Channels

Ryan Eberhardt and Julio Ballista
May 18, 2021

Logistics

- Week 8 :O
- Week 7 exercises due tonight
- Short week 8 exercises coming out today, due next Tuesday
- Let us know if you have questions! We have OH after class
- Let us know when you can make Not Office Hours on Slack

Reconsidering multithreading

Characteristics of multithreading

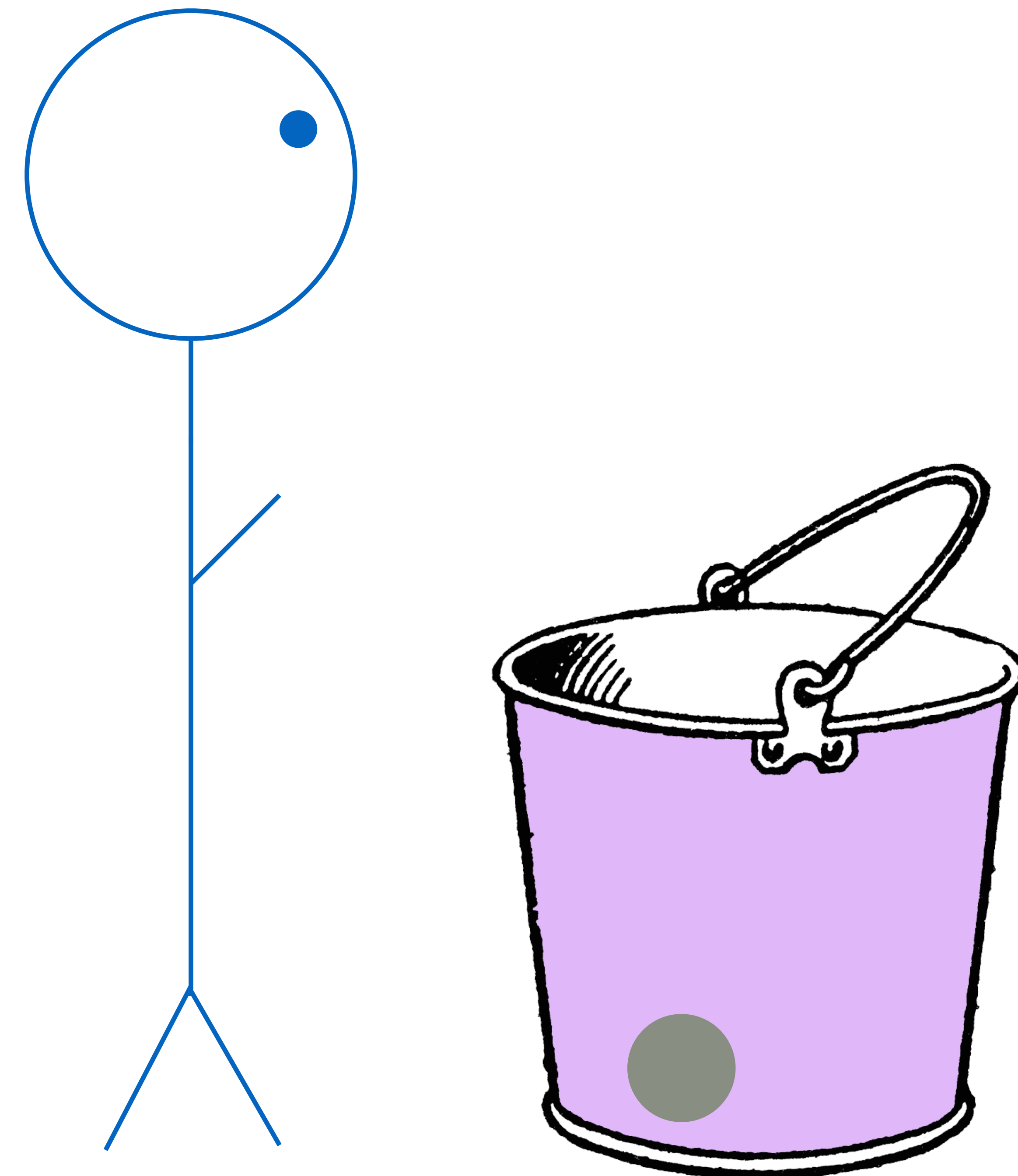
- Why do we like multithreading?
  - It’s fast (lower context switching overhead than multiprocessing)
  - It’s easy (sharing data is straightforward when you share memory)
- Why do we not like multithreading?
  - It’s easy to mess up: data races

Radical proposition

- What if we didn't share memory?
  - Could we come up with a way to do multithreading that is just as fast and just as easy?
- If threads don't share memory, how are they supposed to work together when data is involved?
- Golang concurrency slogan: *"Do not communicate by sharing memory; instead, share memory by communicating."* (Effective Go)
- Message passing: Independent threads/processes collaborate by exchanging messages with each other
  - Can't have data races because there is no shared memory

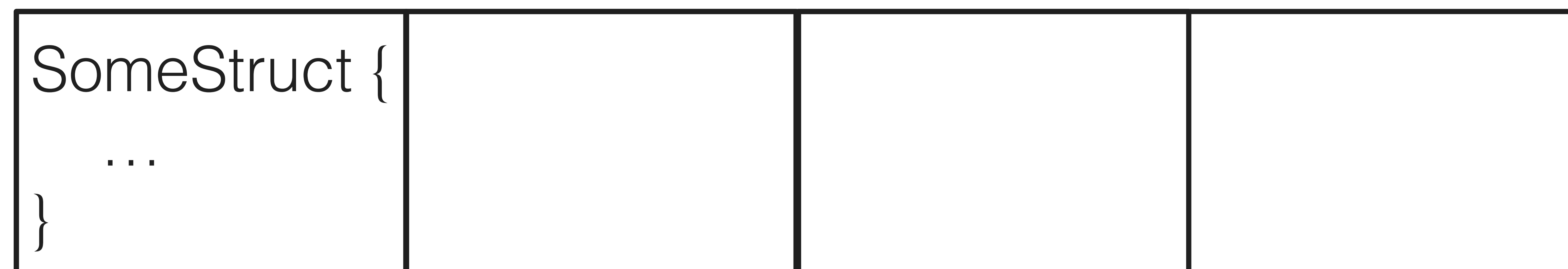
Channels: like semaphores

Semaphores



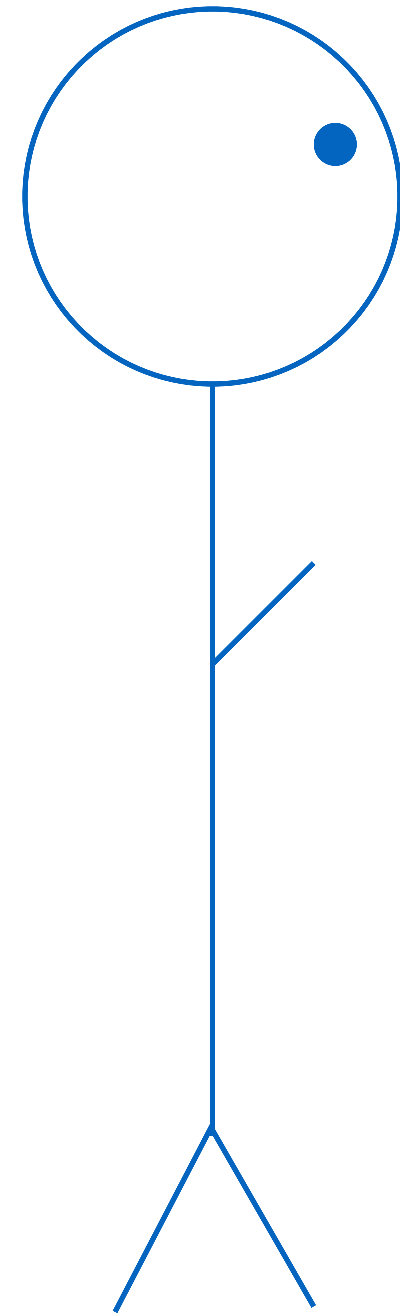
Mutex: Unlocked

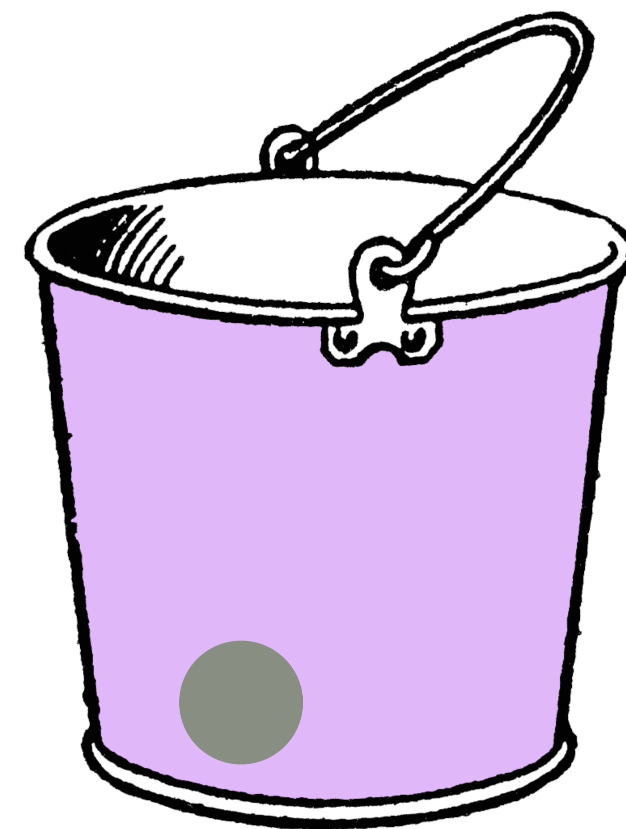
Buffer:



Semaphores

semaphore.wait()

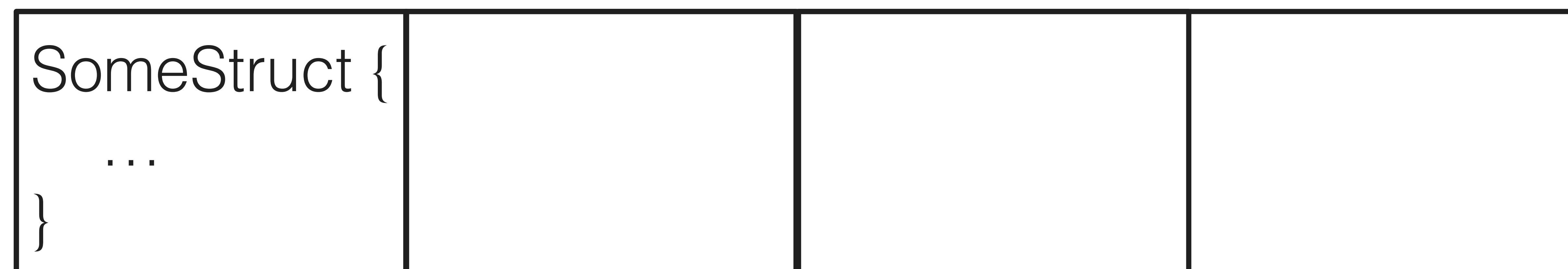




thread1

Mutex: Unlocked

Buffer:



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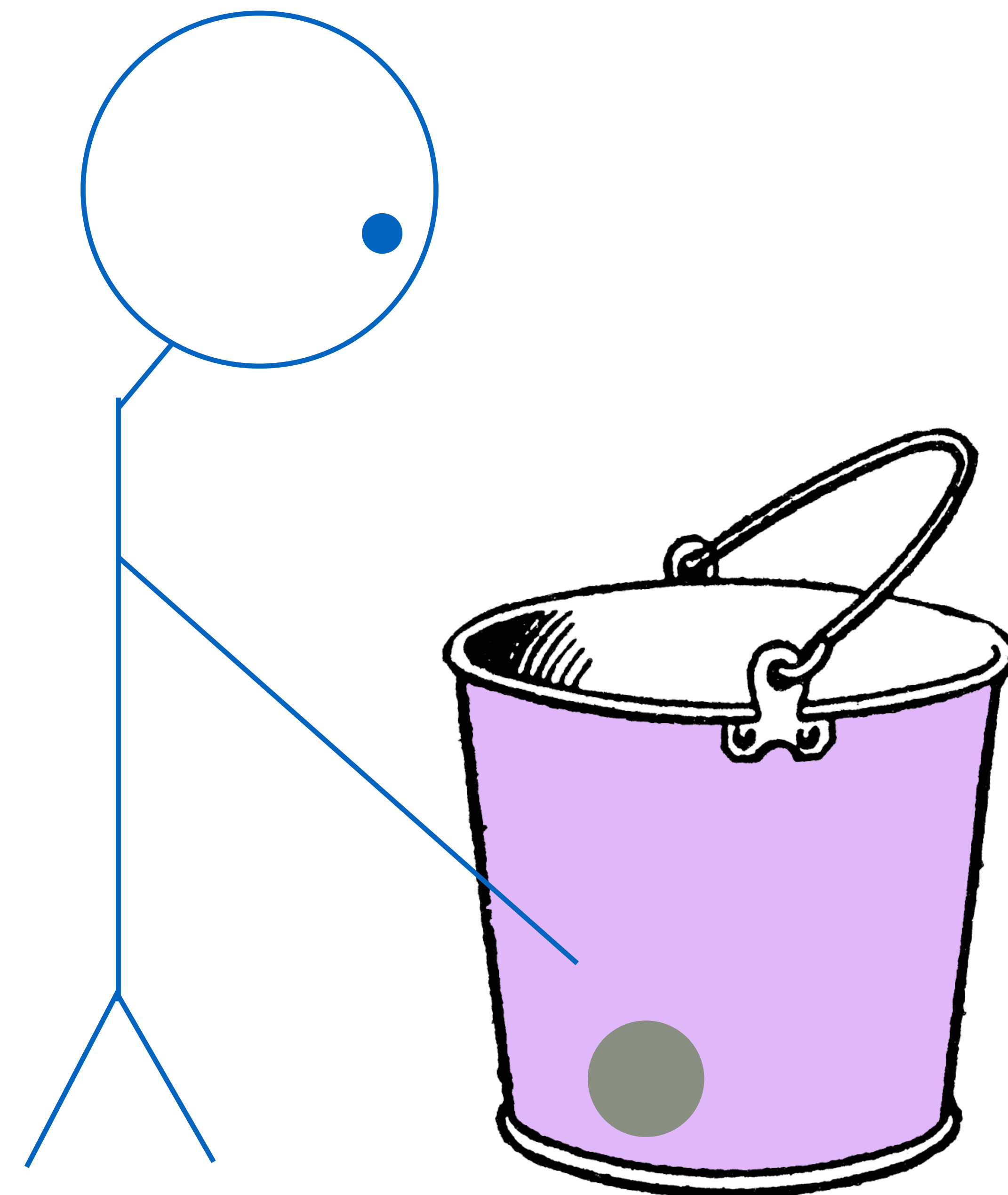

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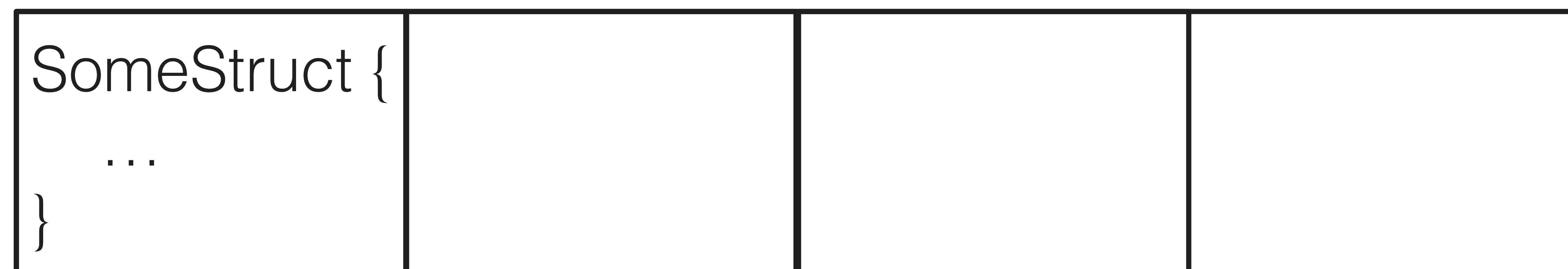

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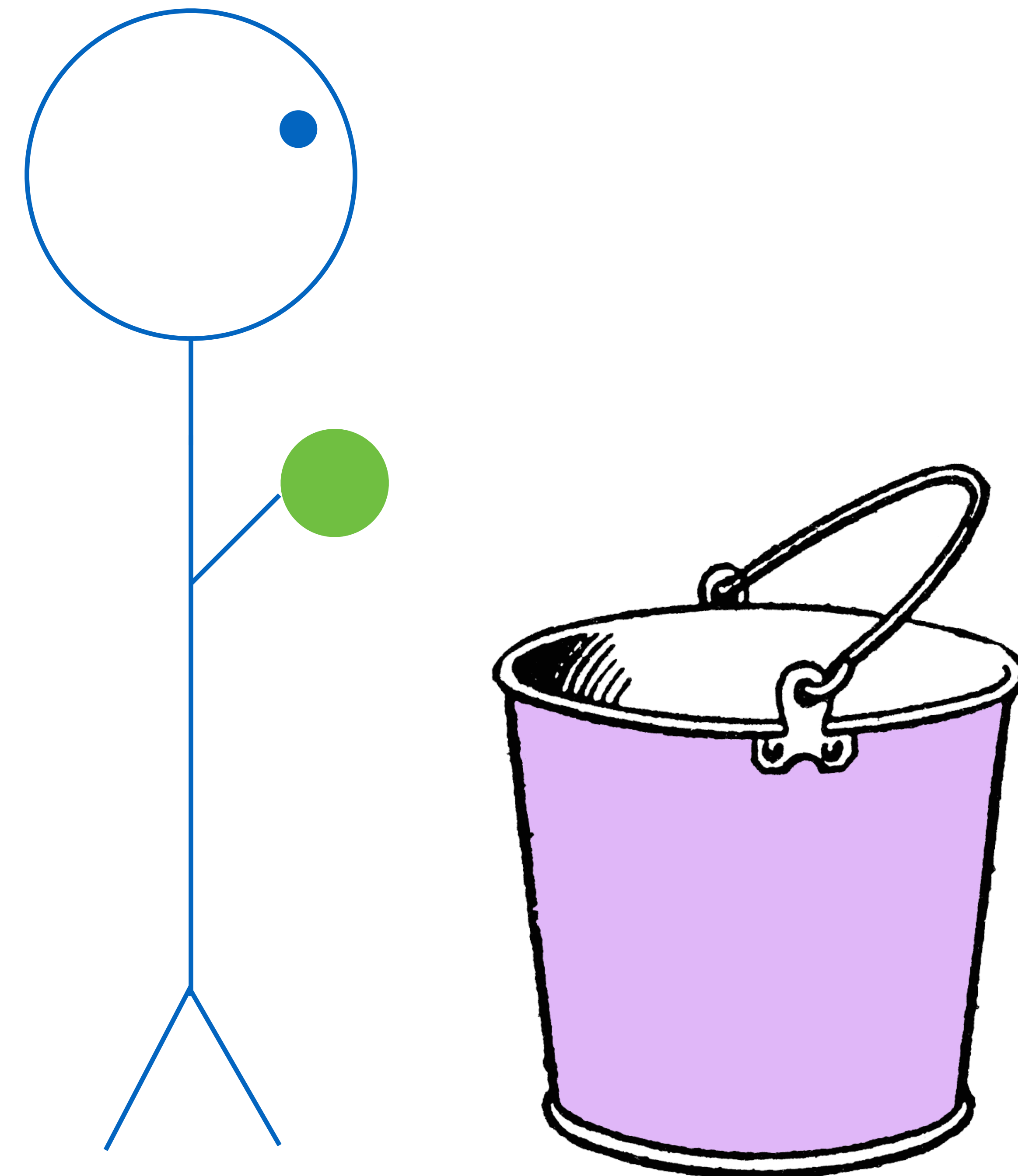

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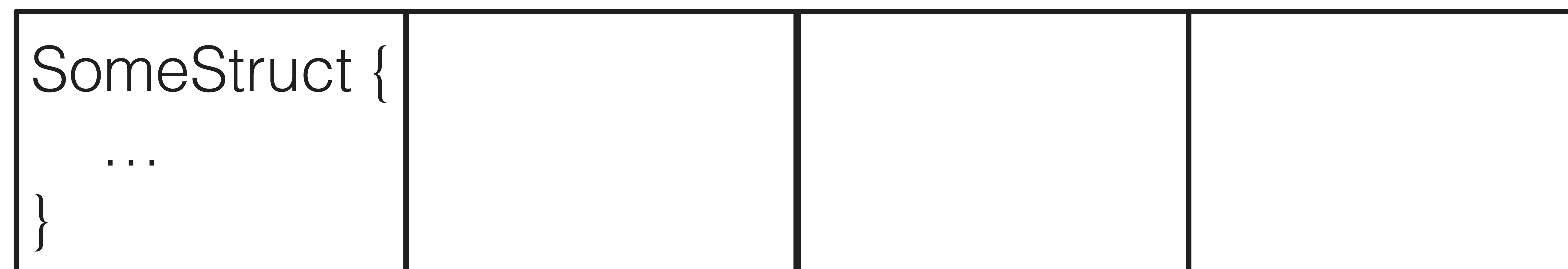
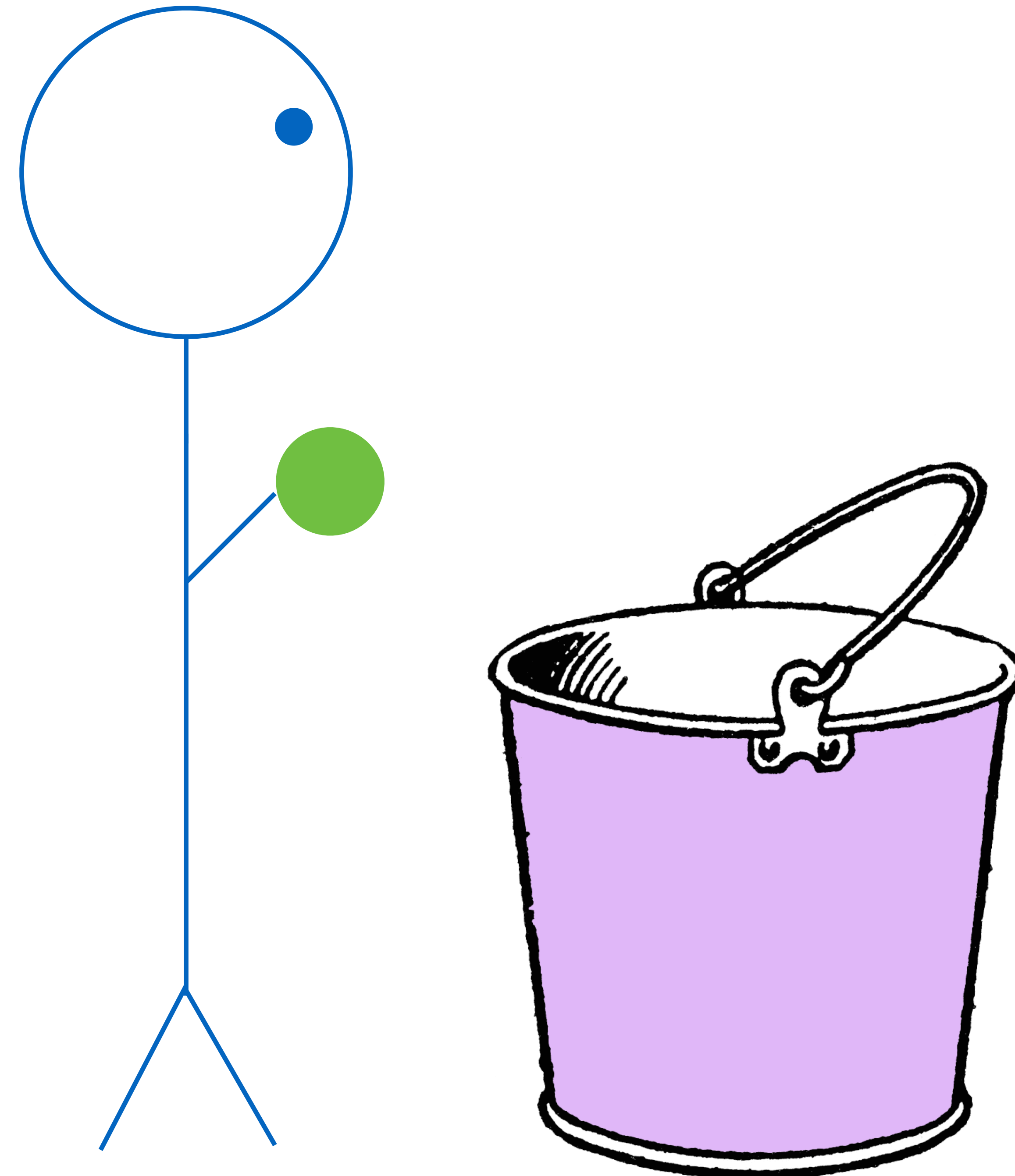


Semaphores

mutex.lock()



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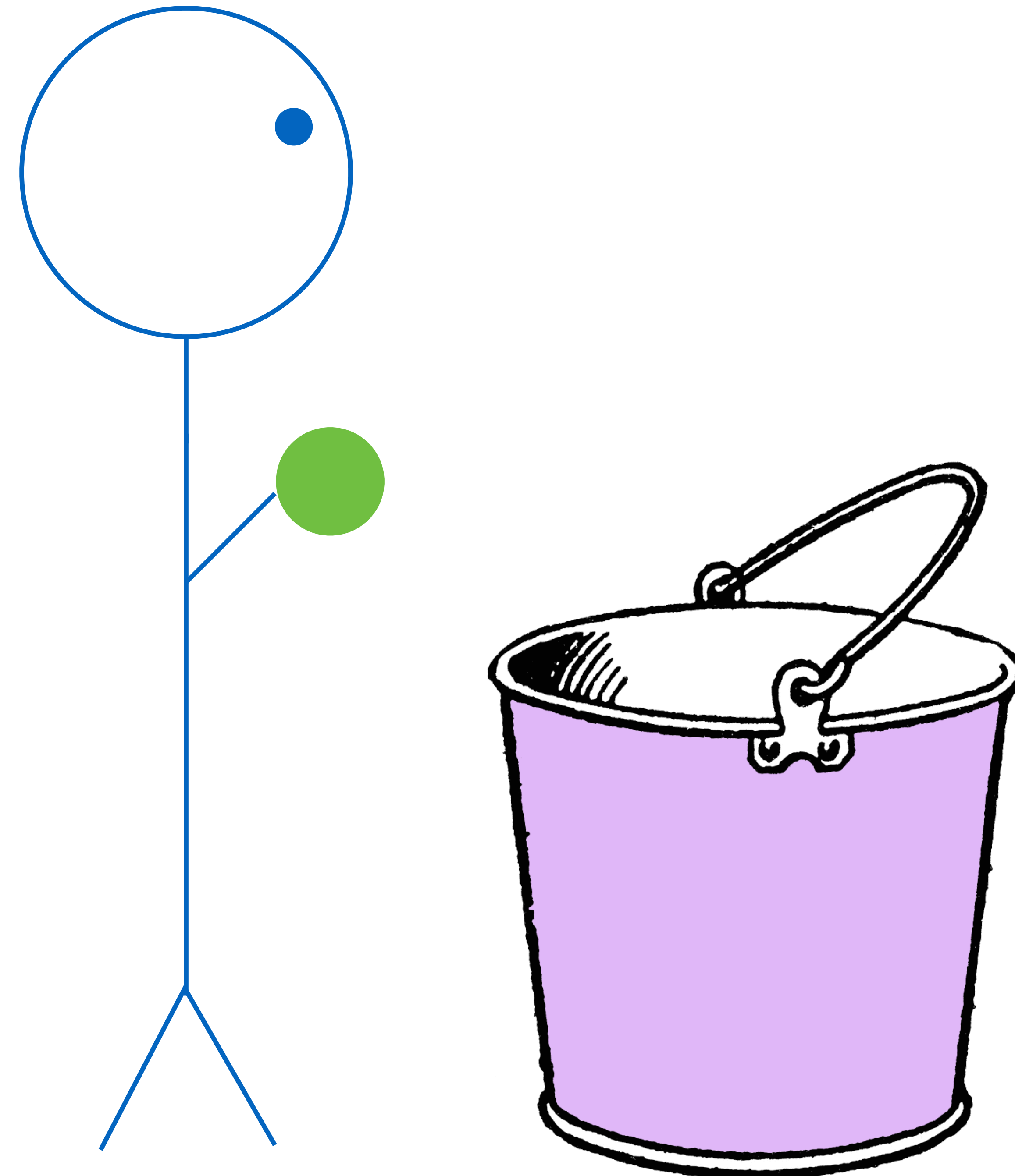
Buffer:

