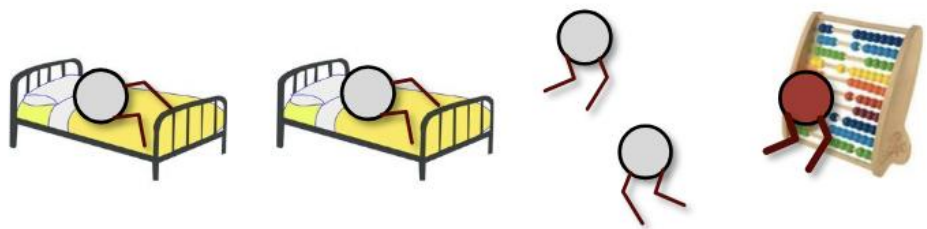


Performance

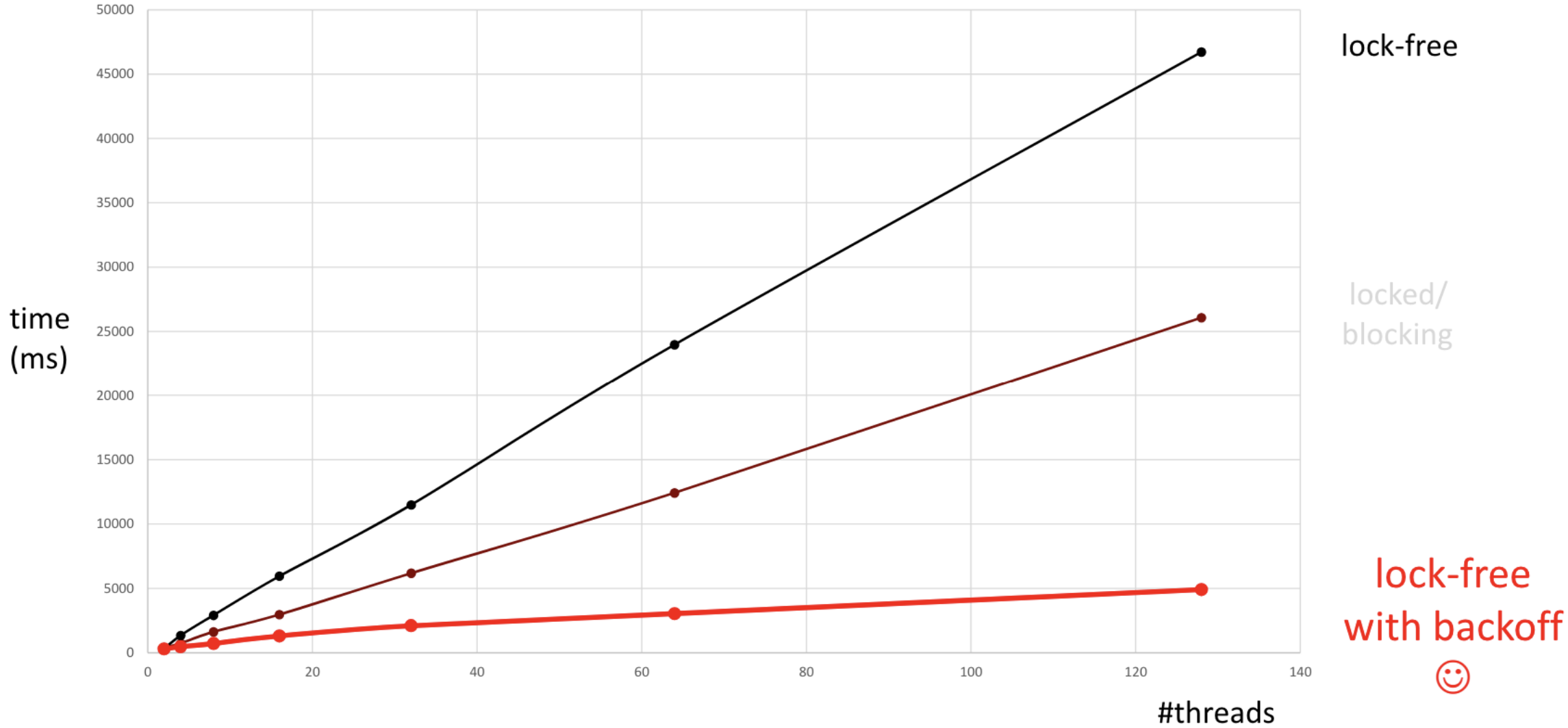
A lock-free algorithm does not automatically provide better performance than its blocking equivalent!

Atomic operations are expensive and contention can still be a problem.

→ Backoff, again.



With backoff



Problems with this implementation?