Semaphores



Mutex: Locked

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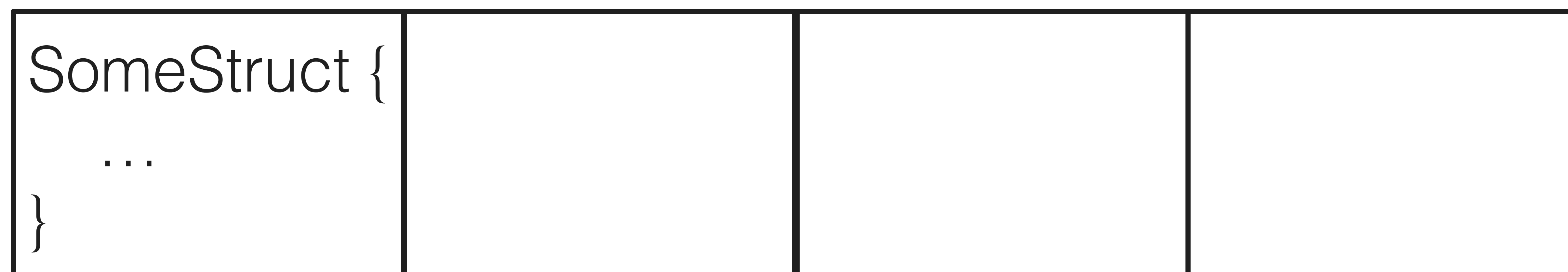
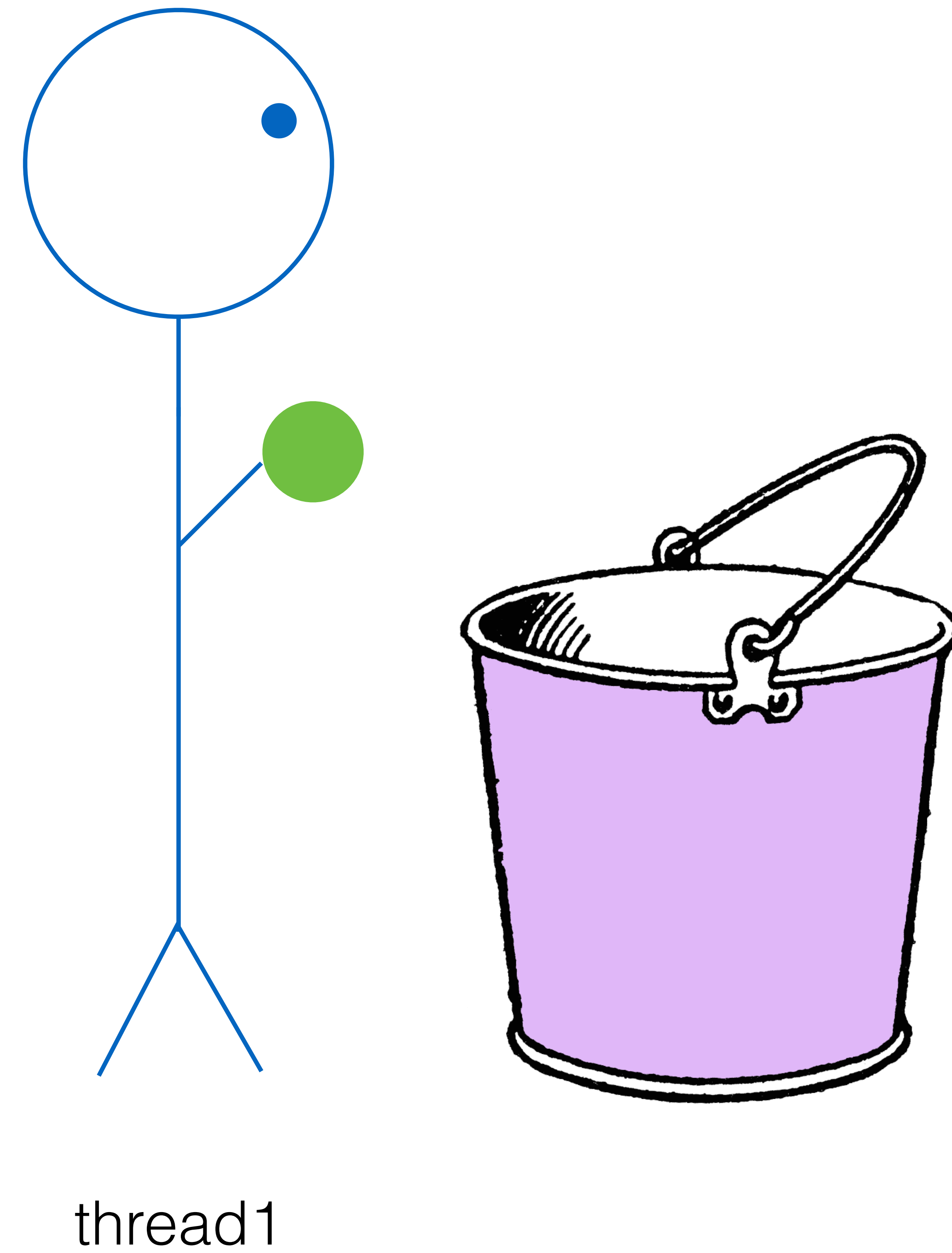


Semaphores

```
SomeStruct {
    ...
}
```



Mutex: Locked

Buffer:

Semaphores

mutex.unlock()

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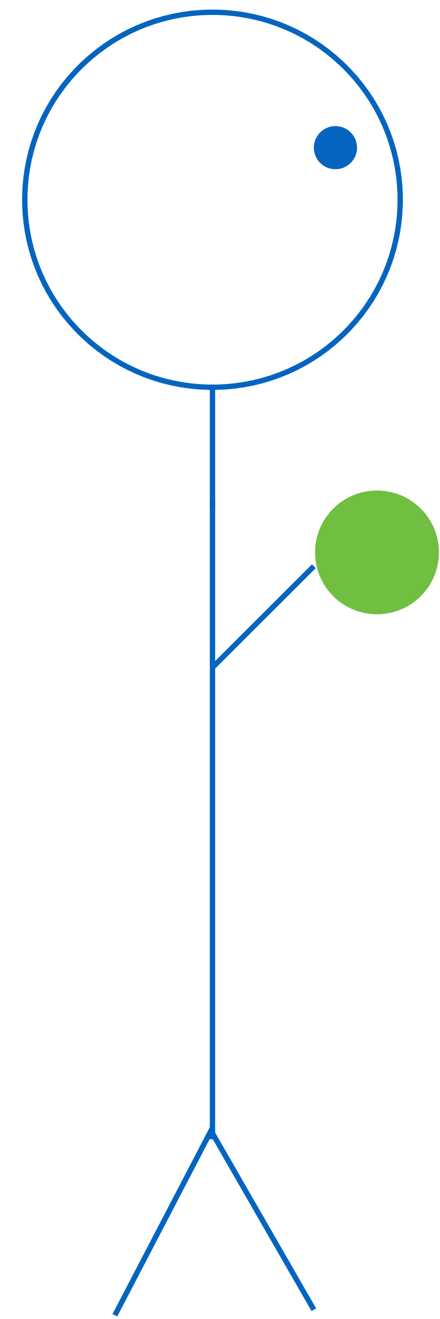
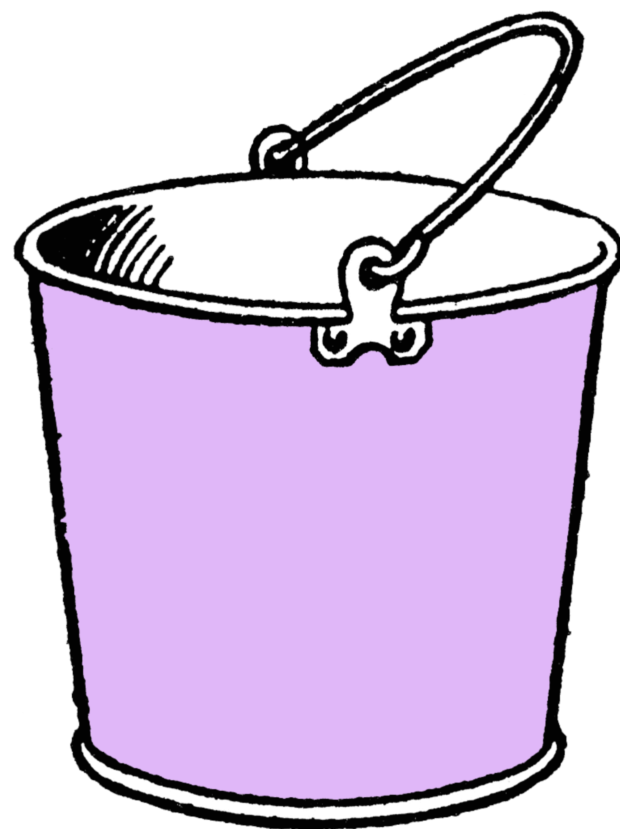
    ...
}





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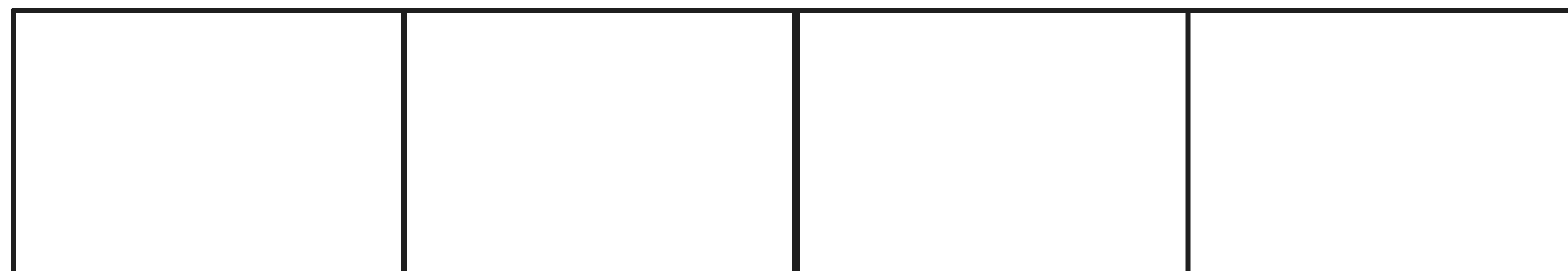

Semaphores

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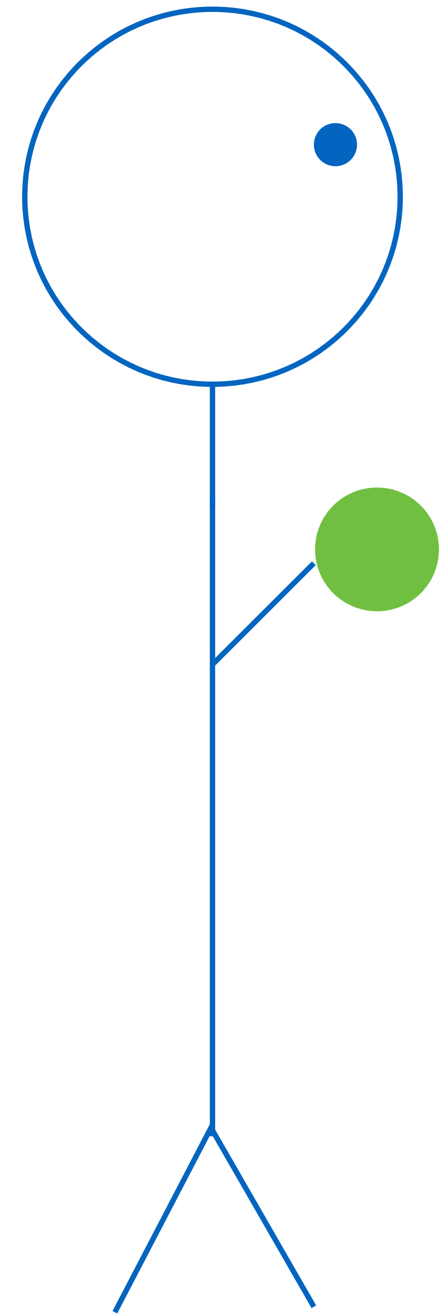

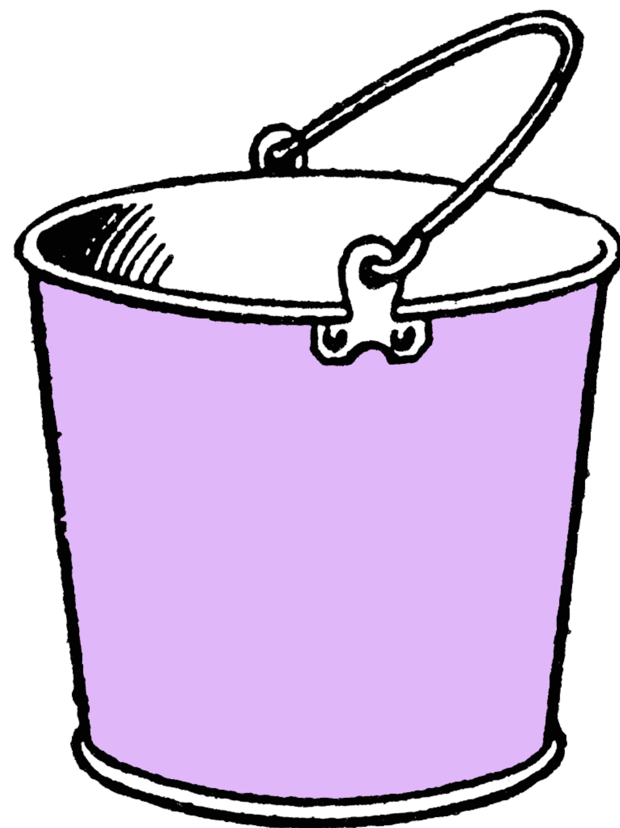

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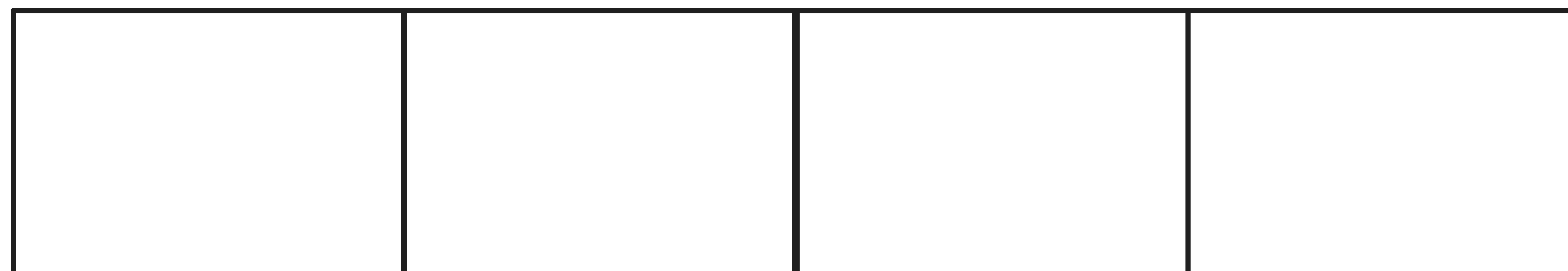

Semaphores

semaphore.wait() (again)

```
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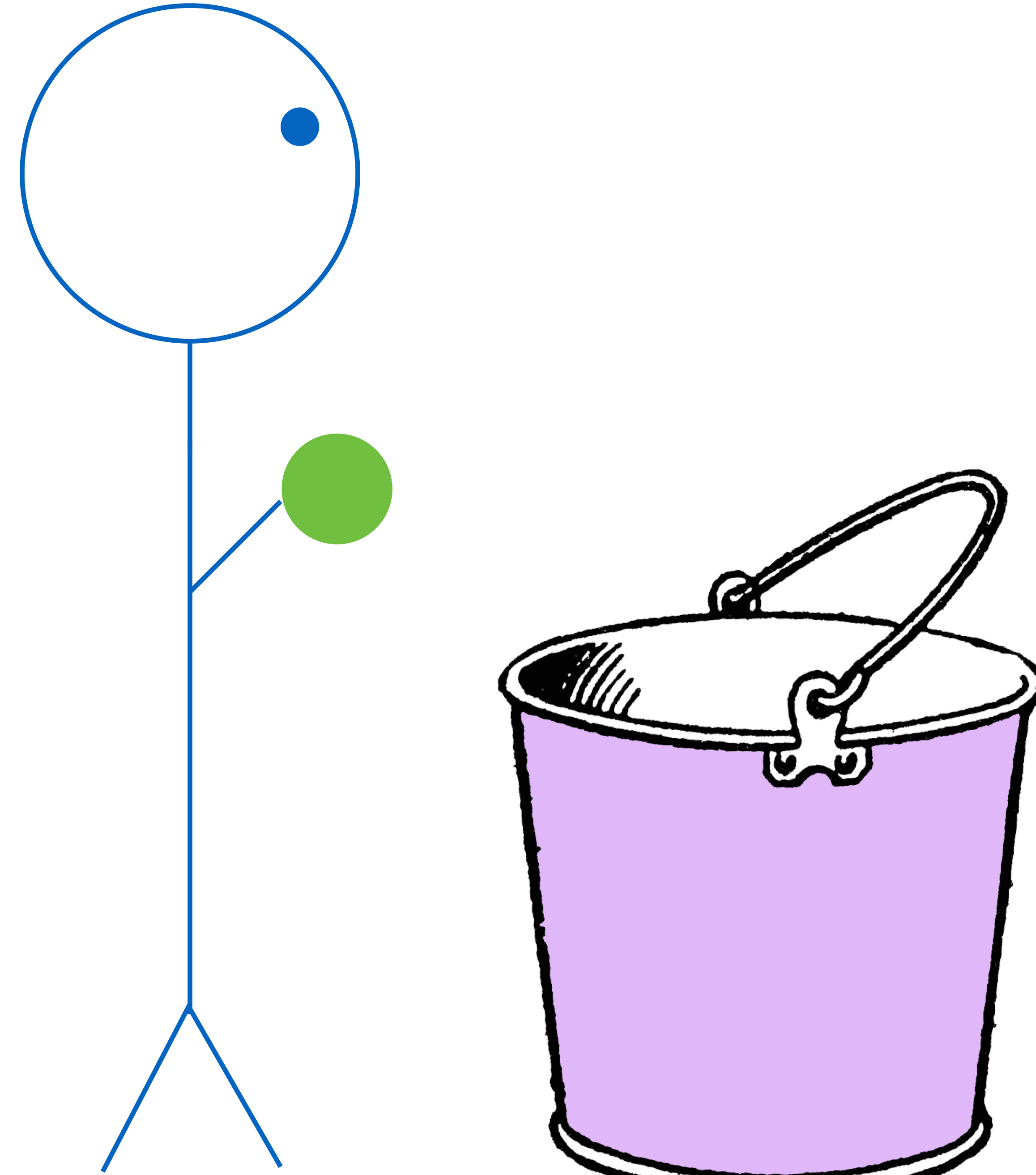
```



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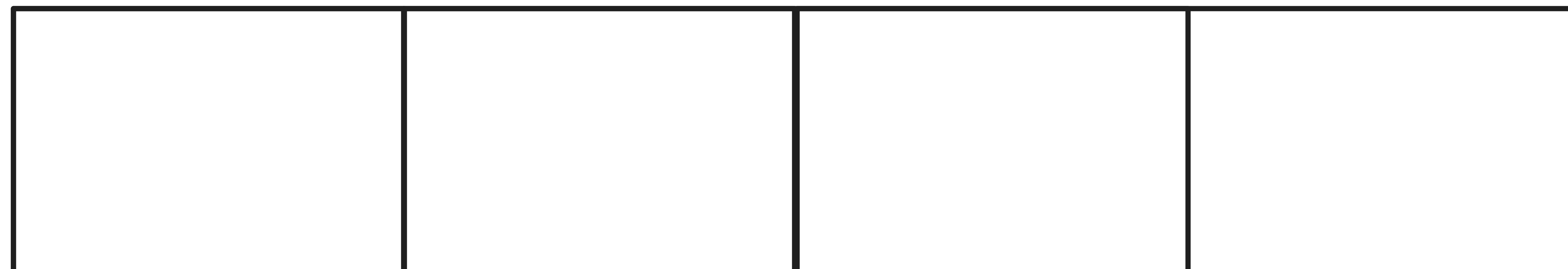

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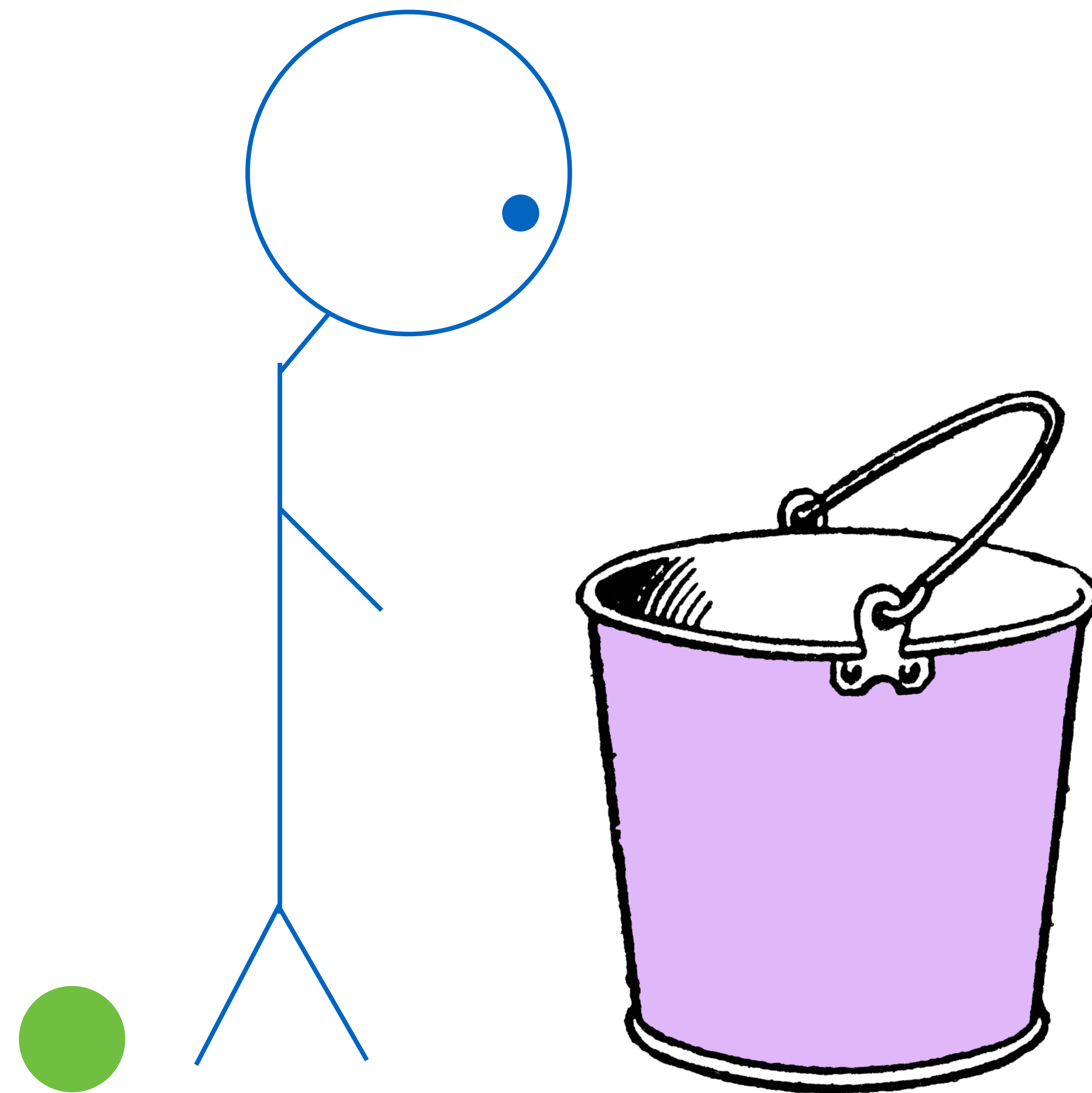

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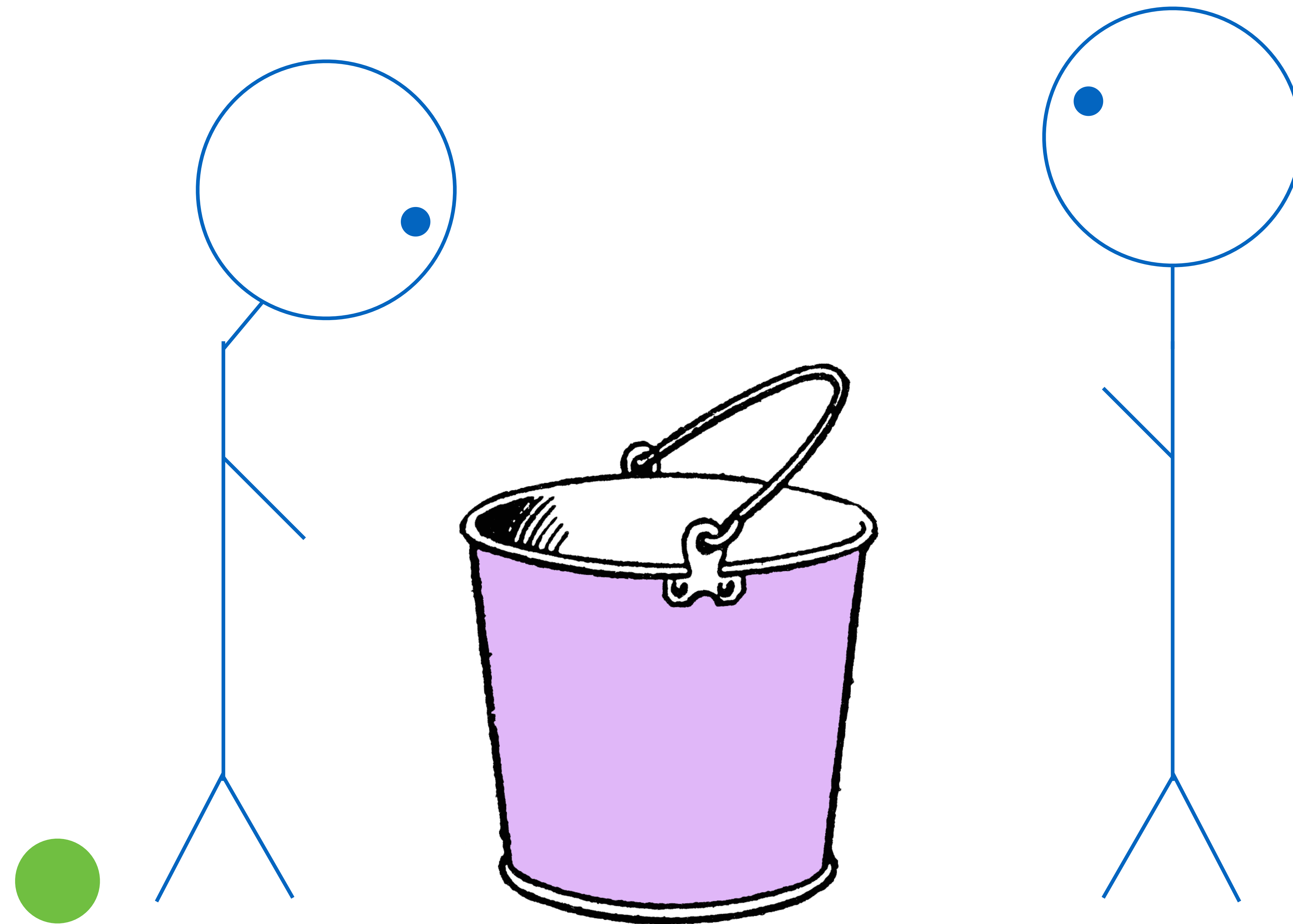

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SomeStruct {
    ...
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```

thread1 (blocked)

thread2

Mutex: Unlocked

Buffer:

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mutex.lock()

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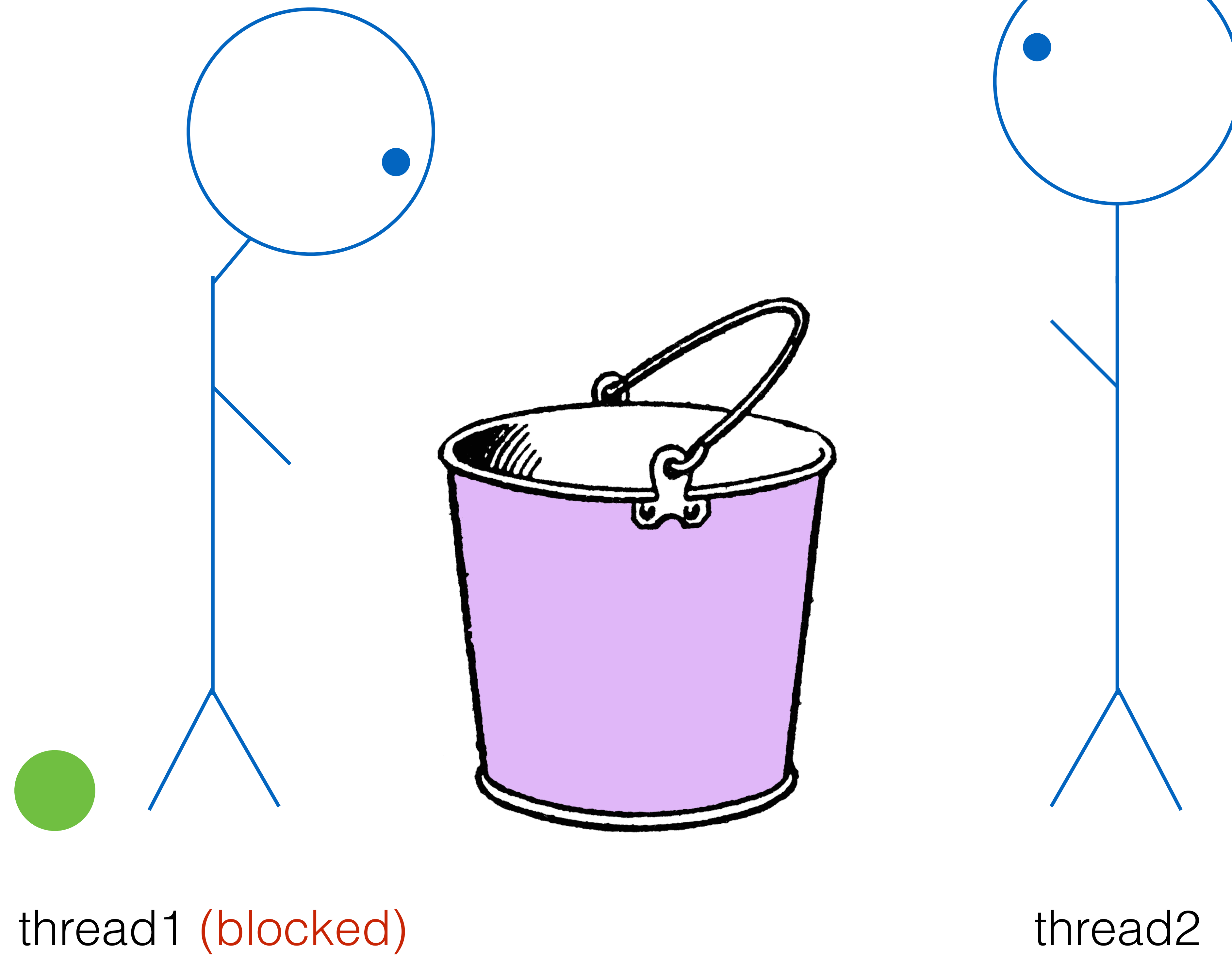

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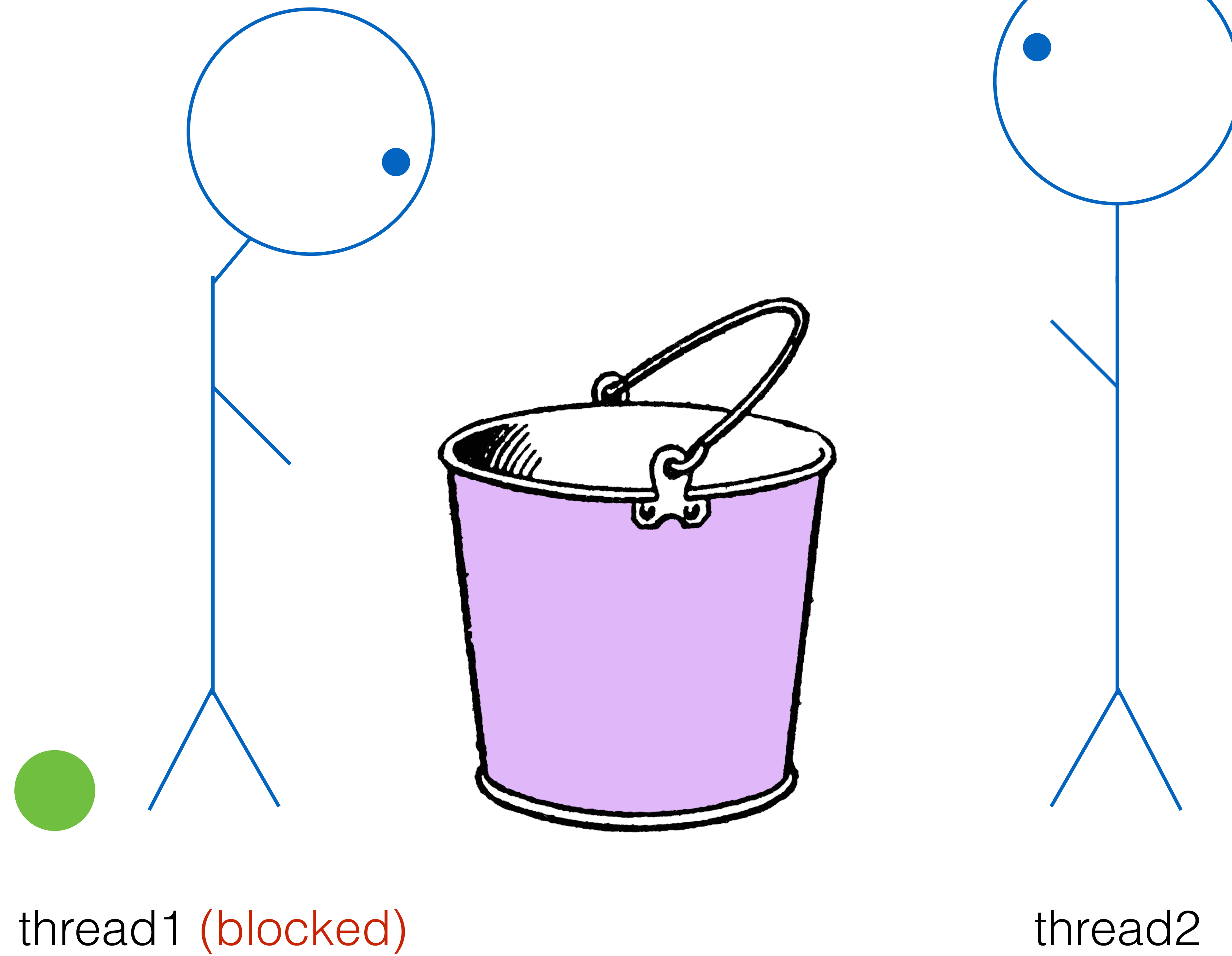

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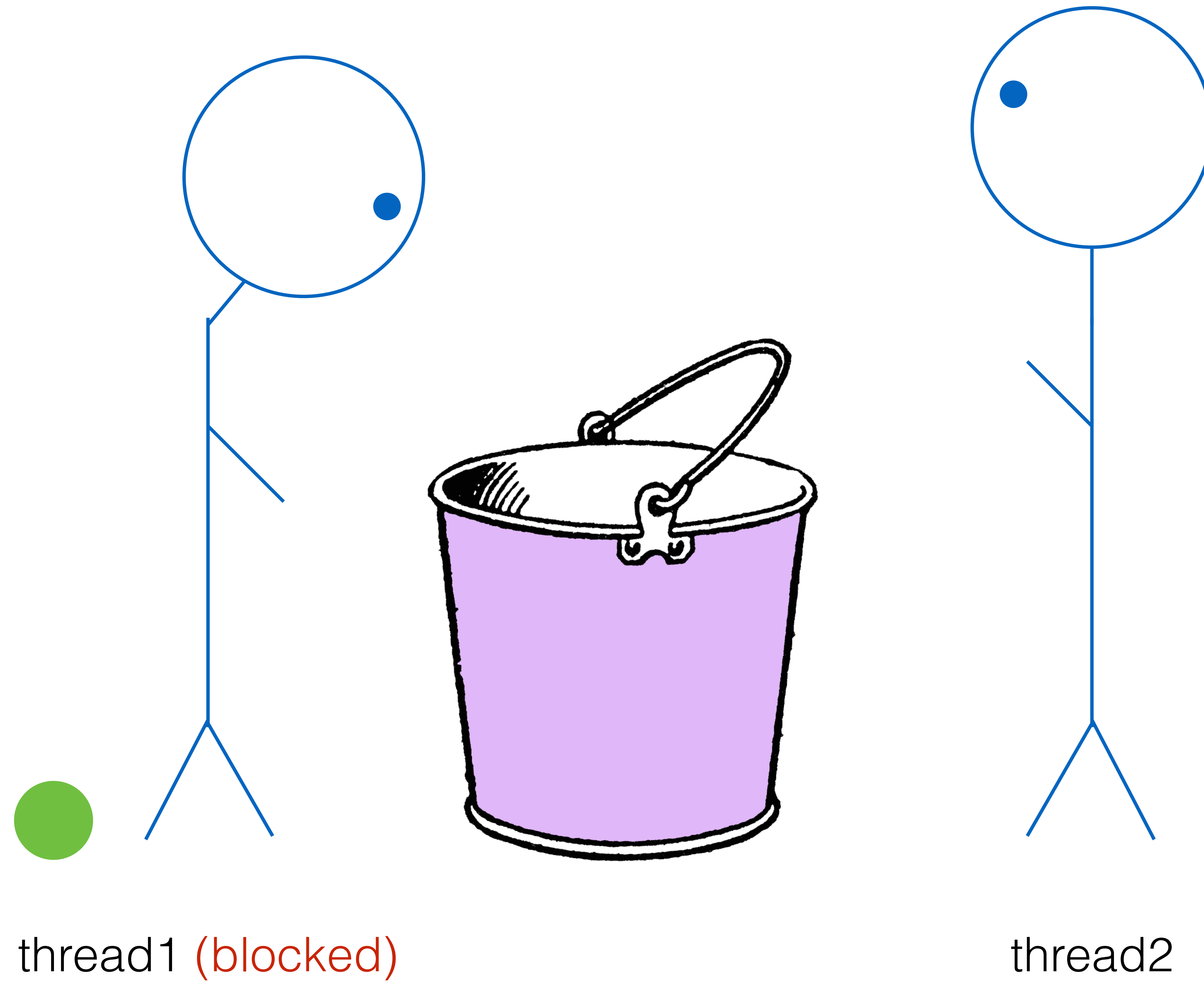

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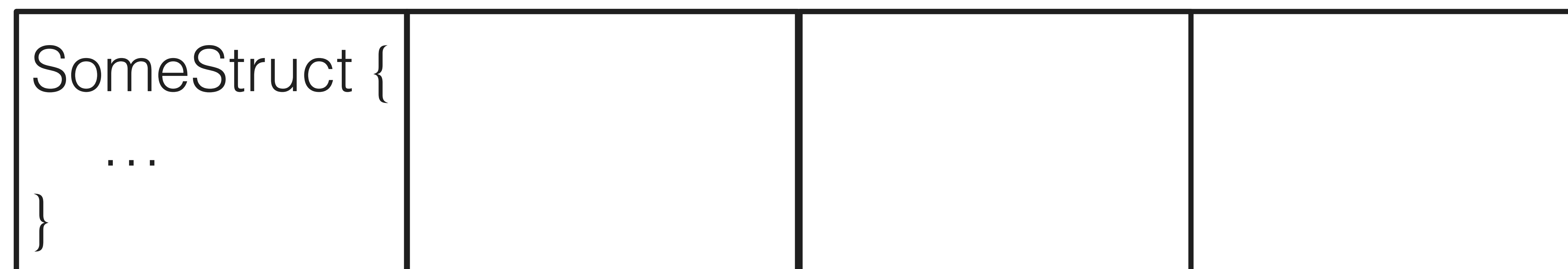

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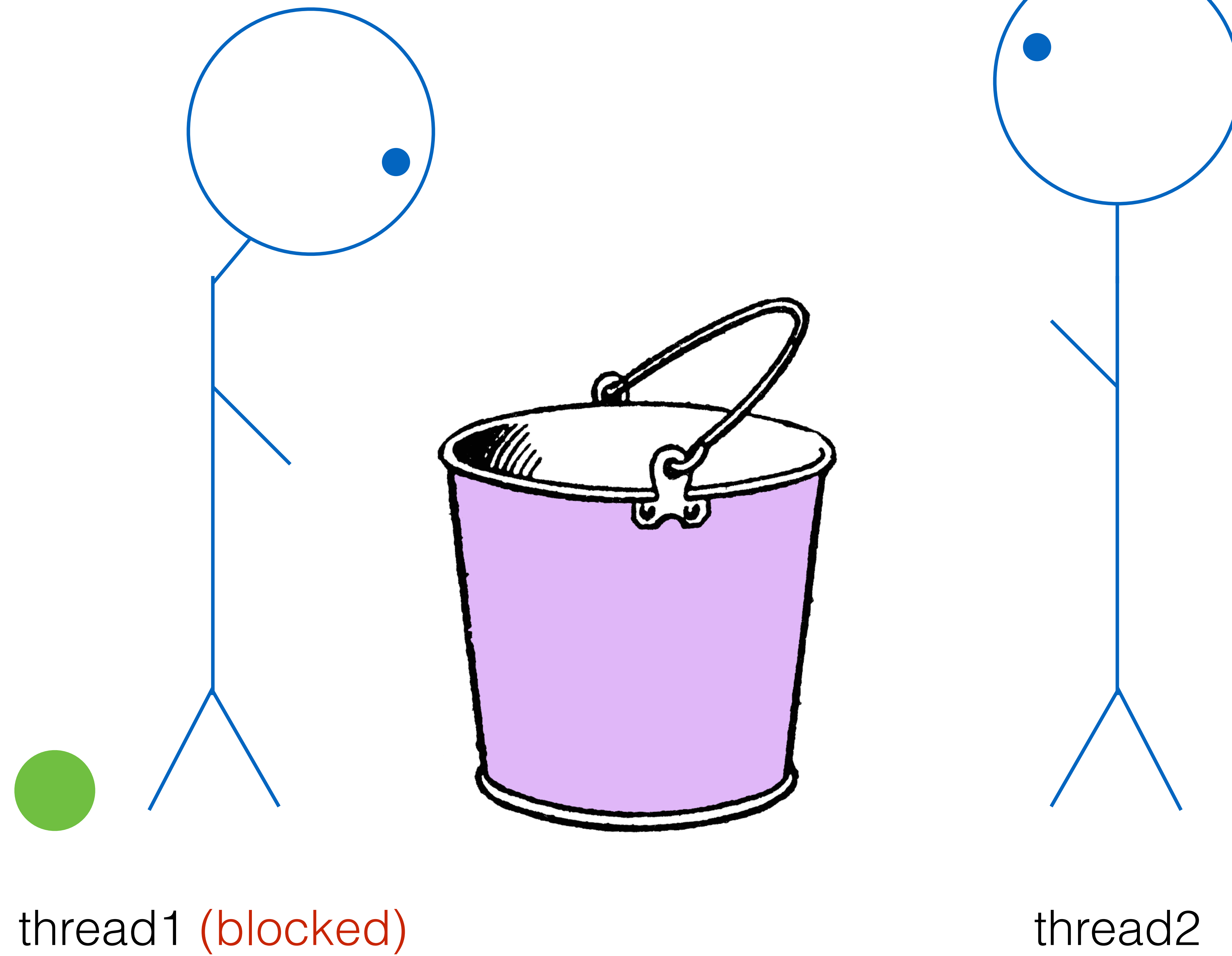

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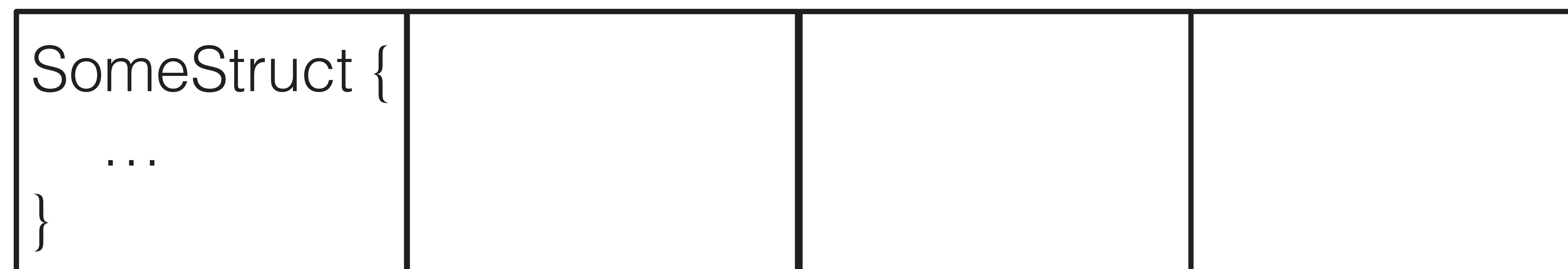

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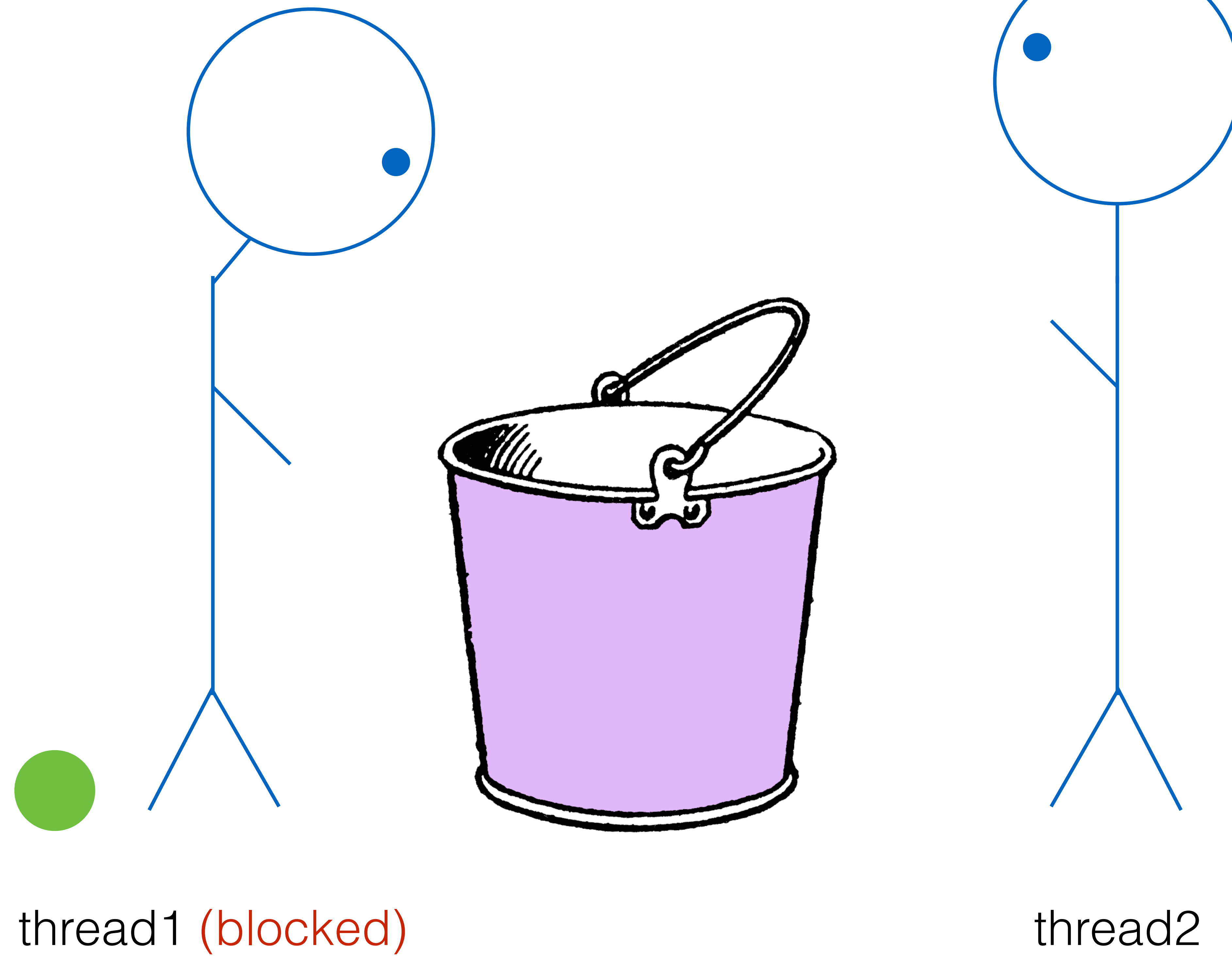

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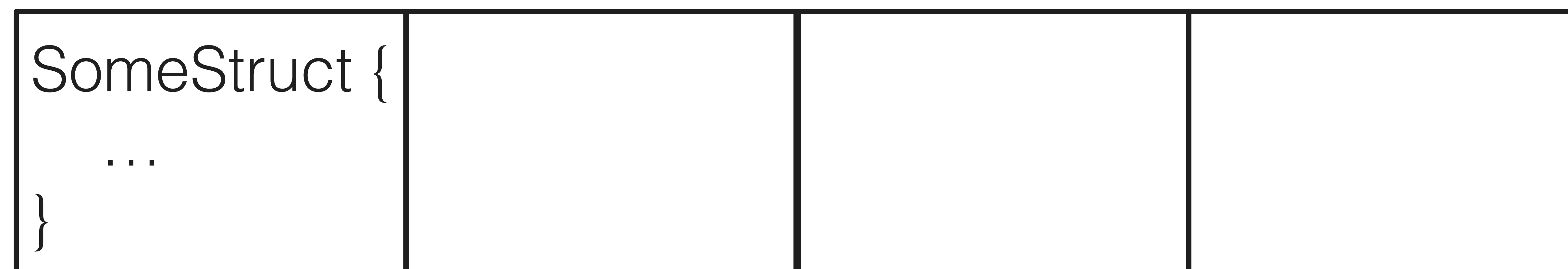
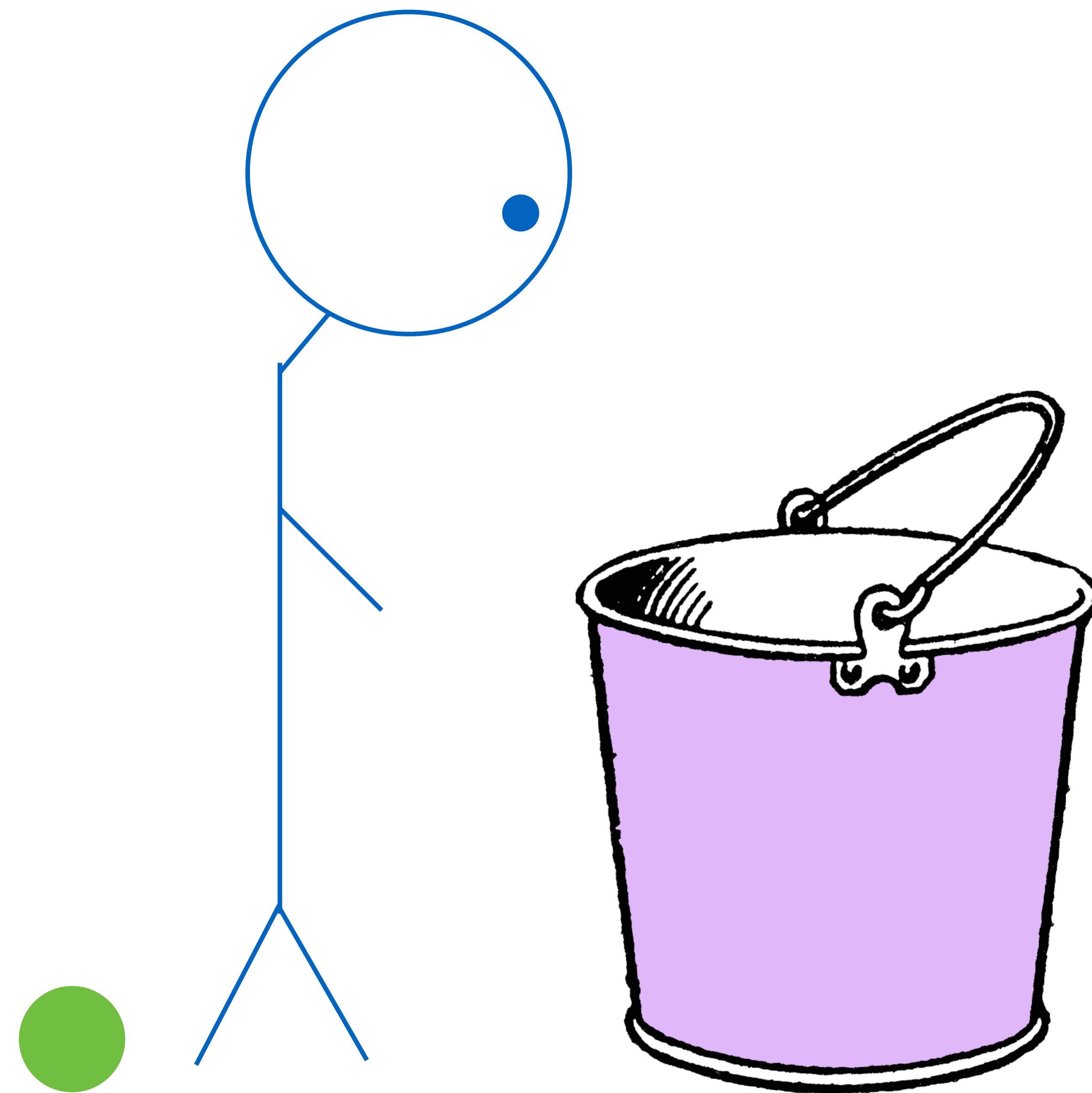