- Say we want to use a node pool instead of always creating new nodes (i.e. not always use new Node() but instead take it out of a list)
- -> ABA Problem (exam relevant)

Plan für heute

- Organisation
- Nachbesprechung Assignment 10
- Theory
- Intro Assignment 11
- **Kahoot**
- Exam questions

Kahoot!

Plan für heute

- Organisation
- Nachbesprechung Assignment 10
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- **Exam questions**

Types of exercises that might come in the exam

Disclaimer: This list is not guaranteed to be complete and is only meant to give you an idea of what has been asked on previous exams.

Locks

- Usually there are not too many question on this topic. true/false questions of which lock has which properties (fairness, starvation free)
- find bug in lock code (violation of mutual exclusion or deadlock freedom)
- draw state space diagram and/or read off correctness properties
- reproduce Peterson/Filter/Bakery lock
- prove correctness of Peterson lock or similar (but not Filter or Bakery)

Monitors, semaphores, barriers

- semaphore implementation (mostly with monitors)
- (never seen rendezvous with semaphores in an exam)
- barrier implementation (mostly with monitors)
- (only seen a task on implementing a barrier with semaphores *once* in FS21, 8b)
- fill out some program using monitors (similar to wait/notify exercises, maybe with lock conditions)

Credits @aellison PProg23

Barriers and Synchronization (9 points)

11. (a) Wir möchten eine einfache Barriere (muss nicht wiederverwendbar sein) implementieren. Die Barriere soll `N` threads synchronisieren. Markieren Sie welche der folgenden Aussagen auf die jeweiligen implementierungen zutreffen. Sollten Sie den Code für ineffizient halten, nennen sie kurz den Grund.

We want to implement a simple barrier (does not have to be reusable) that allows to synchronize the execution of `N` threads. Mark whether each of the following statements is true for each implementation. If you consider this code to be inefficient, shortly state why. (4)

i.
```
1   class Barrier {
2       AtomicInteger i = new AtomicInteger(0);
3       final int threads = N;
4       public void await() throws InterruptedException {
5           int cur_threads = i.incrementAndGet();
6           if(cur_threads < threads) {
7             while (i.get() < threads) {}
8           }
9       }
10  }
```

◯ Der gezeigte Code hat die gewünschte Semantik. *Code has the desired semantics.*

Barriers and Synchronization (9 points)

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8               }
9       }
10 }
```

◯ Der gezeigte Code hat die gewünschte Semantik. *Code has the desired semantics.*

True, there is no data race since `incrementAndGet` increases `i` atomically.

Barriers and Synchronization (9 points)

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8          }
9      }
10 }
```

◯ Der Code beendet sich immer. *Code will always complete.*

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6              if(cur_threads < threads) {
7                while (i.get() < threads) {}
8              }
9      }
10 }
```

◯ Der Code beendet sich immer. *Code will always complete.*

True, it is a correct barrier implementation.

Barriers and Synchronization (9 points)

11. (a) Wir möchten eine einfache Barriere (muss nicht wiederverwendbar sein) implementieren. Die Barriere soll `N` threads synchronisieren. Markieren Sie welche der folgenden Aussagen auf die jeweiligen implementierungen zutreffen. Sollten Sie den Code für ineffizient halten, nennen sie kurz den Grund.

We want to implement a simple barrier (does not have to be reusable) that allows to synchronize the execution of `N` threads. Mark whether each of the following statements is true for each implementation. If you consider this code to be inefficient, shortly state why.

(4)

i.
```
1  class Barrier {
2      AtomicInteger i = new AtomicInteger(0);
3      final int threads = N;
4      public void await() throws InterruptedException {
5          int cur_threads = i.incrementAndGet();
6          if(cur_threads < threads) {
7            while (i.get() < threads) {}
8          }
9      }
```

◯ Der Code verendet die Rechenressourcen unter Umständen ineffizient. Warum?

Code might not use compute resources efficiently. Why?

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Code might not use compute resources efficiently. Why?

True, the waiting threads are busy waiting.

ii.

```
1  class Barrier {
2      int i = 0;
3      final int threads = N;
4      public synchronized void await() throws InterruptedException {
5          ++i;
6          while (i < threads) { wait(); }
7          notify();
8      }
9  }
```

◯ Der gezeigte Code hat die gewünschte Semantik.

Code has the desired semantics.

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Yes

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◯ Der Code beendet sich immer. *Code will always complete.*

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Code might not use compute resources efficiently. Why?

False, the code makes use of wait/notify and thus does not waste compute resources.

Feedback

- Falls ihr Feedback möchtet sagt mir bitte Bescheid!
- Schreibt mir eine Mail oder auf Discord

Teaching Awards

- Ich wäre dankbar, wenn ihr für mich abstimmen könntet!

Danke

- Bis nächste Woche!