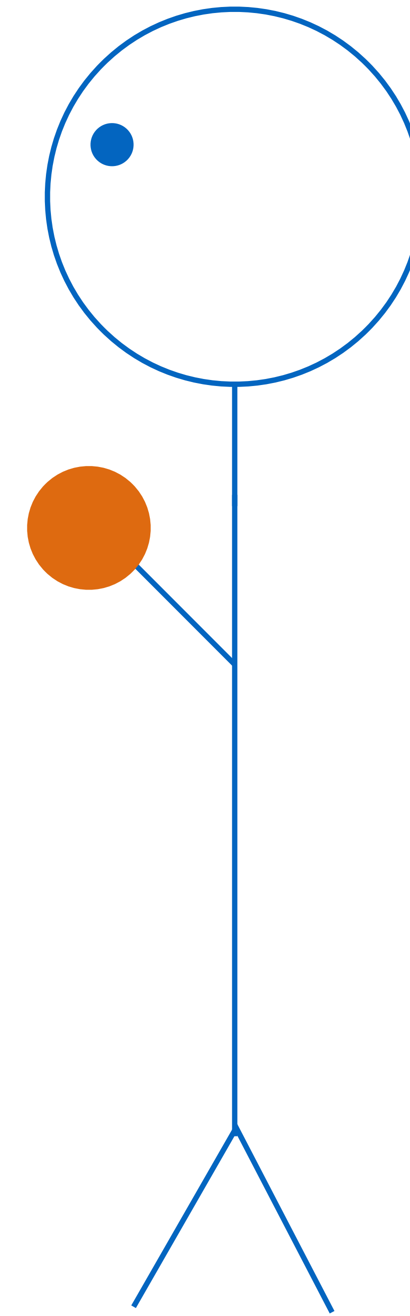
Semaphores

semaphore.wait() (again)

semaphore.signal()

SomeStruct {
…
}



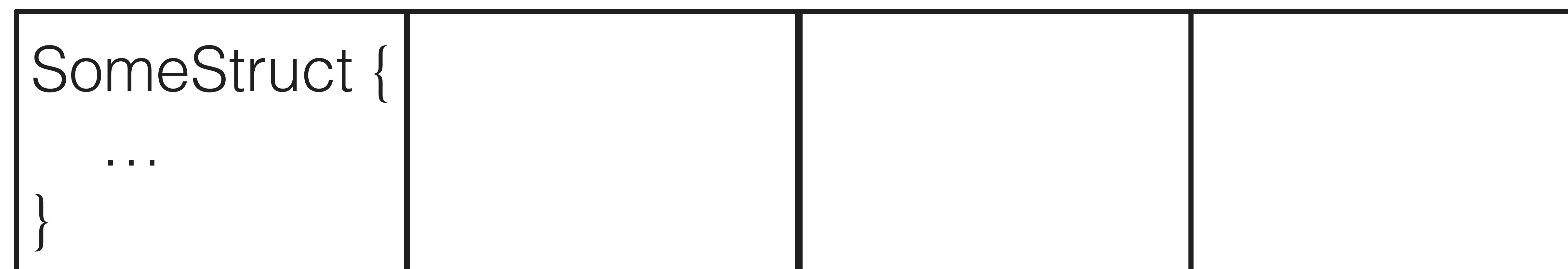


thread1 (blocked)

thread2

Mutex: Unlocked

Buffer:



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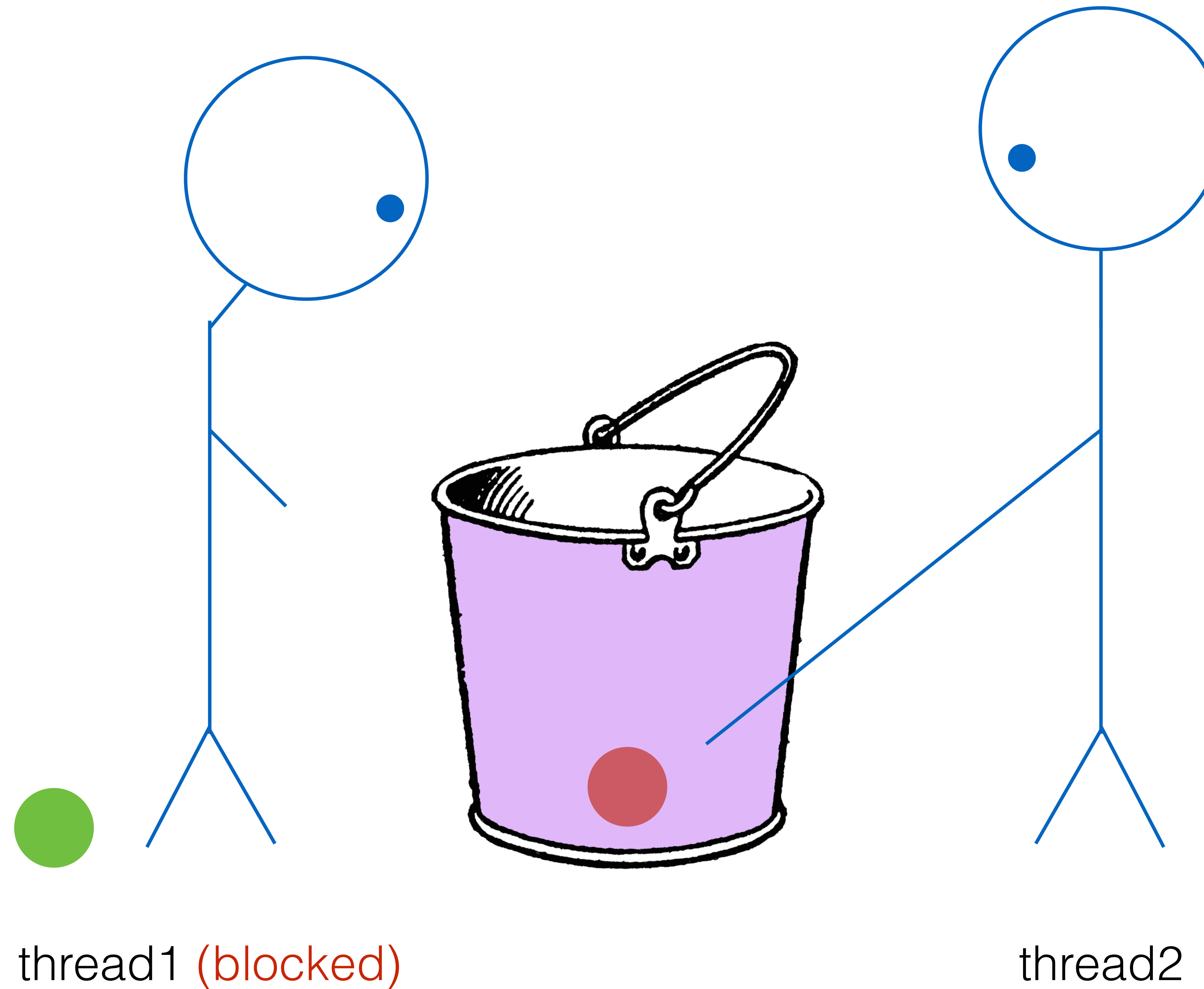

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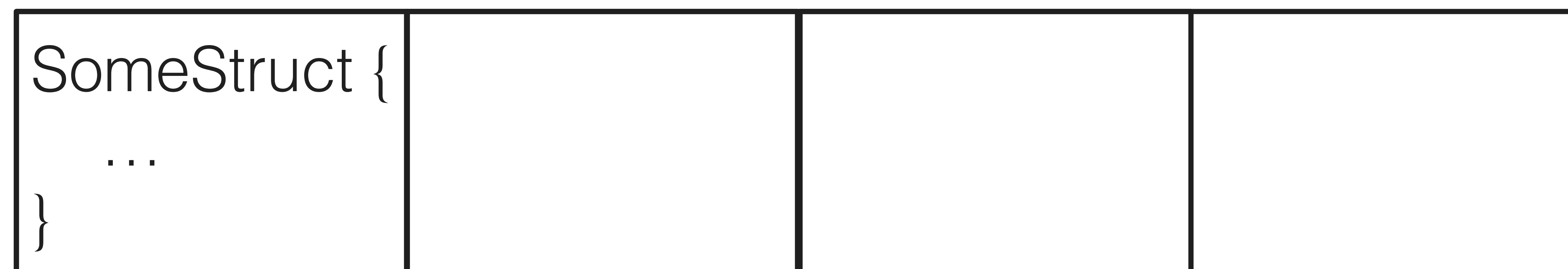

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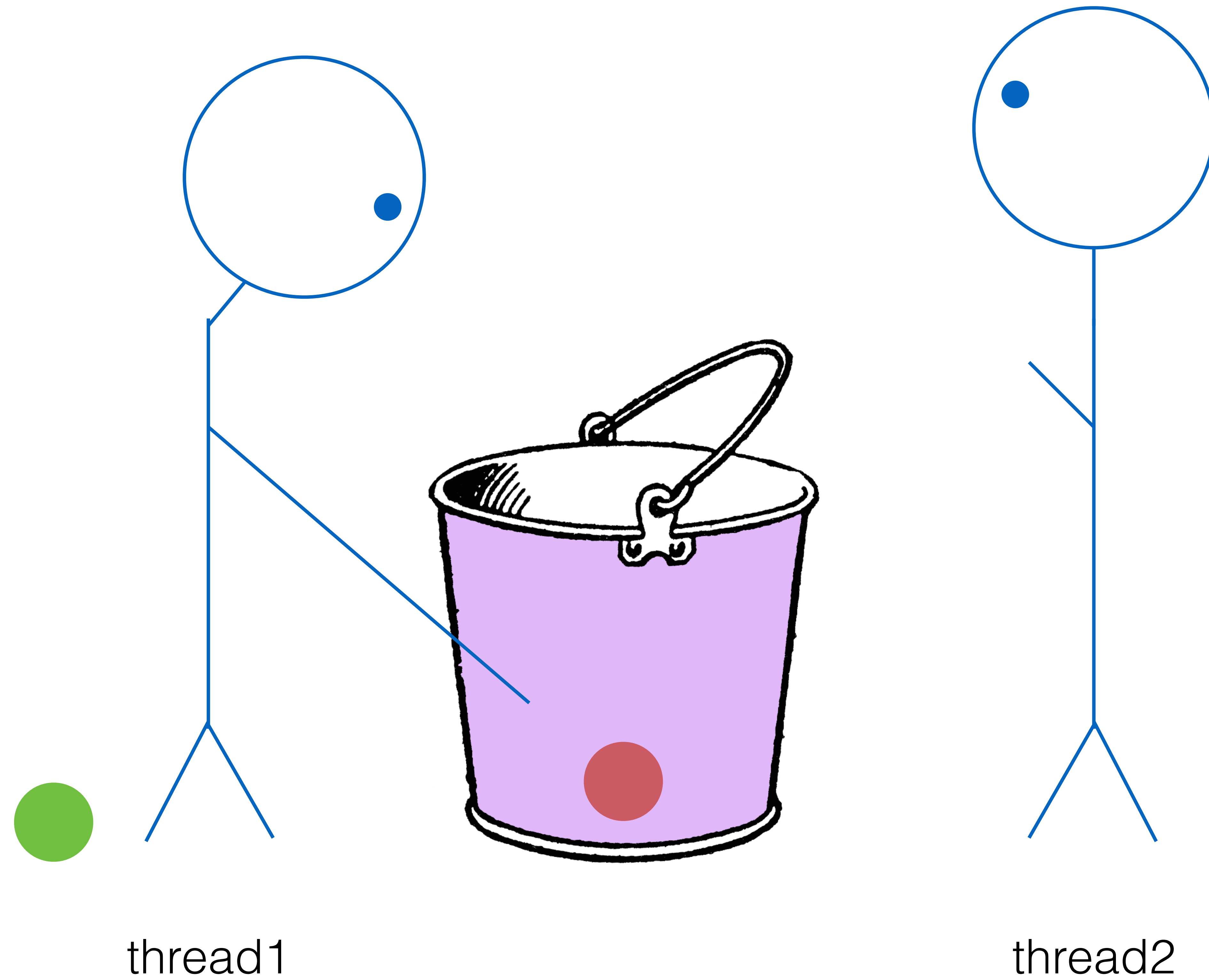

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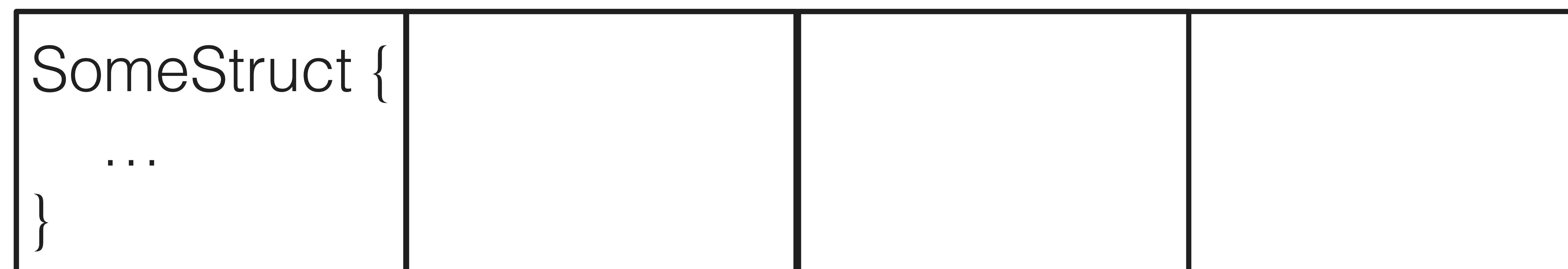

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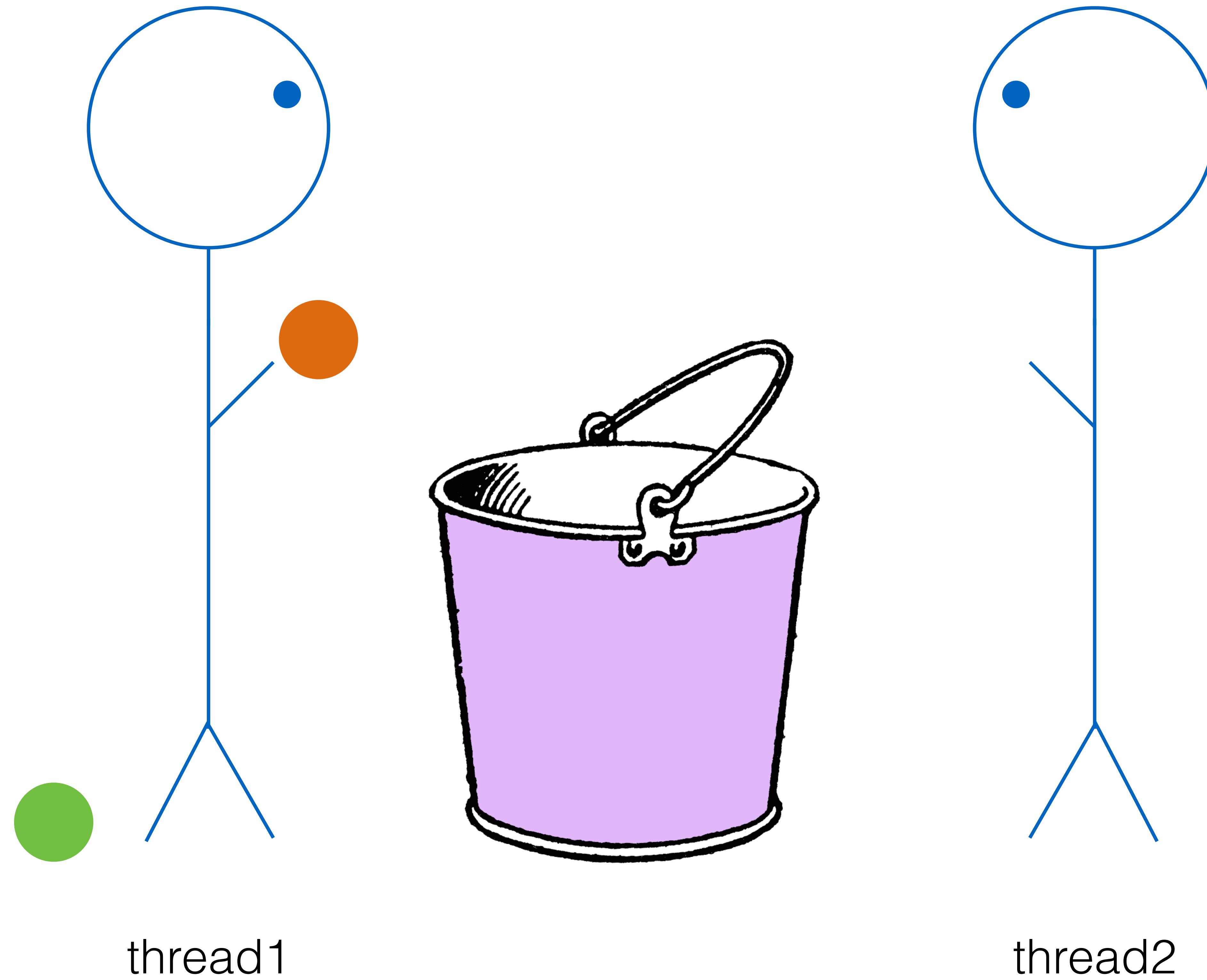

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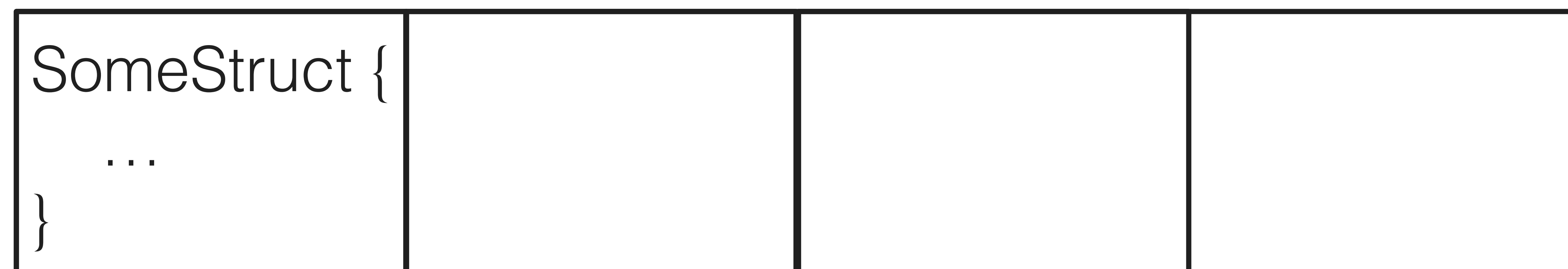

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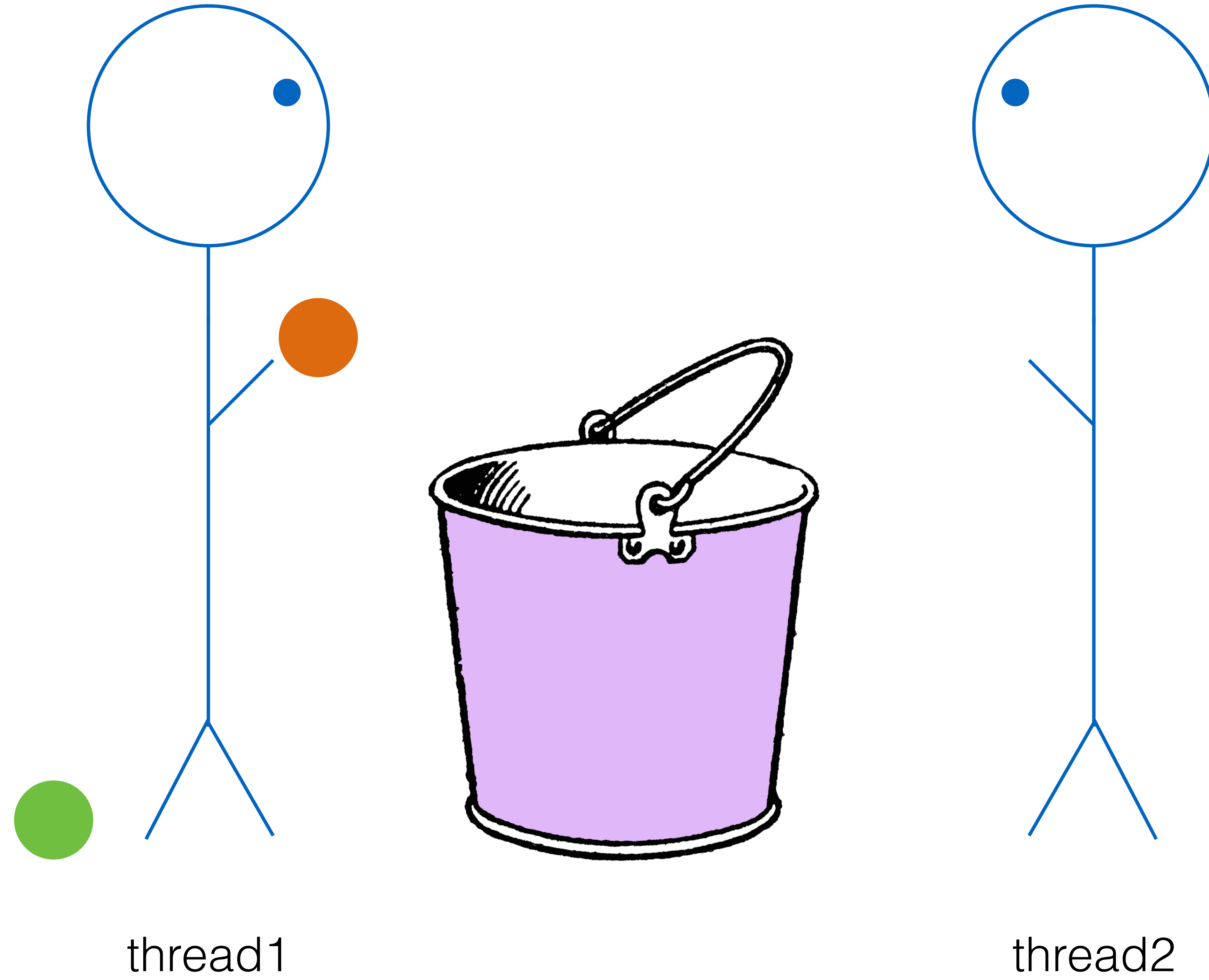

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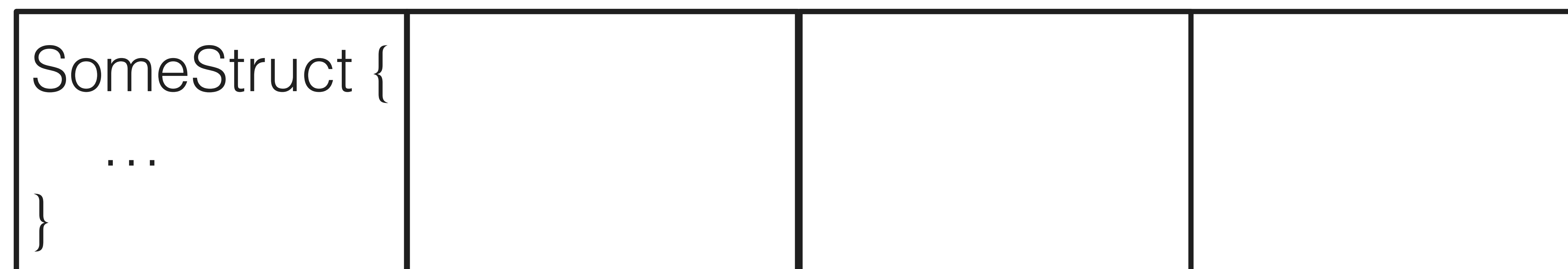

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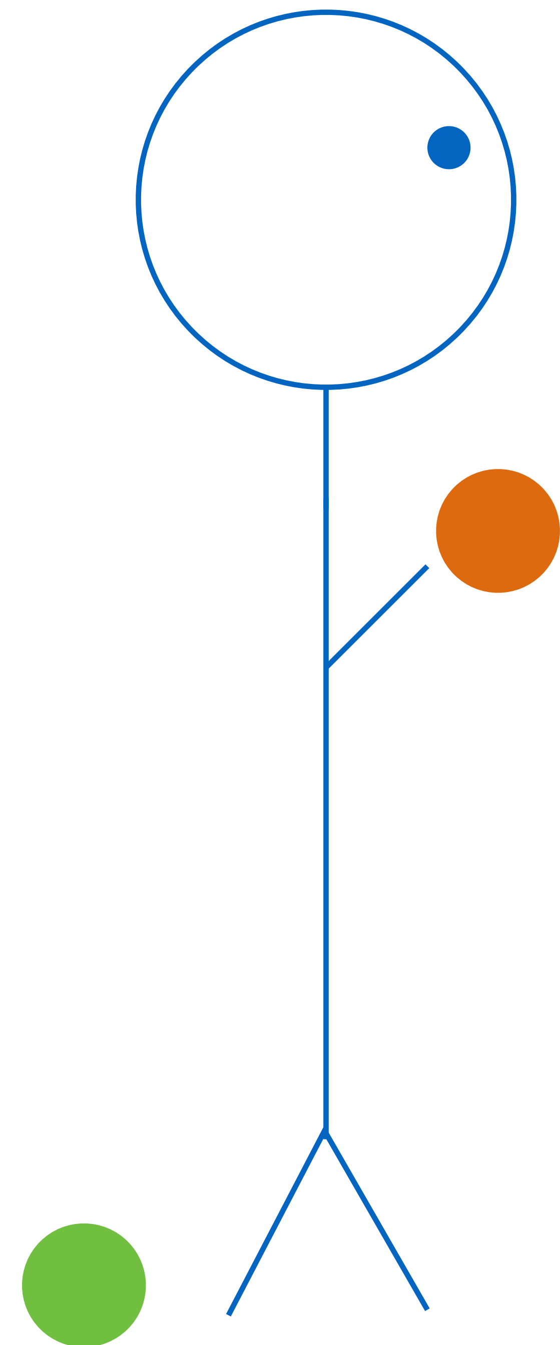
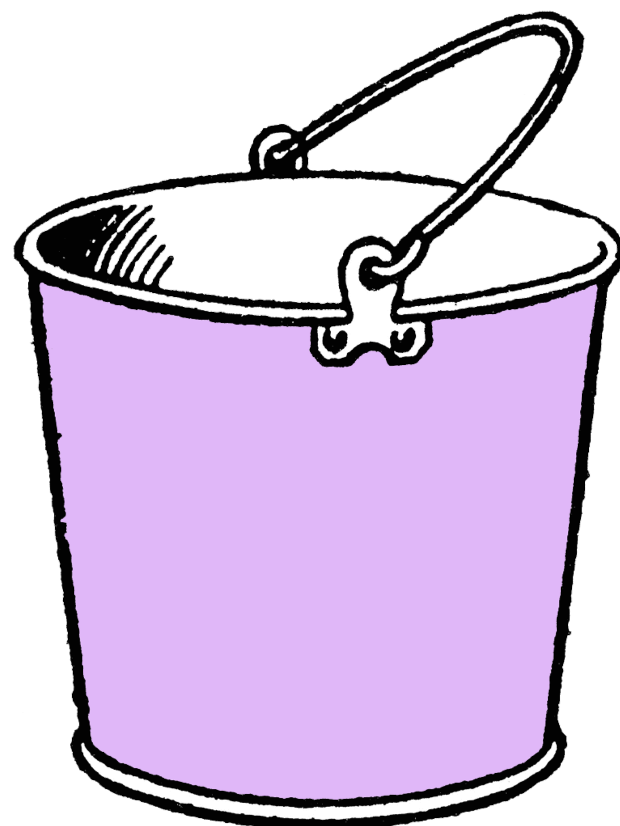
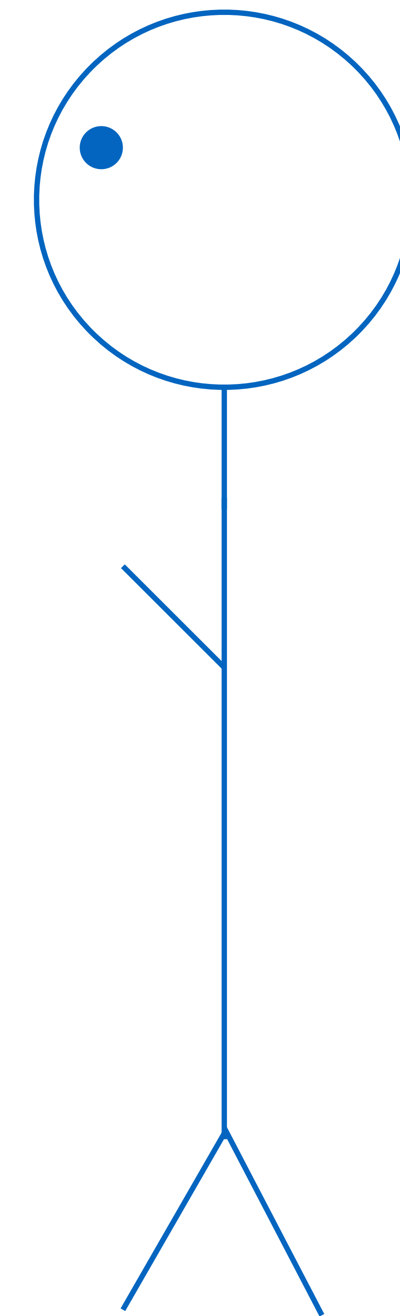




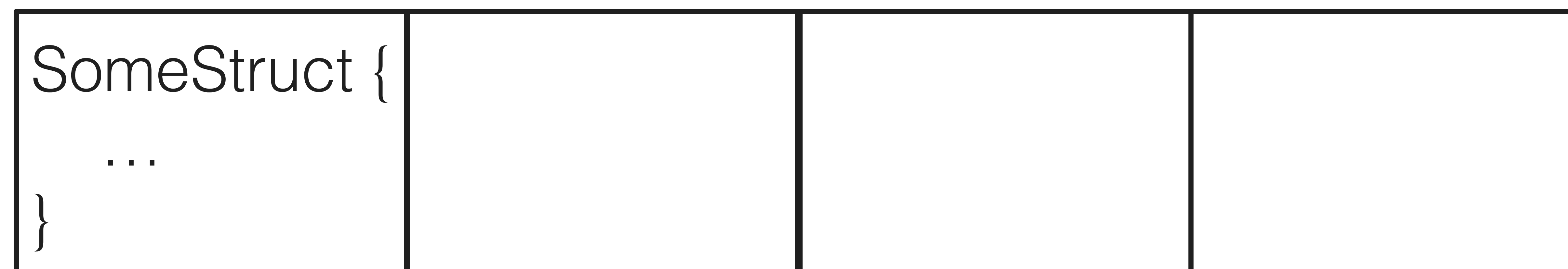


thread1

thread2

Mutex: Locked

Buffer:



Semaphores

SomeStruct {
…
}

SomeStruct {
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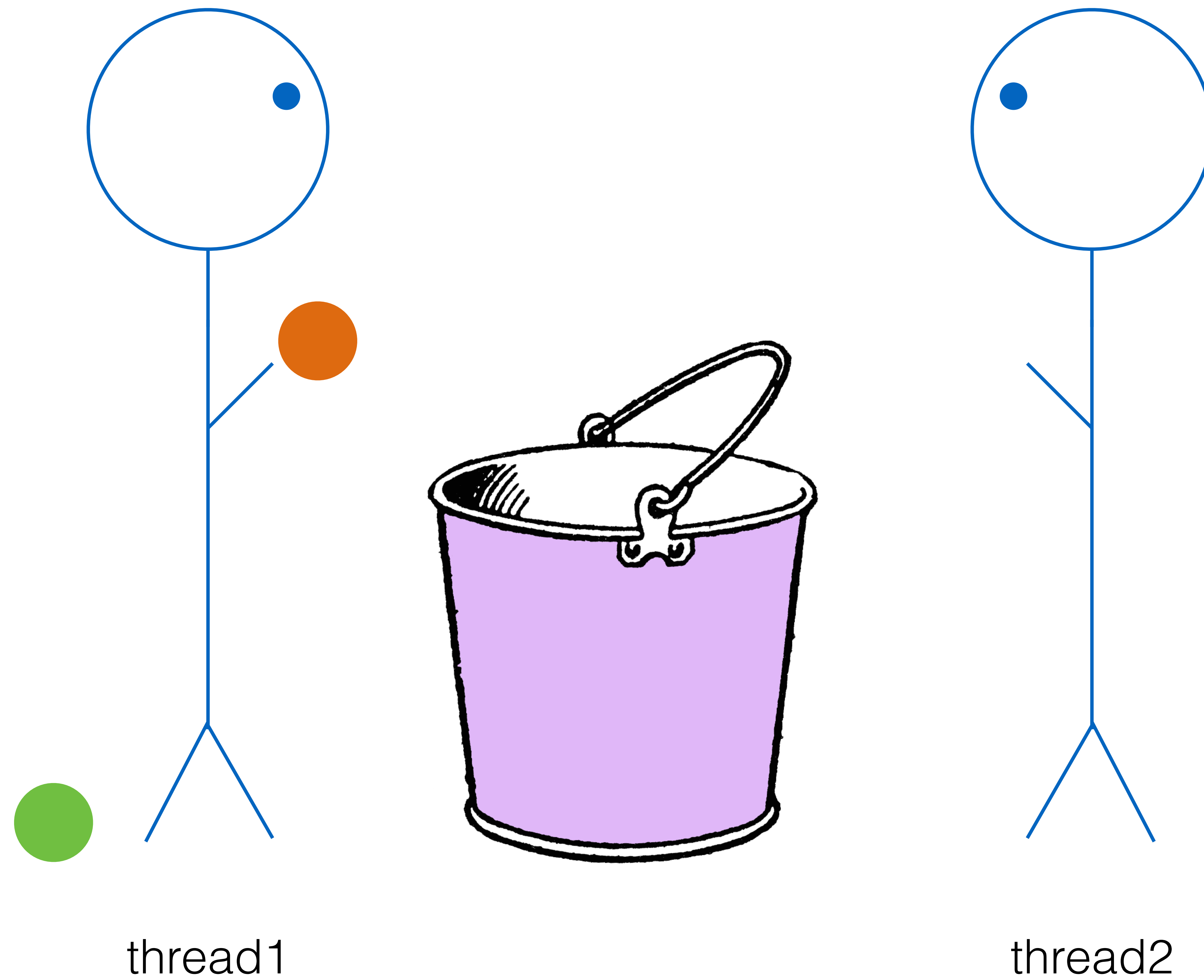


Mutex: Locked

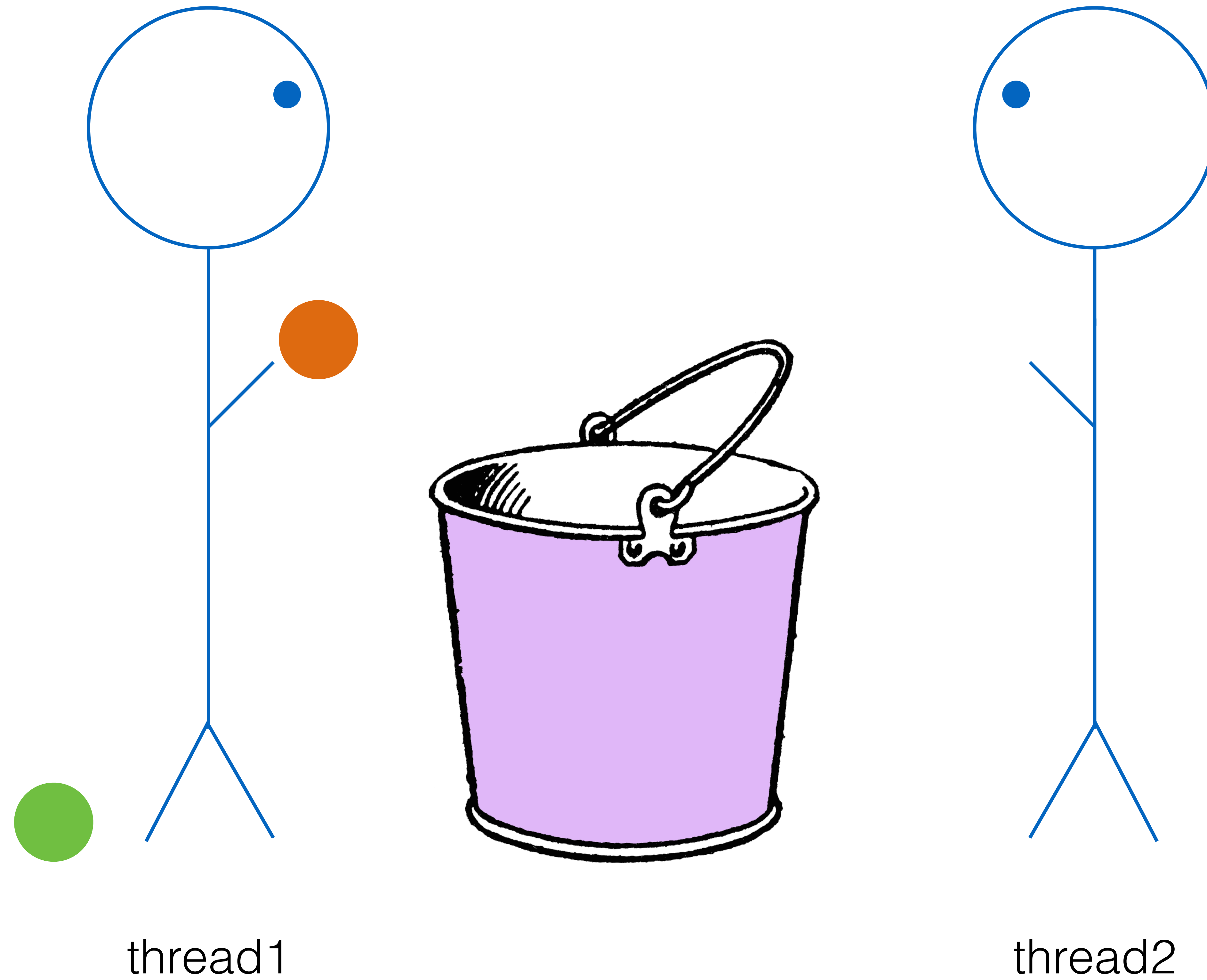
Buffer:

Semaphores

mutex.unlock()

SomeStruct {
    …
}

SomeStruct {
    …
}



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Semaphores

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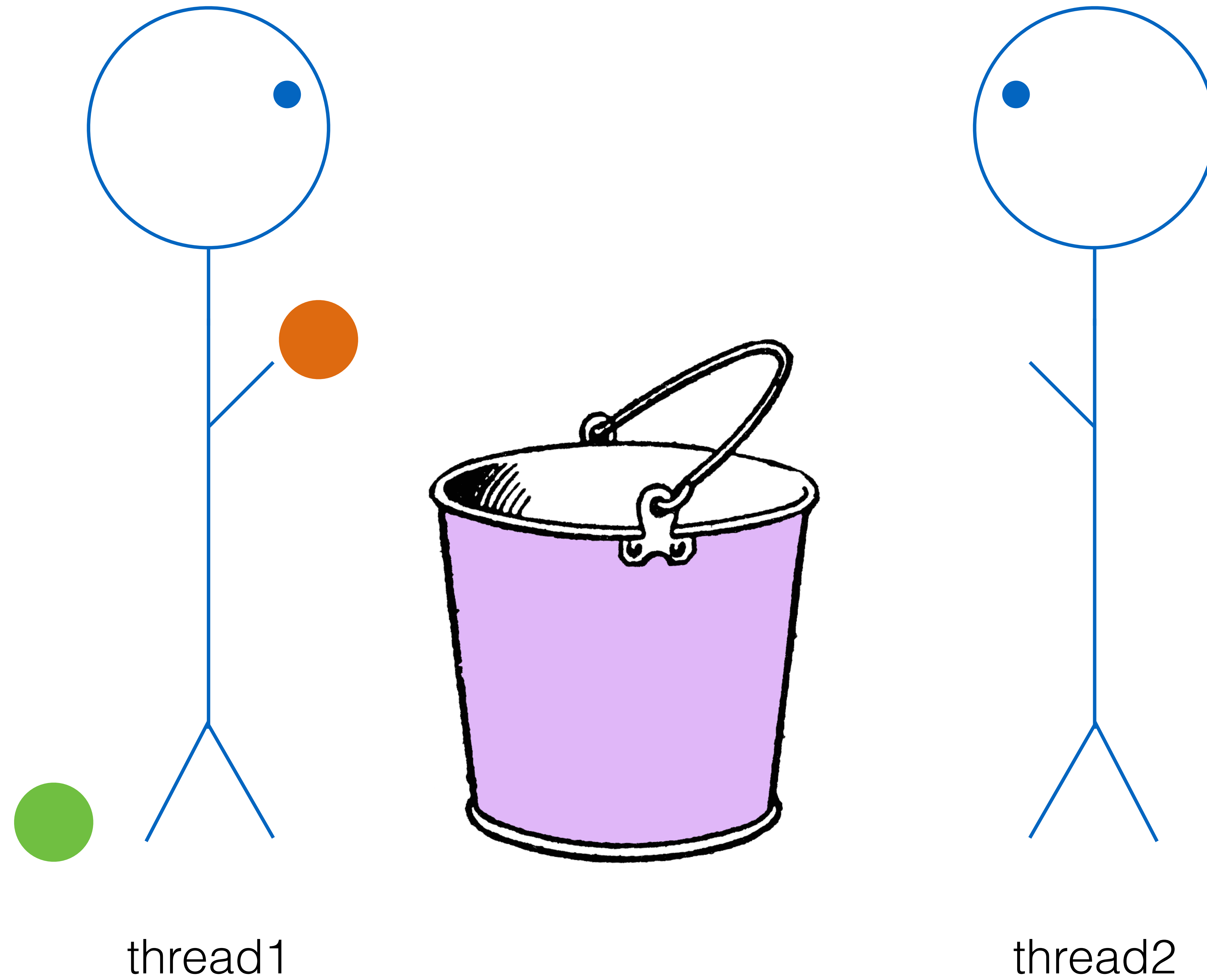
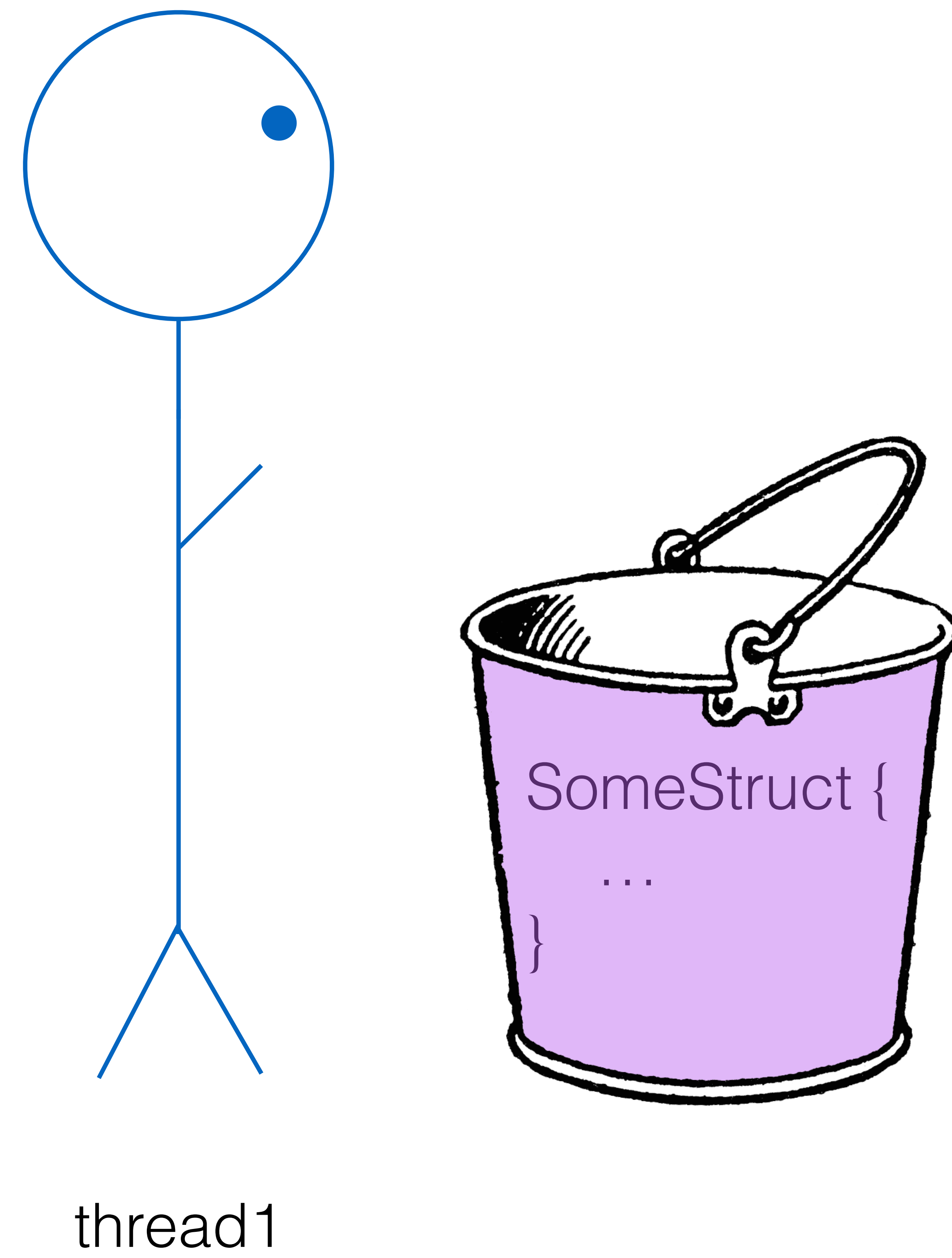


Mutex: Unlocked

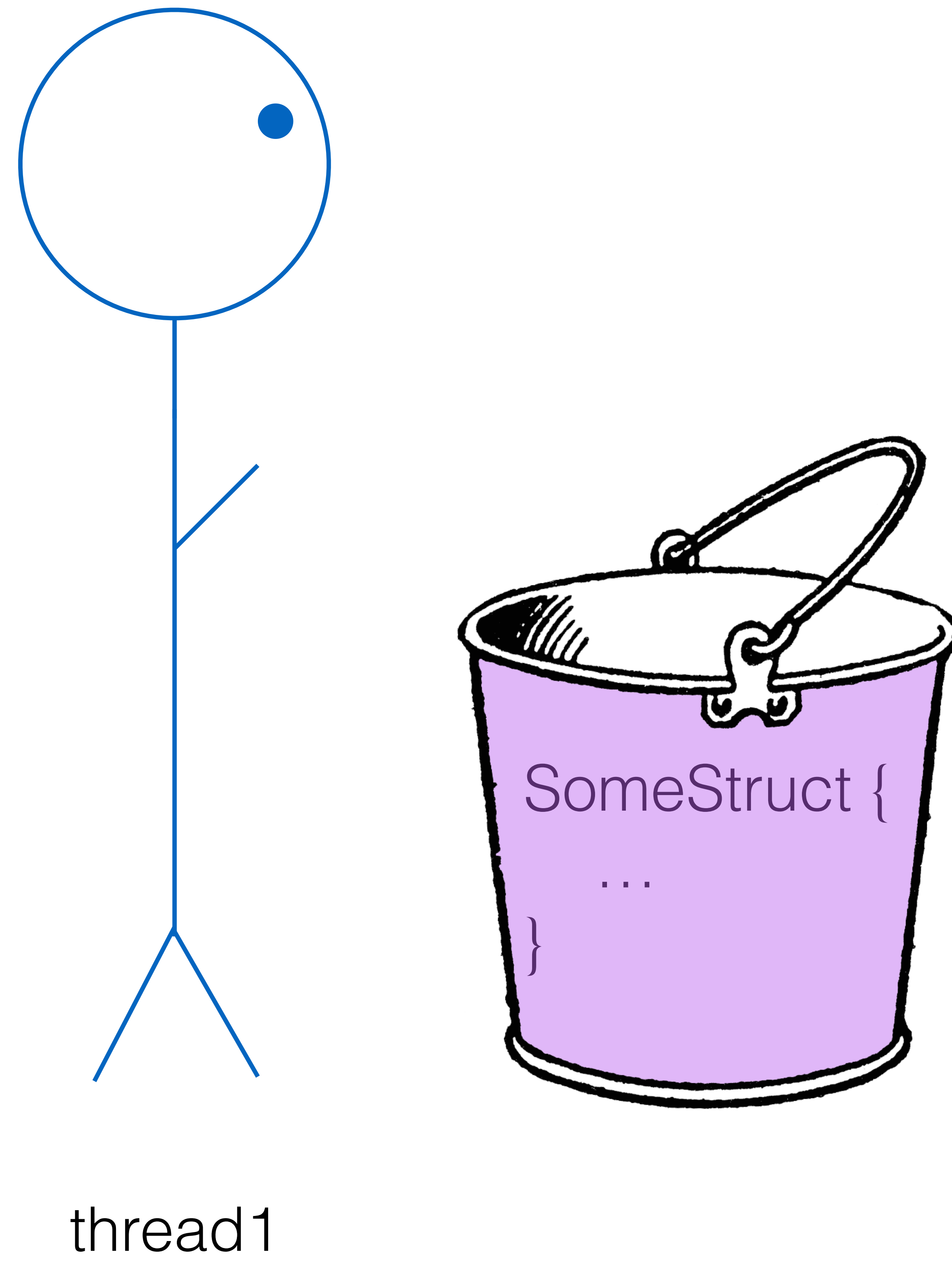
Buffer:

Channels



Channels

```
let struct = receive_end.recv().unwrap()
```



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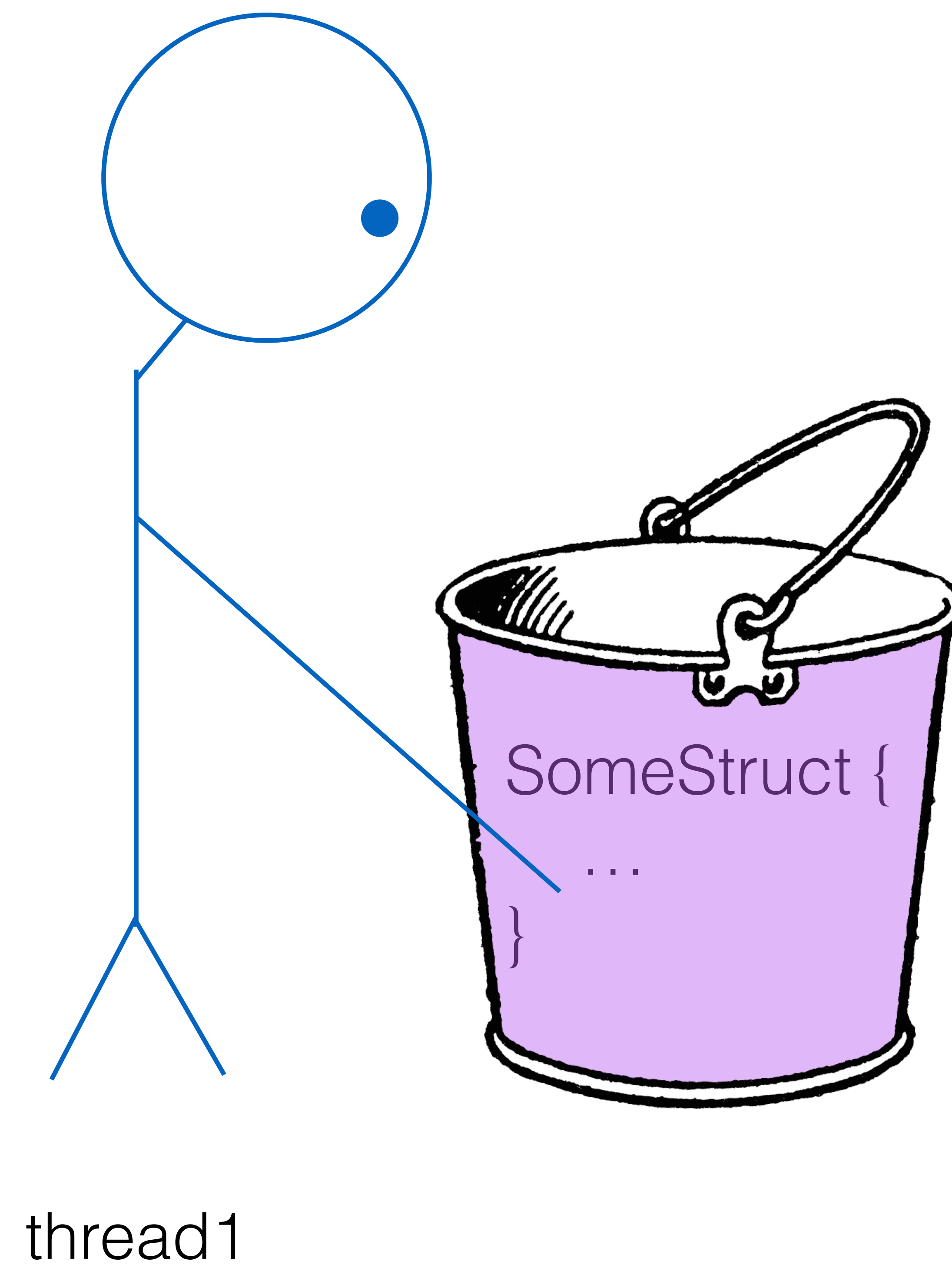

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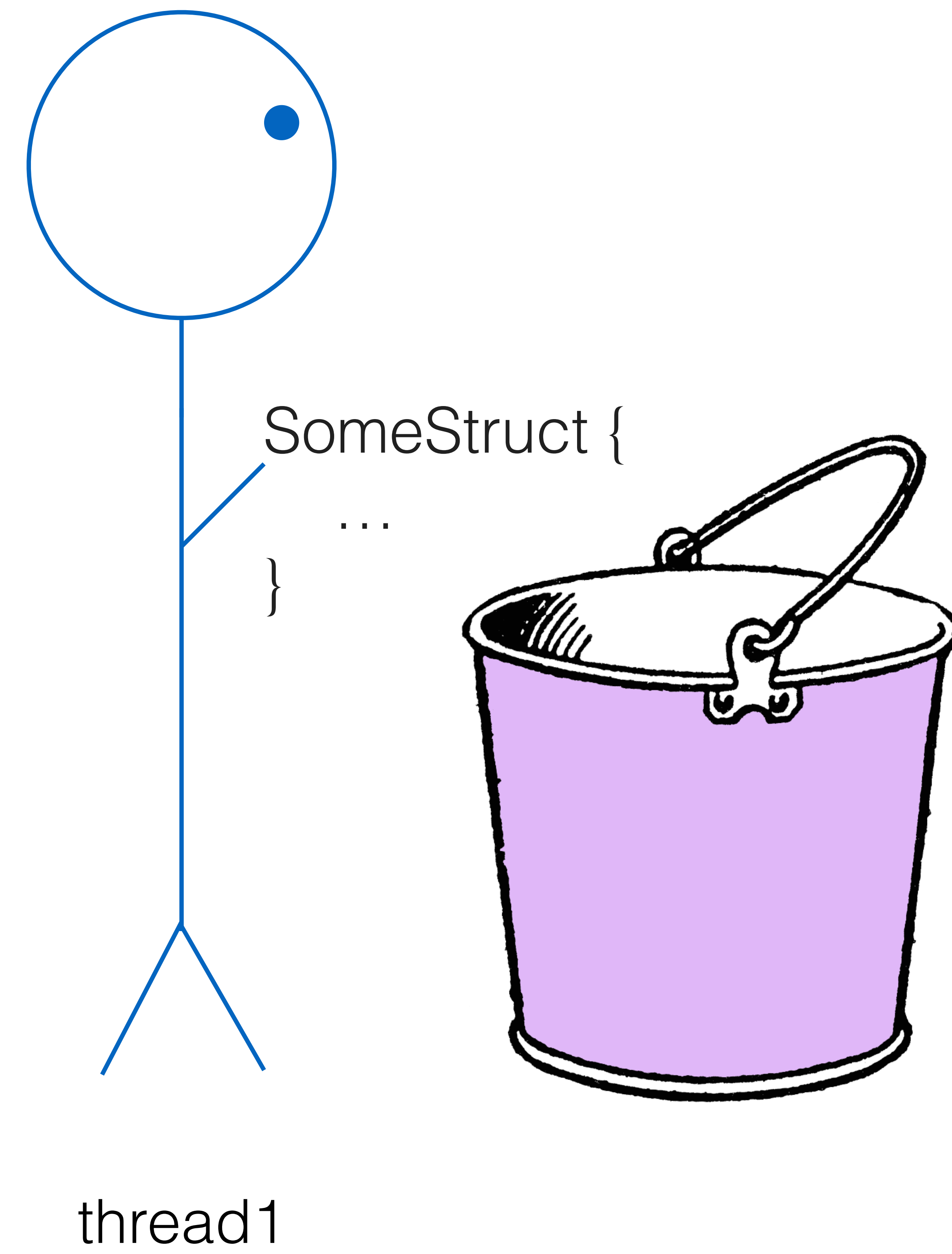
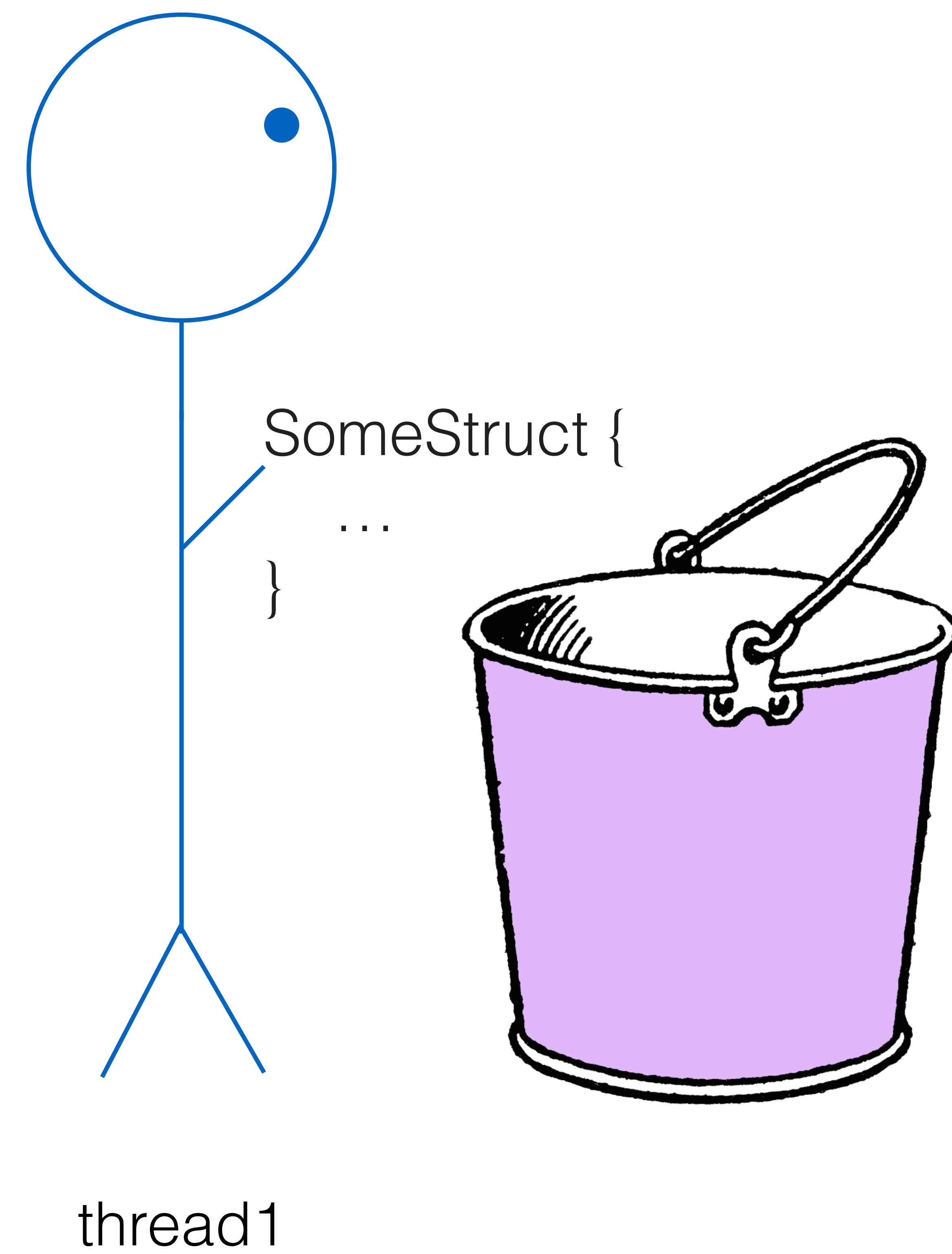


Channels

let struct2 = receive_end.recv().unwrap() (again)



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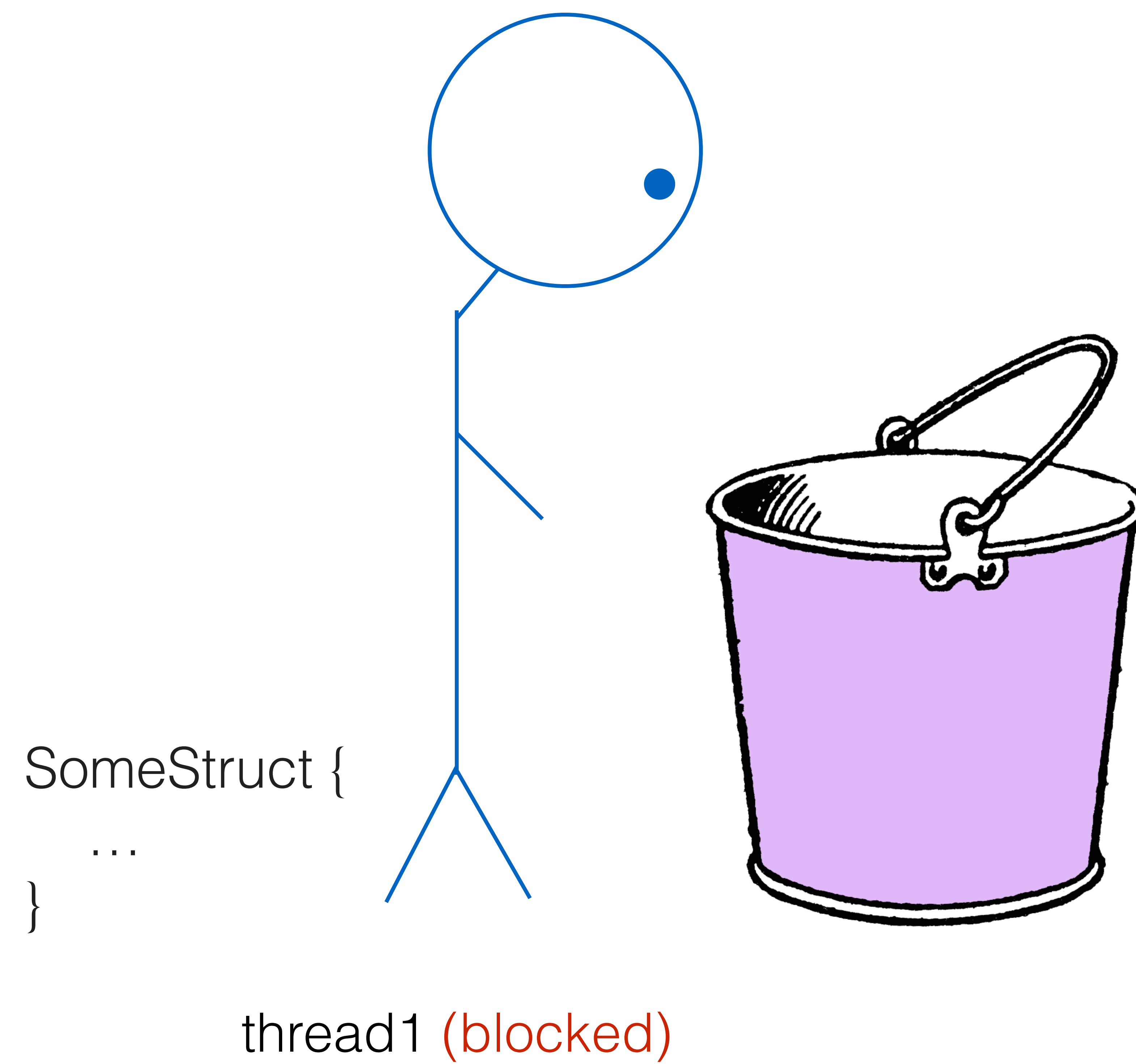

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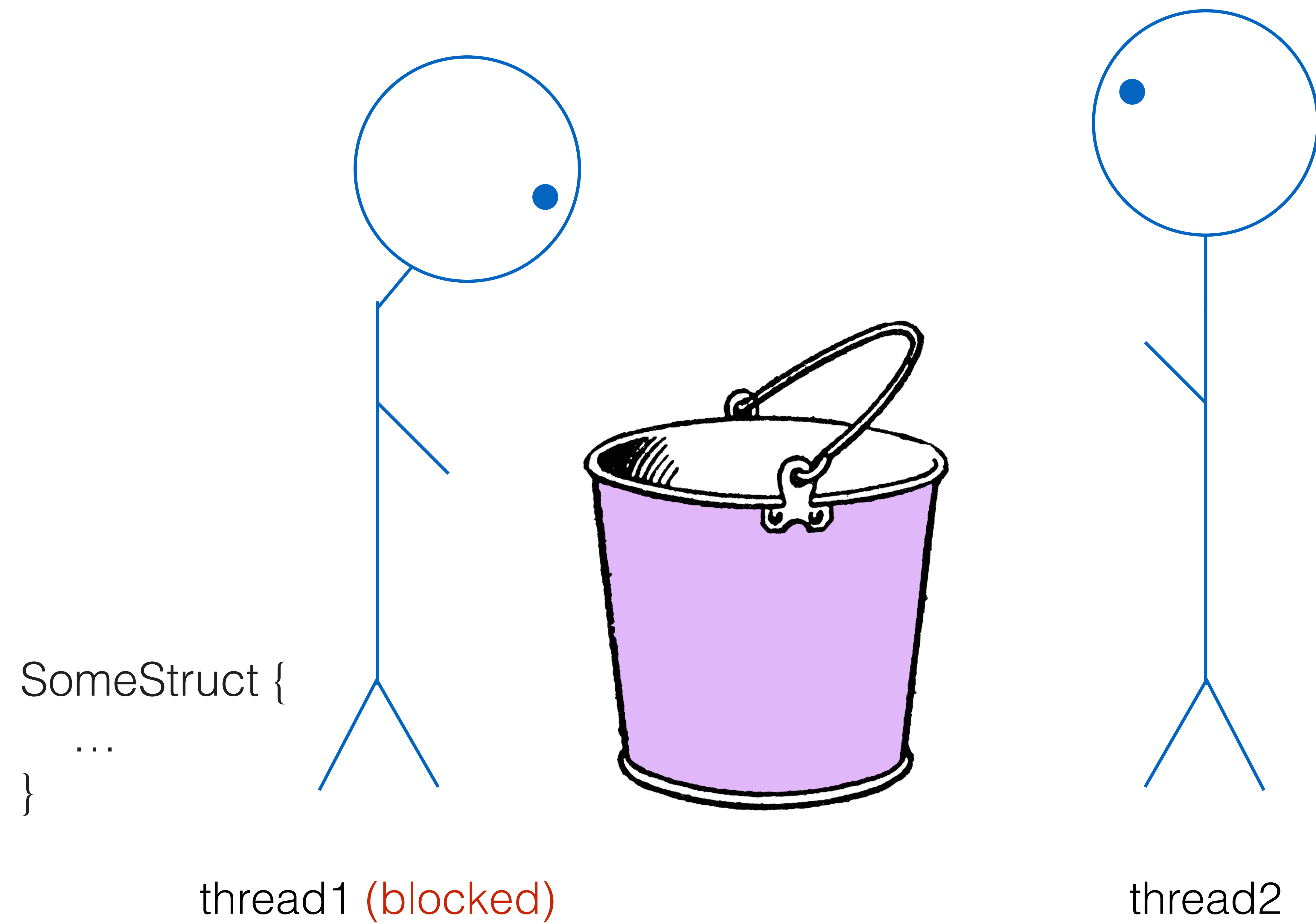
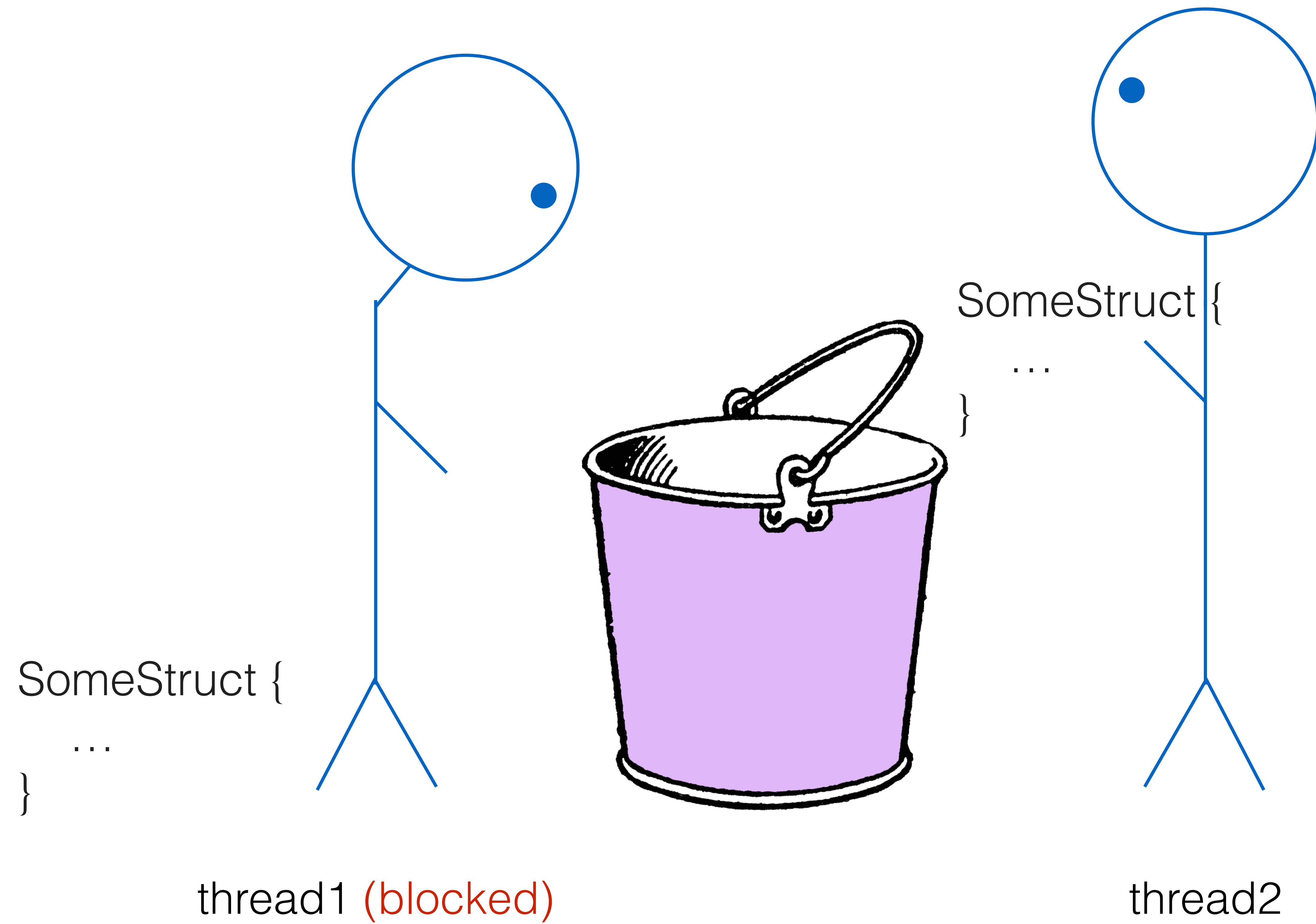


Channels

let struct2 = receive_end.recv().unwrap() (again)

send_end.send(struct).unwrap()



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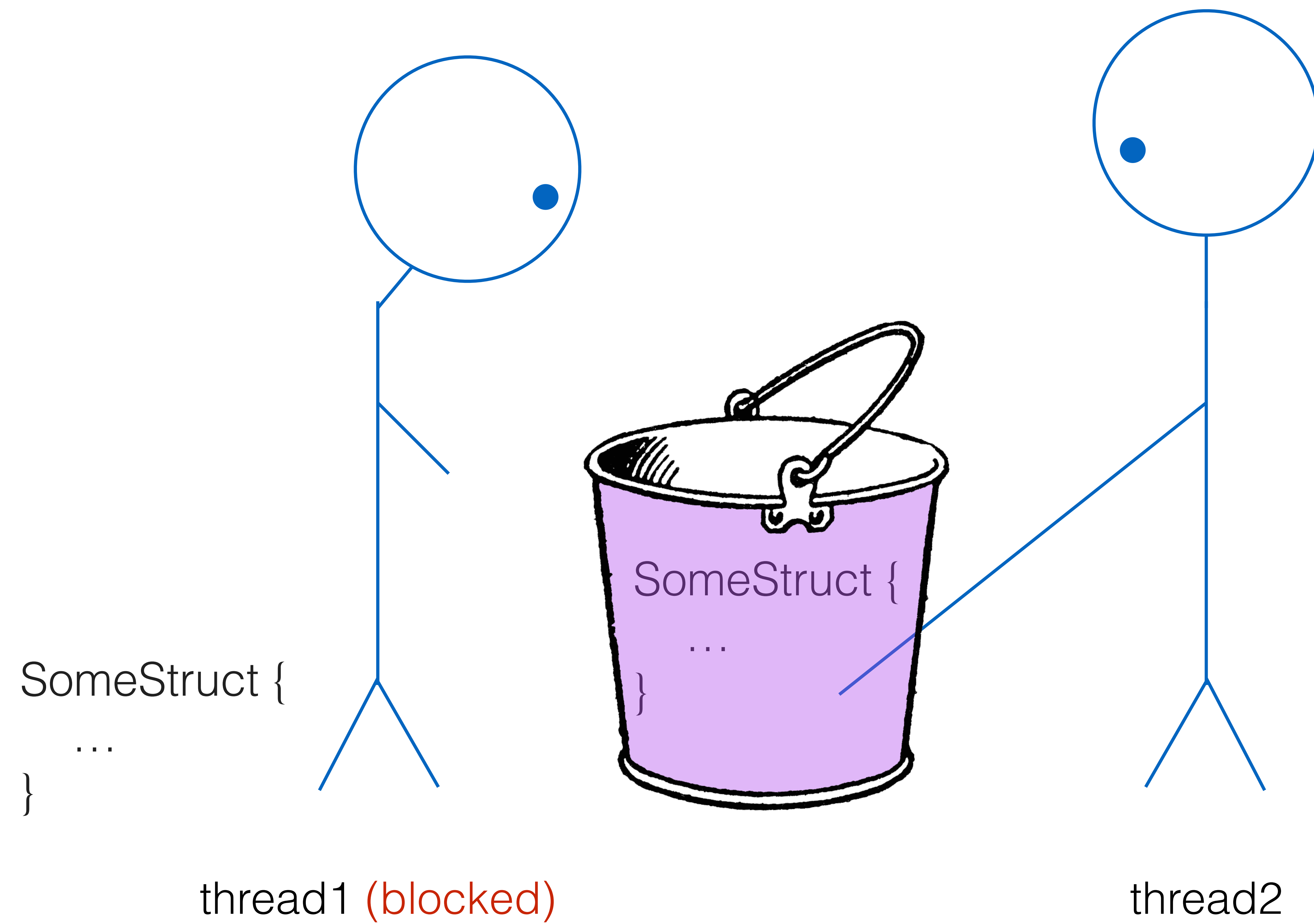

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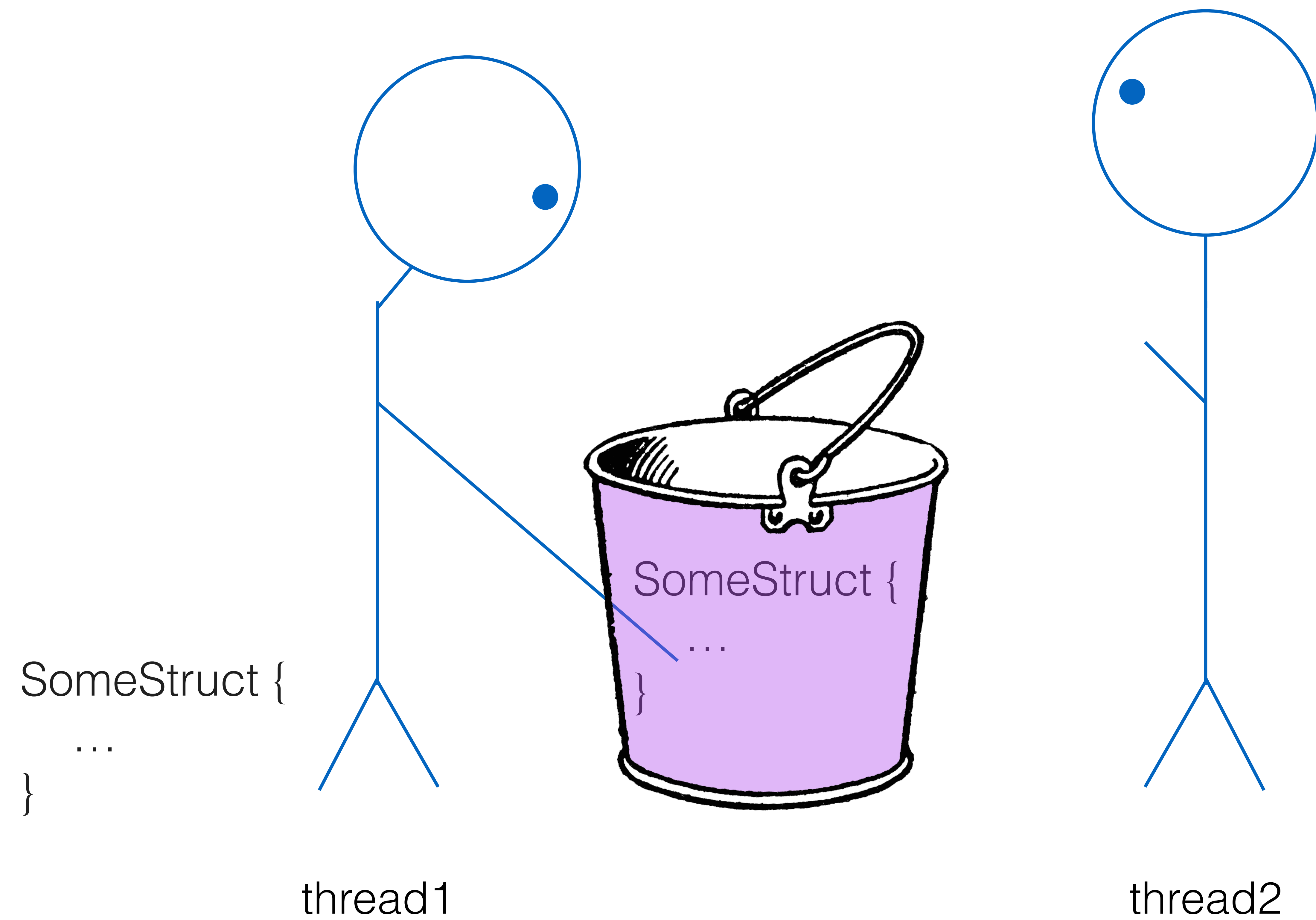

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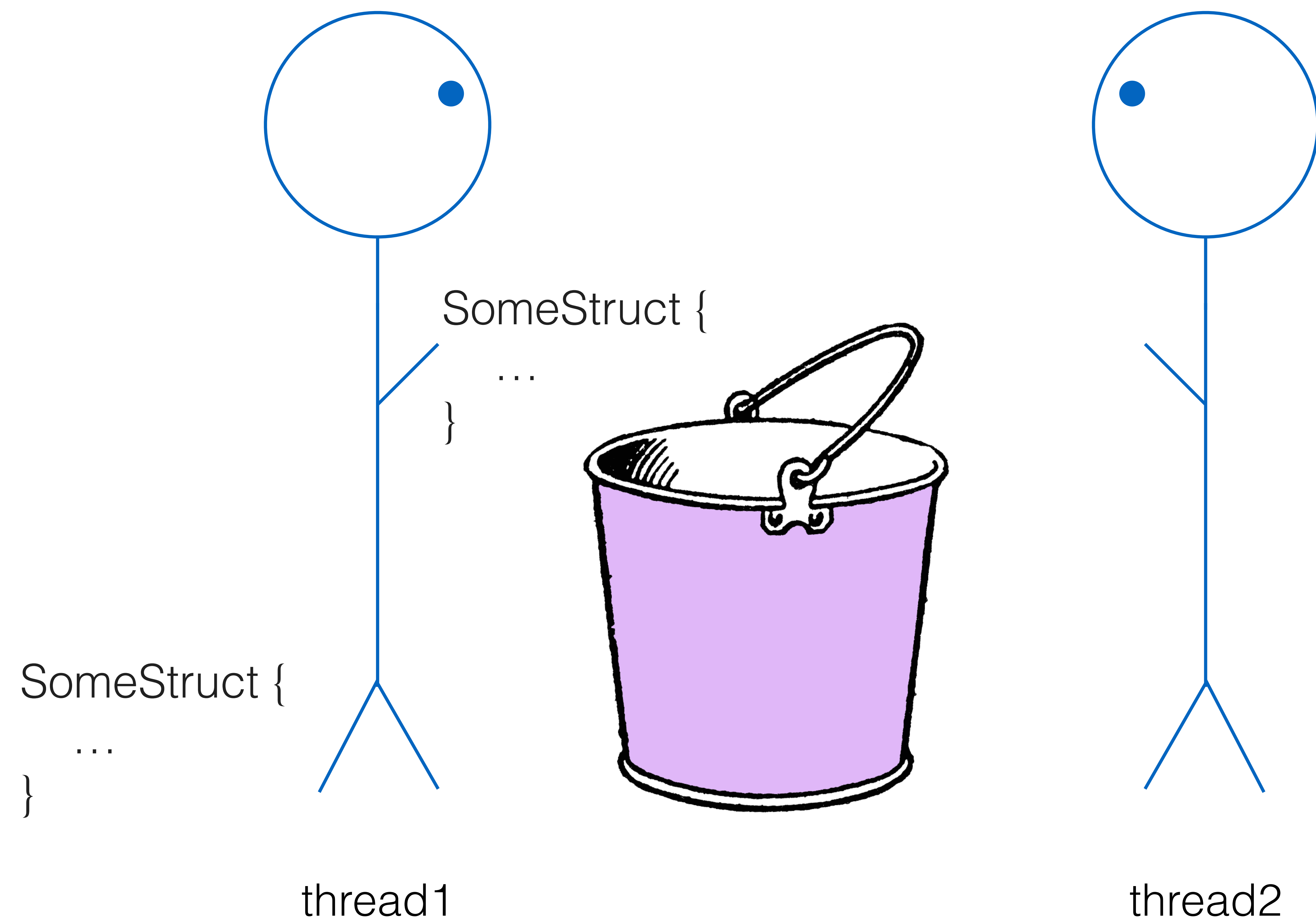
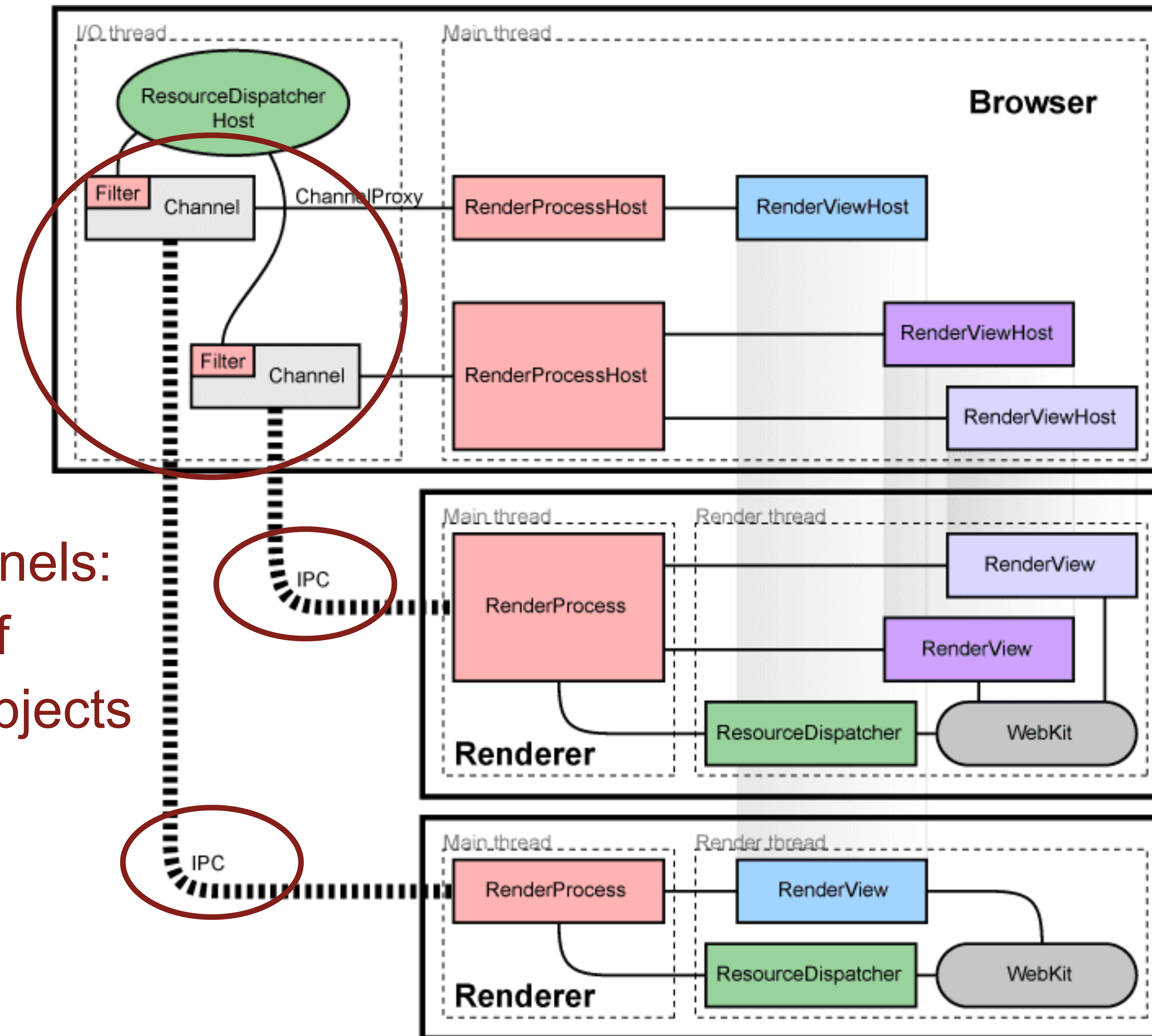


Channels: like strongly-typed pipes

Chrome architecture diagram



Inter-Process Communication channels:
Pipes, but with an extra layer of
abstraction to serialize/deserialize objects

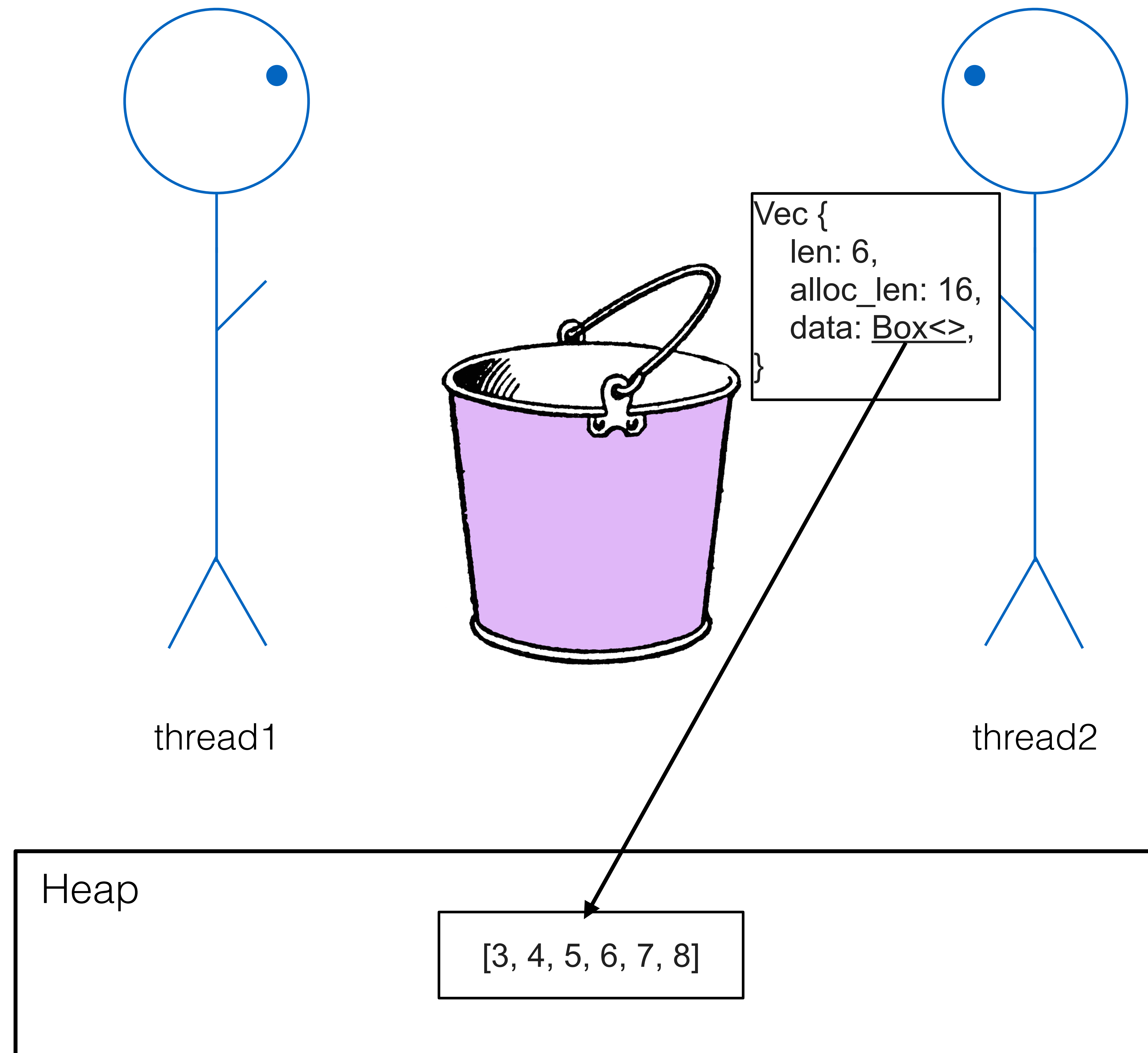
https://www.chromium.org/developers/design-documents/multi-process-architecture (slightly out of date)

Using channels

Isn’t message passing bad for performance?

- If you don’t share memory, then you need to copy data into/out of messages. That seems expensive. What gives?
- Theory != practice
  - We share *some* memory (the heap) and only make shallow copies into channels

Partly-shared memory (shallow copies only)



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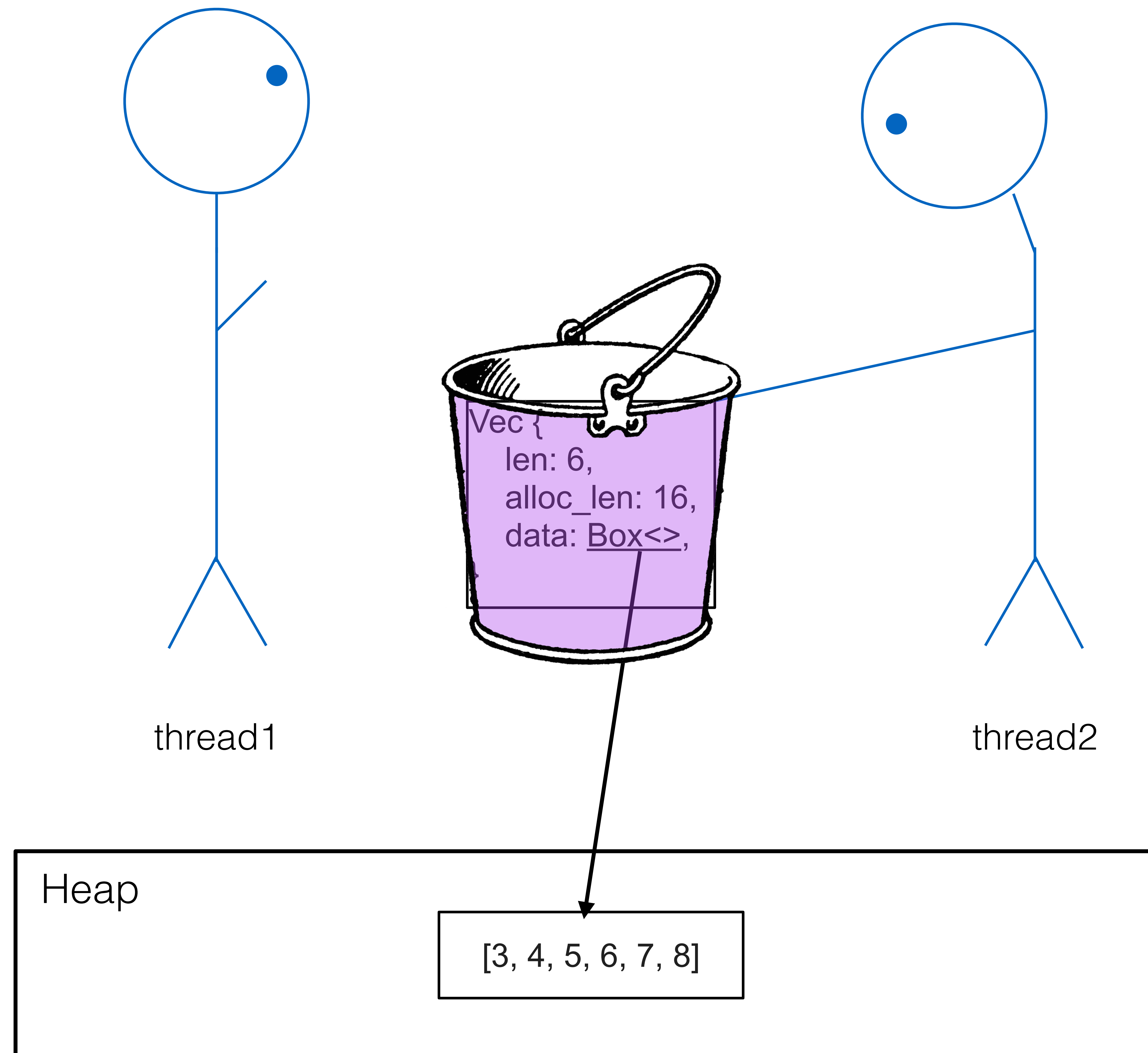

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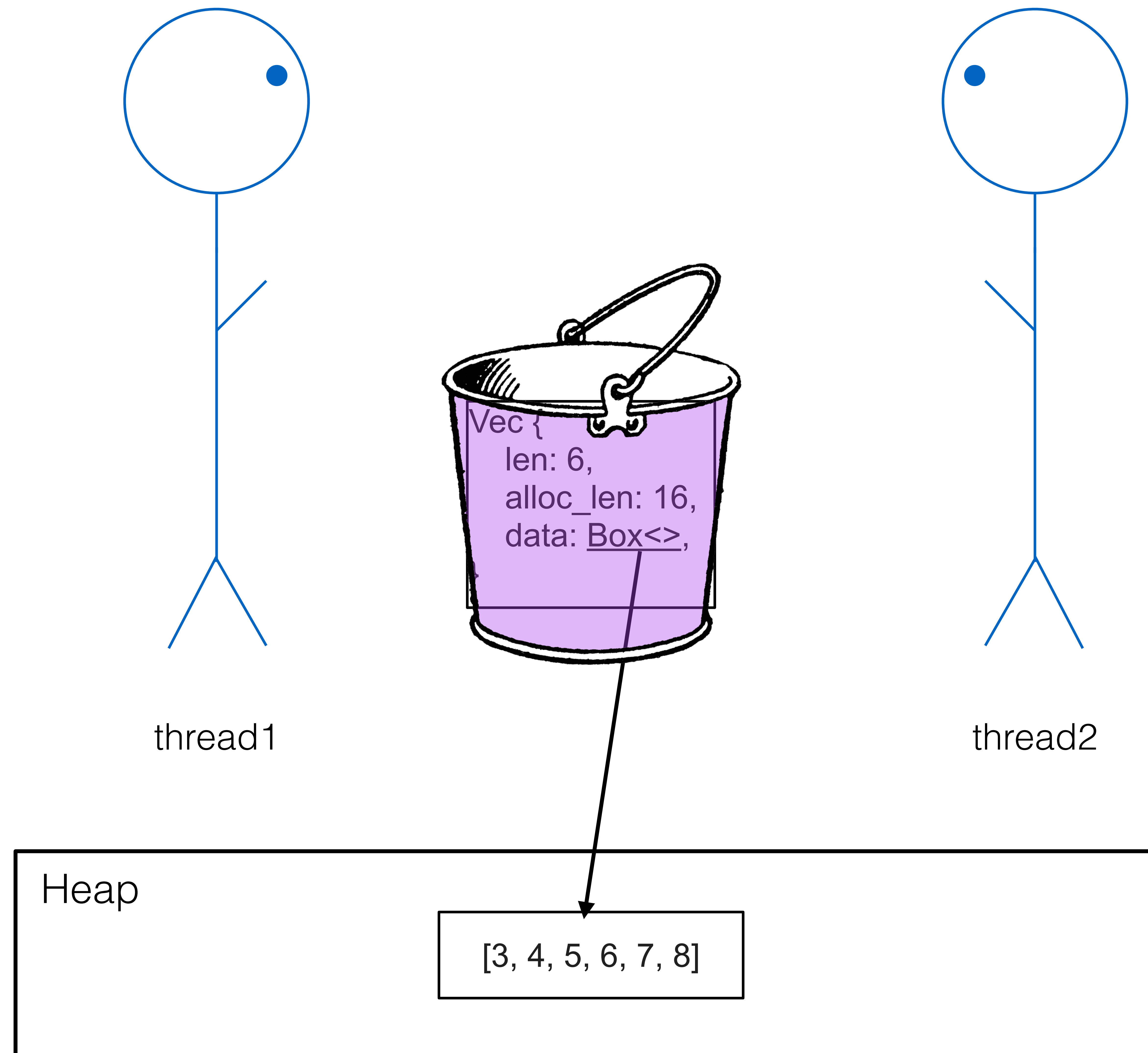

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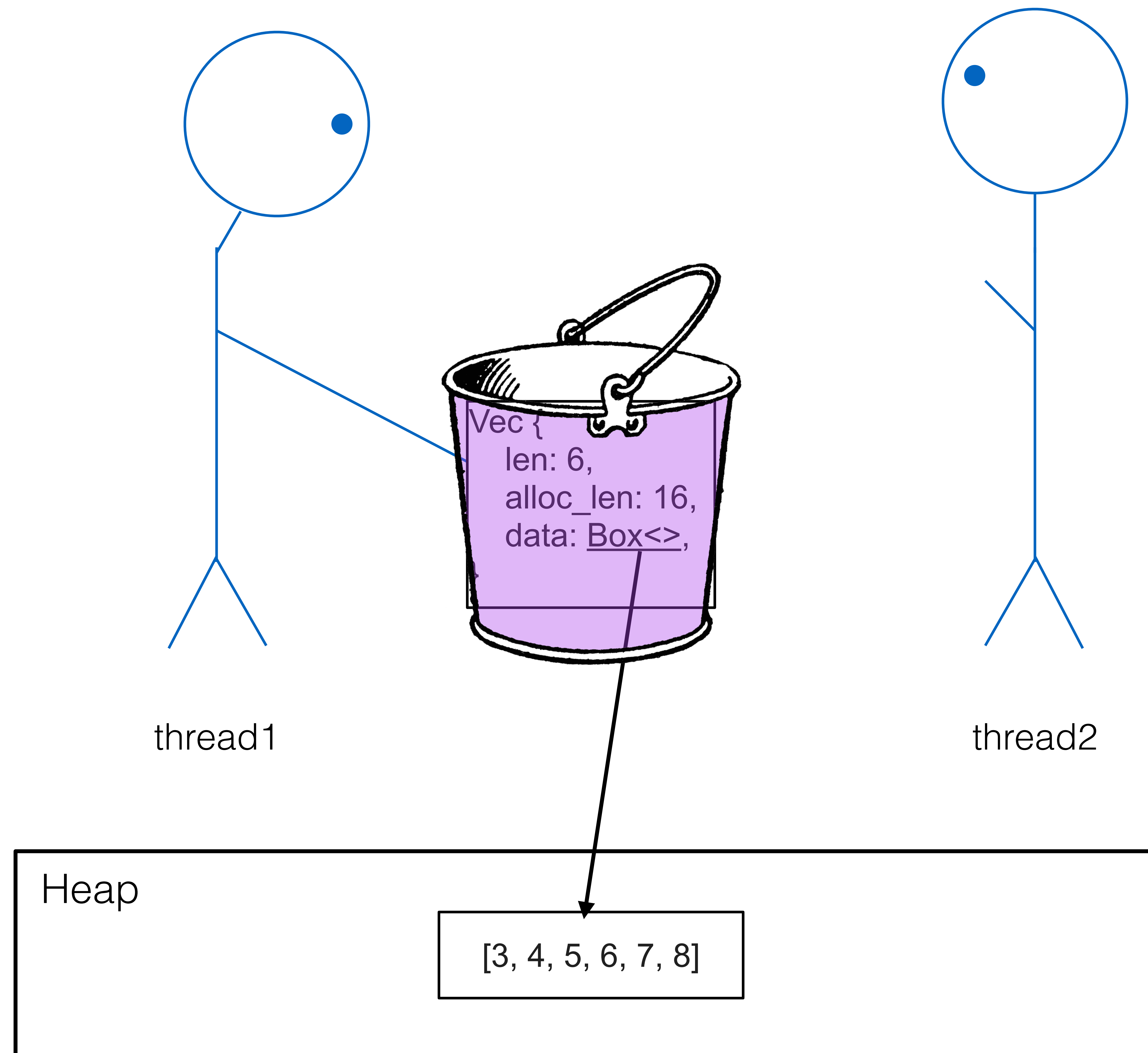

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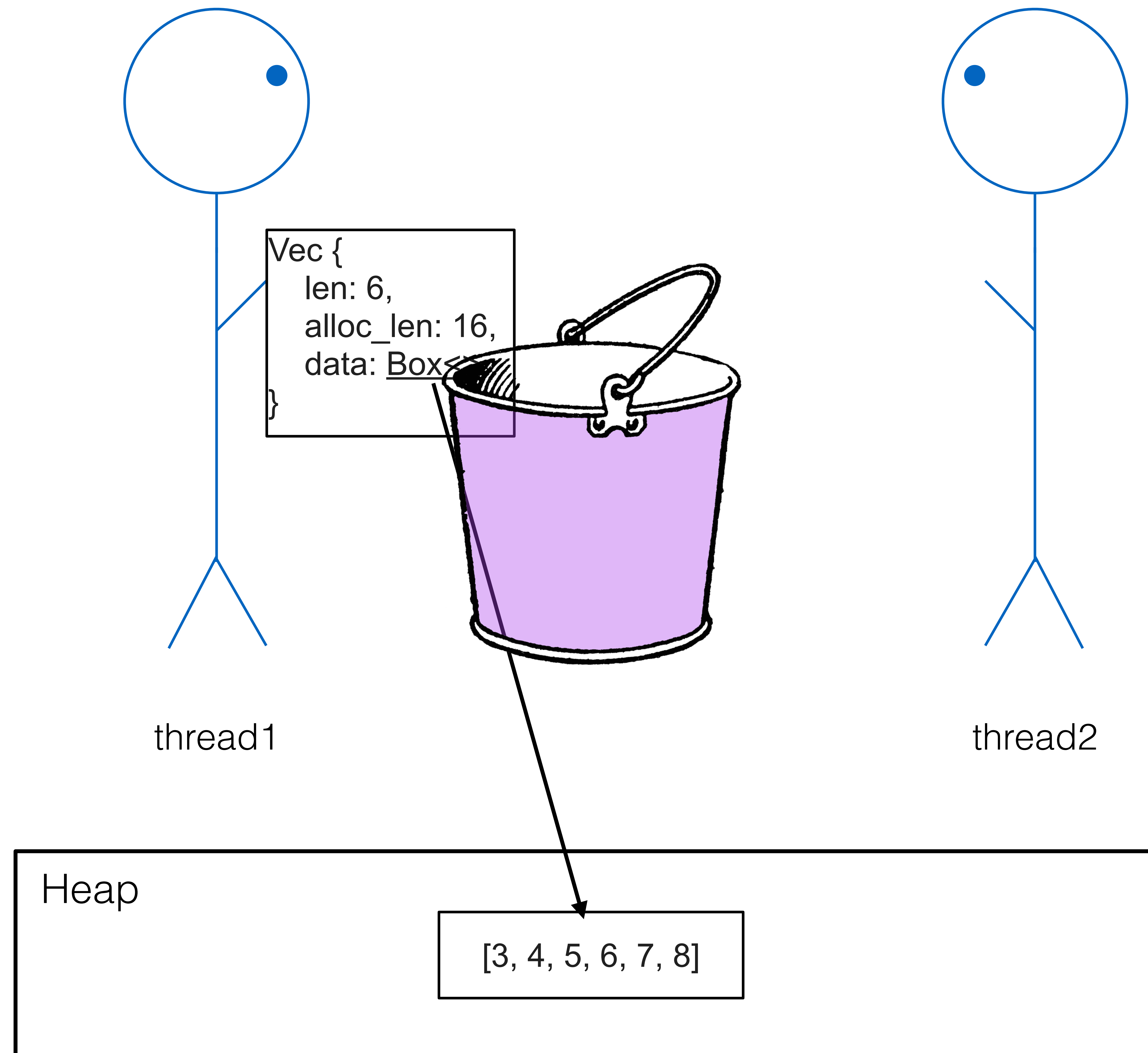


Isn’t message passing bad for performance?

- If you don’t share memory, then you need to copy data into/out of messages. That seems expensive. What gives?
- Theory != practice
    - We share *some* memory (the heap) and only make shallow copies into channels
- In Go, passing pointers is potentially dangerous! Channels make data races less likely but don’t preclude races if you use them wrong
- In Rust, passing pointers (e.g. Box) is always safe despite sharing memory
    - When you send to a channel, ownership of value is transferred to the channel
    - The compiler will ensure you don’t use a pointer after it has been moved into the channel

Channel APIs and implementations

- The ideal channel is an MPMC (multi-producer, multi-consumer) channel
- It’s really, really hard to implement a fast and safe MPMC channel!
  - Go’s channels are known for being slow
  - A fast implementation needs to use lock-free programming techniques to avoid lock contention and reduce latency

Channel APIs and implementations

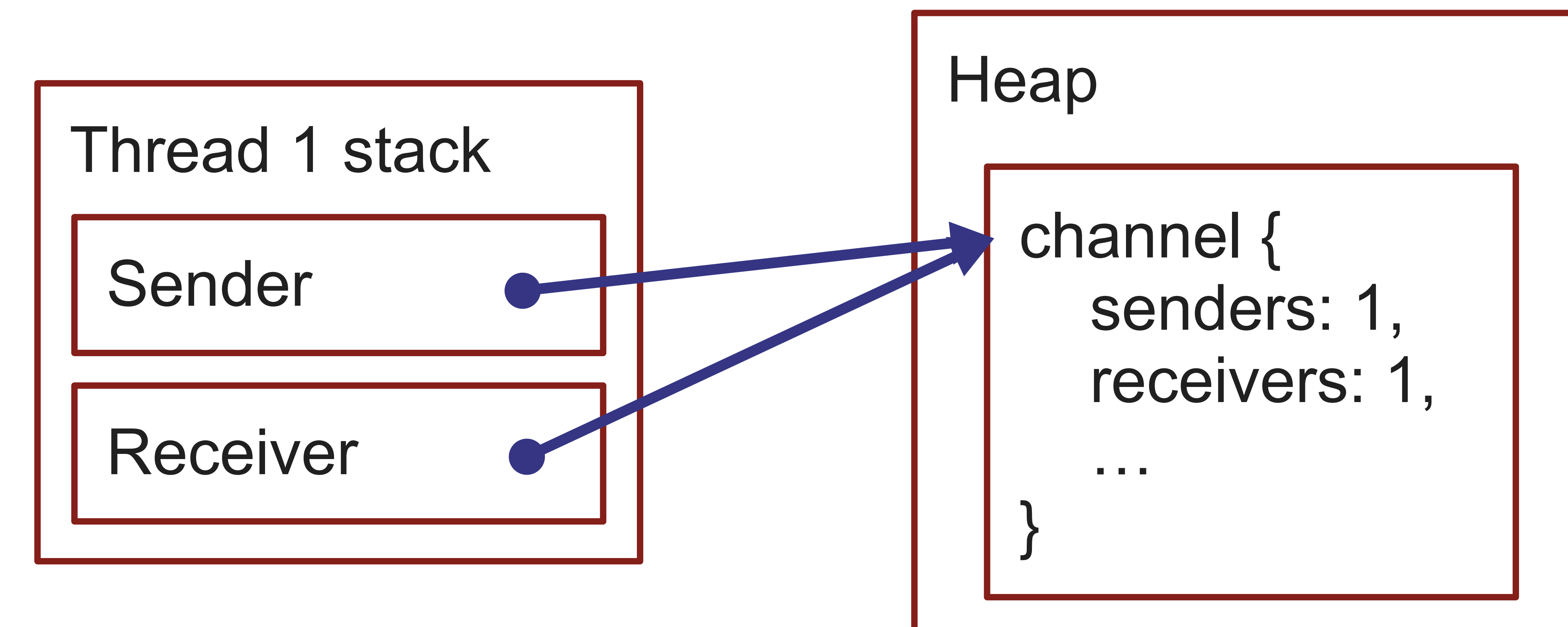
- The Rust standard library includes an MPSC (multi-producer, single-consumer) channel, but it's not ideal (one of the oldest APIs in Rust stdlib)
  - Great if you want multiple threads to send to one thread (e.g. aggregating results of an operation)
  - Also great for thread-to-thread communication (superset of SPSC)
  - Not so great if you want to distribute data/work (e.g. a work queue)
  - Additionally, the API has some oddities (great article)
  - There's a good chance this channel implementation will be replaced within the next year or two (discussion)

Channel APIs and implementations

- The crossbeam crate recently (2018) added an excellent MPMC implementation
  - "If we were to redo Rust channels from scratch, how should they look?" Much improved API
  - Mostly lock free
  - Even faster than the existing MPSC channels
  - Likely to replace the stdlib channels in some capacity

Implementing farm v3.0

```
fn main() {
    let (sender, receiver) = crossbeam::channel::unbounded();
```



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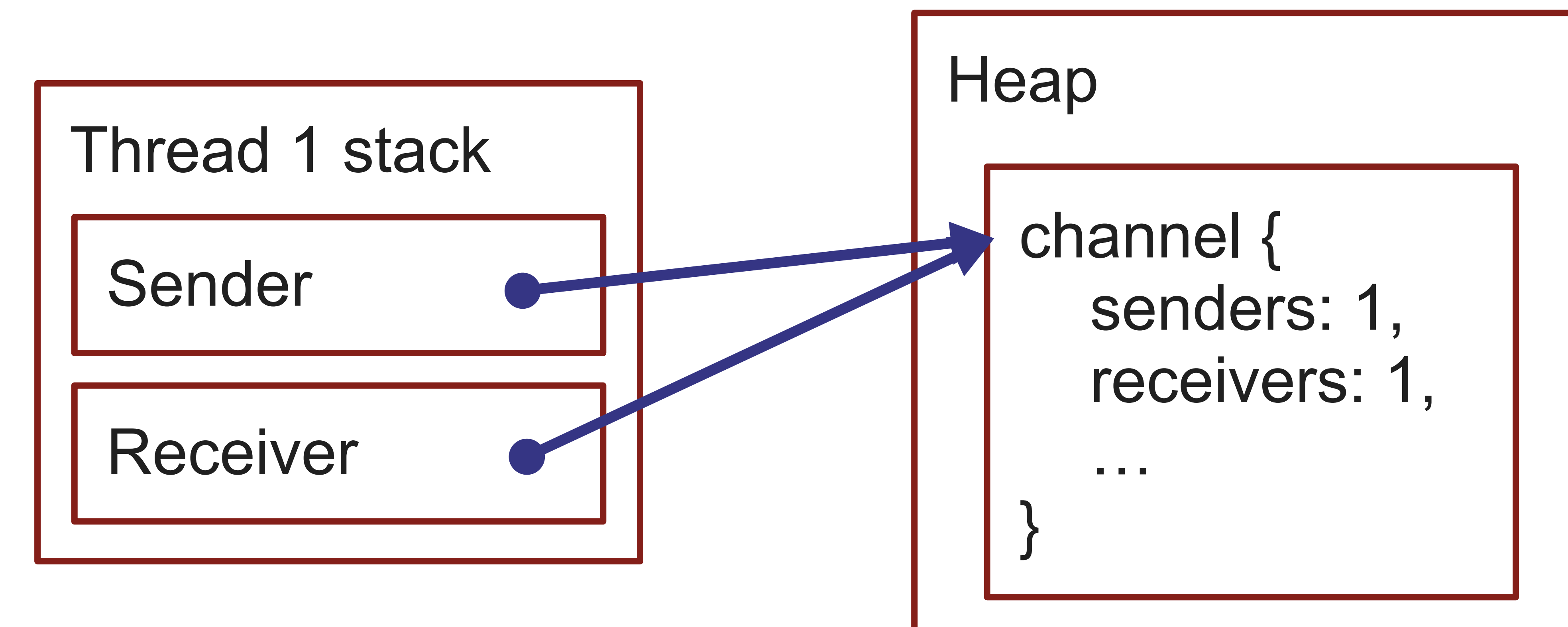

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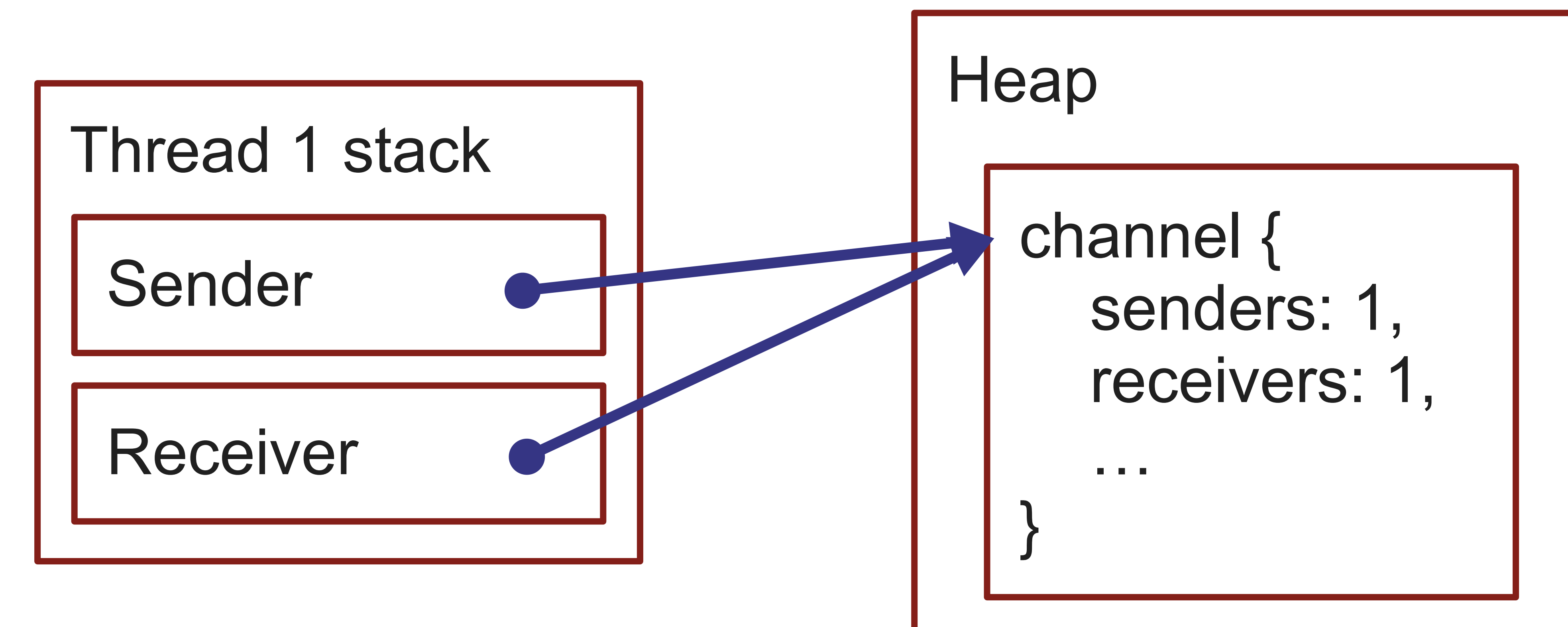

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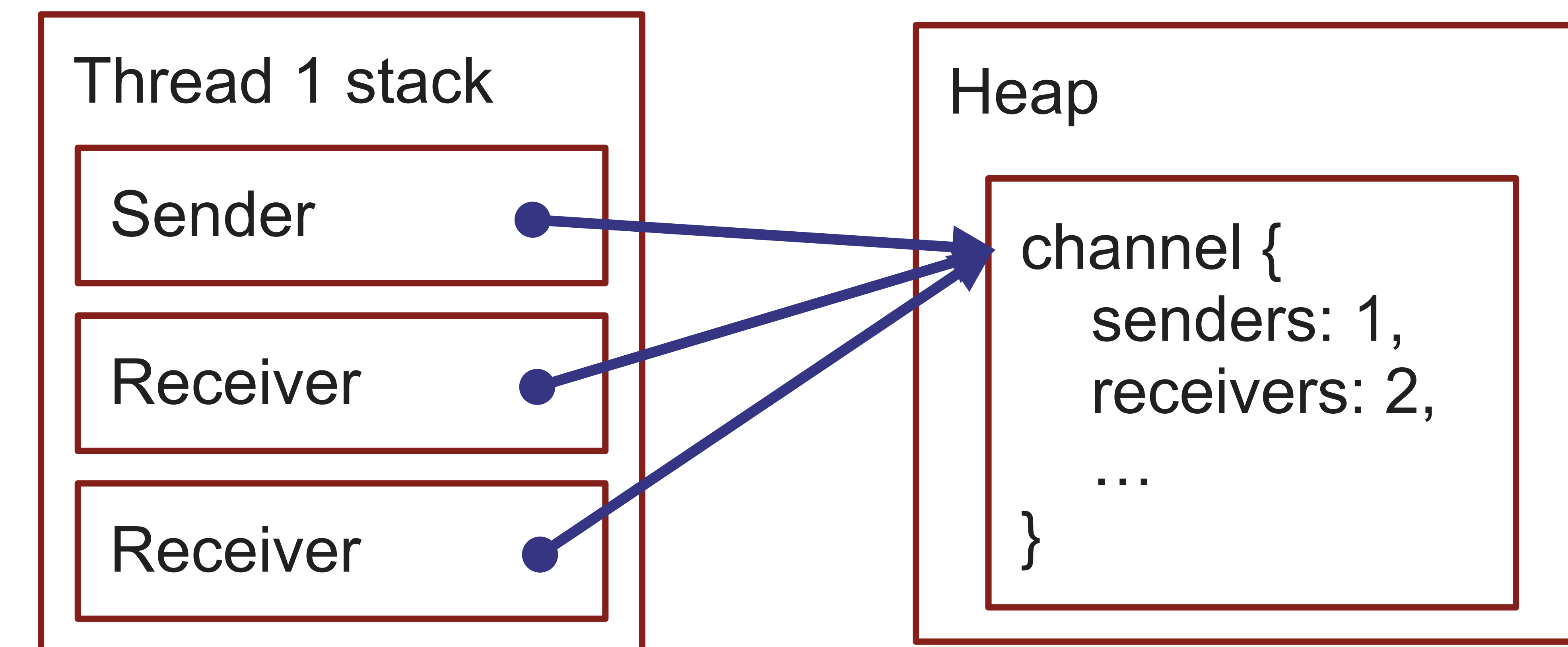

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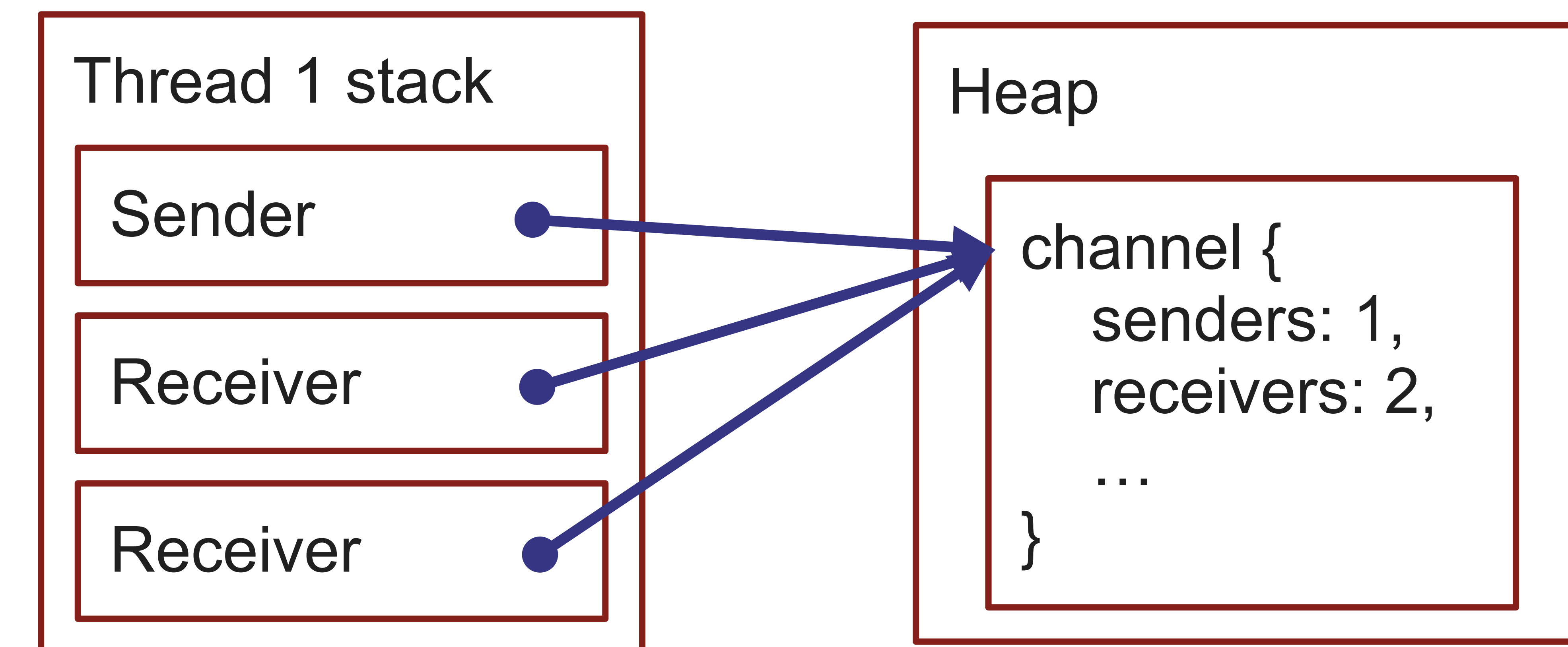

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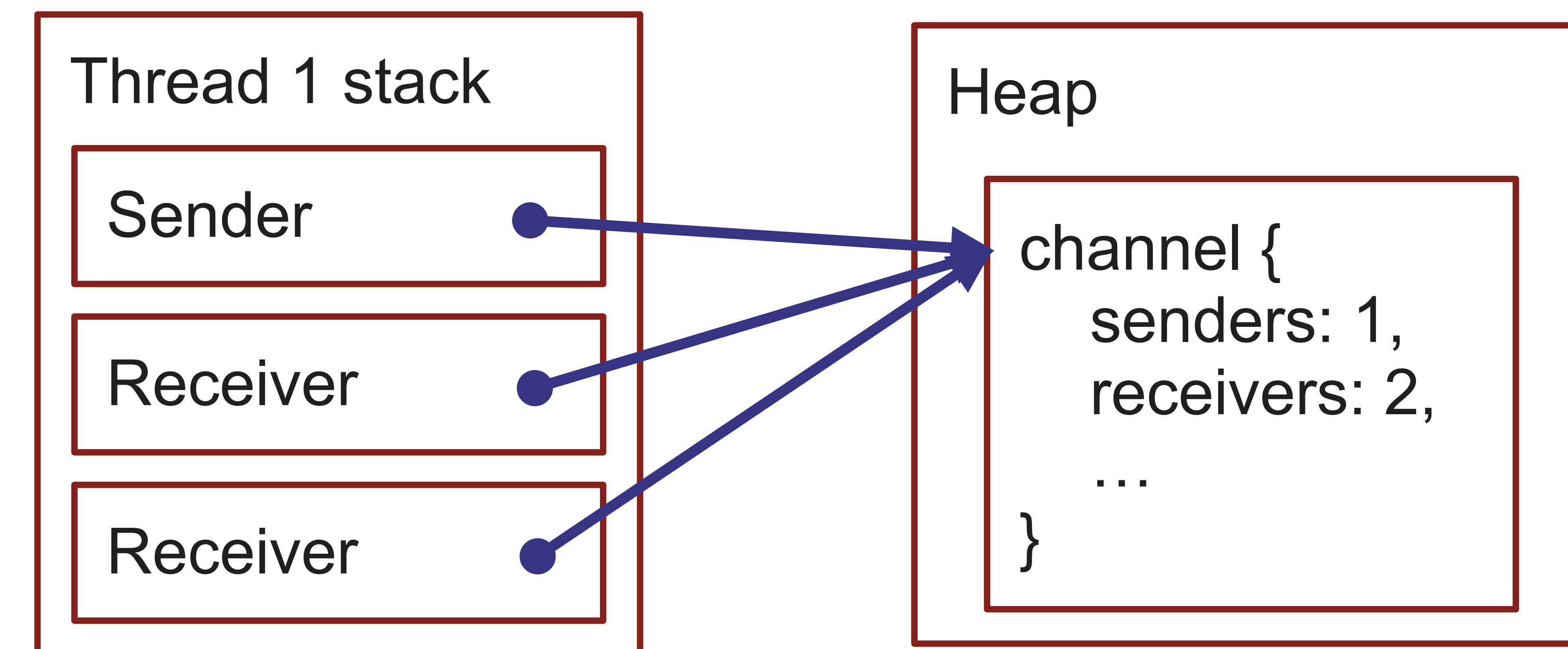

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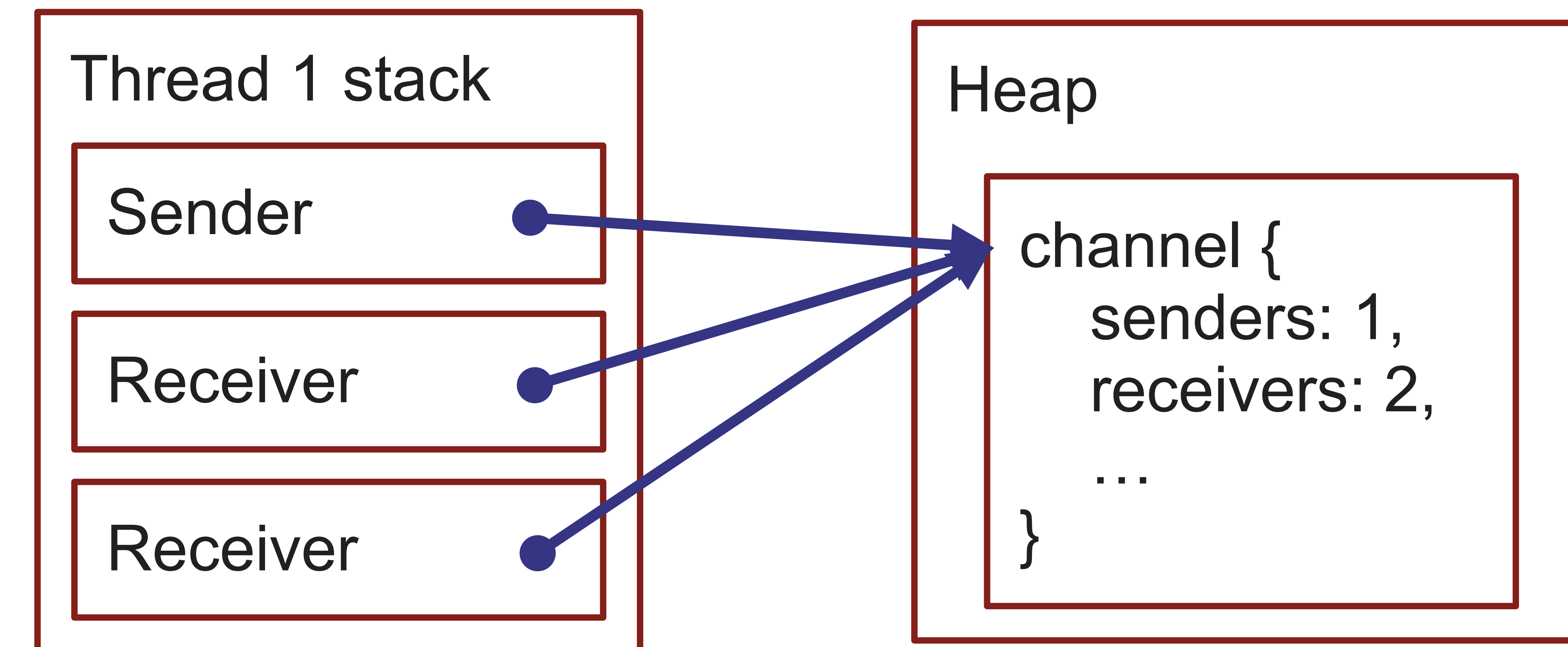

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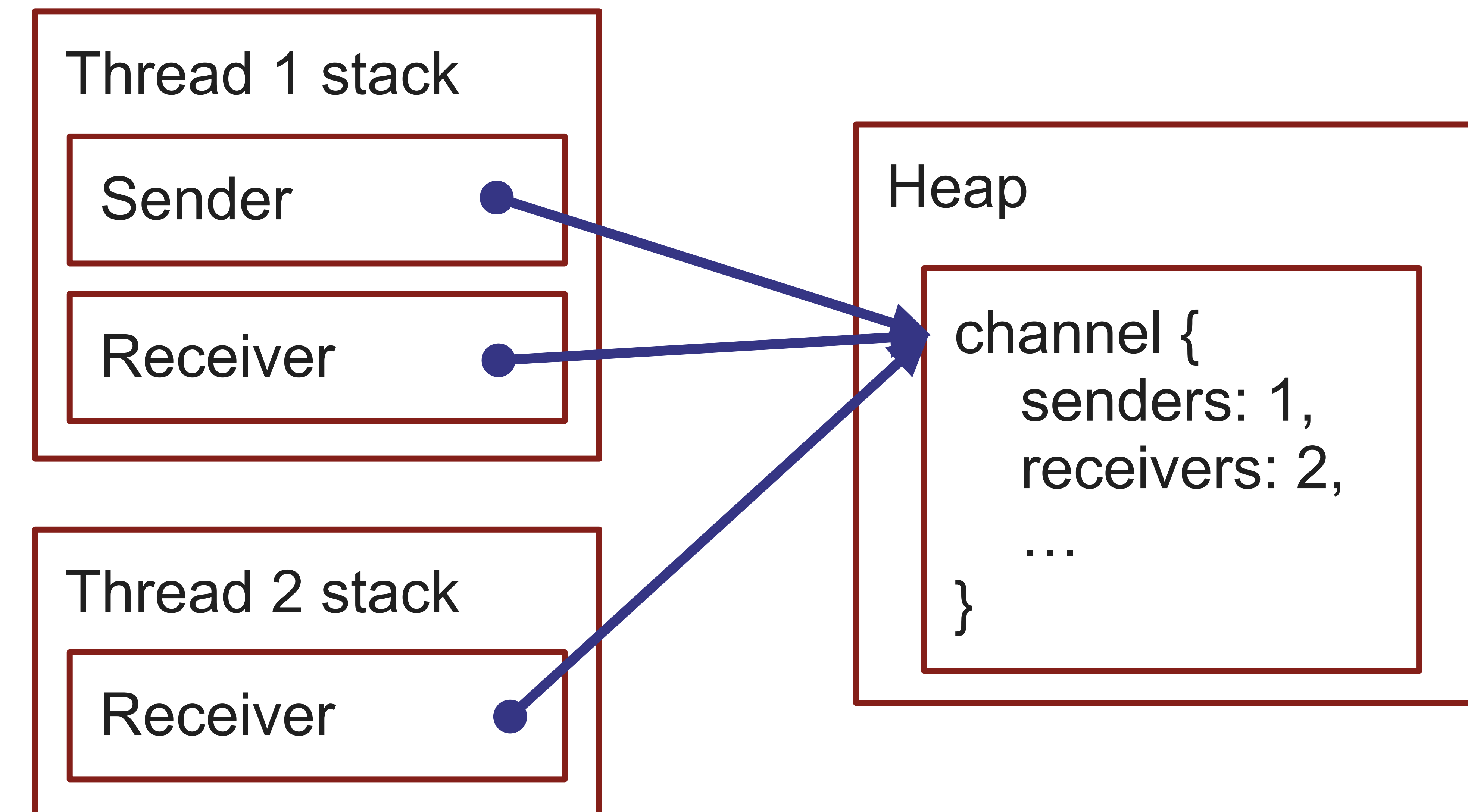

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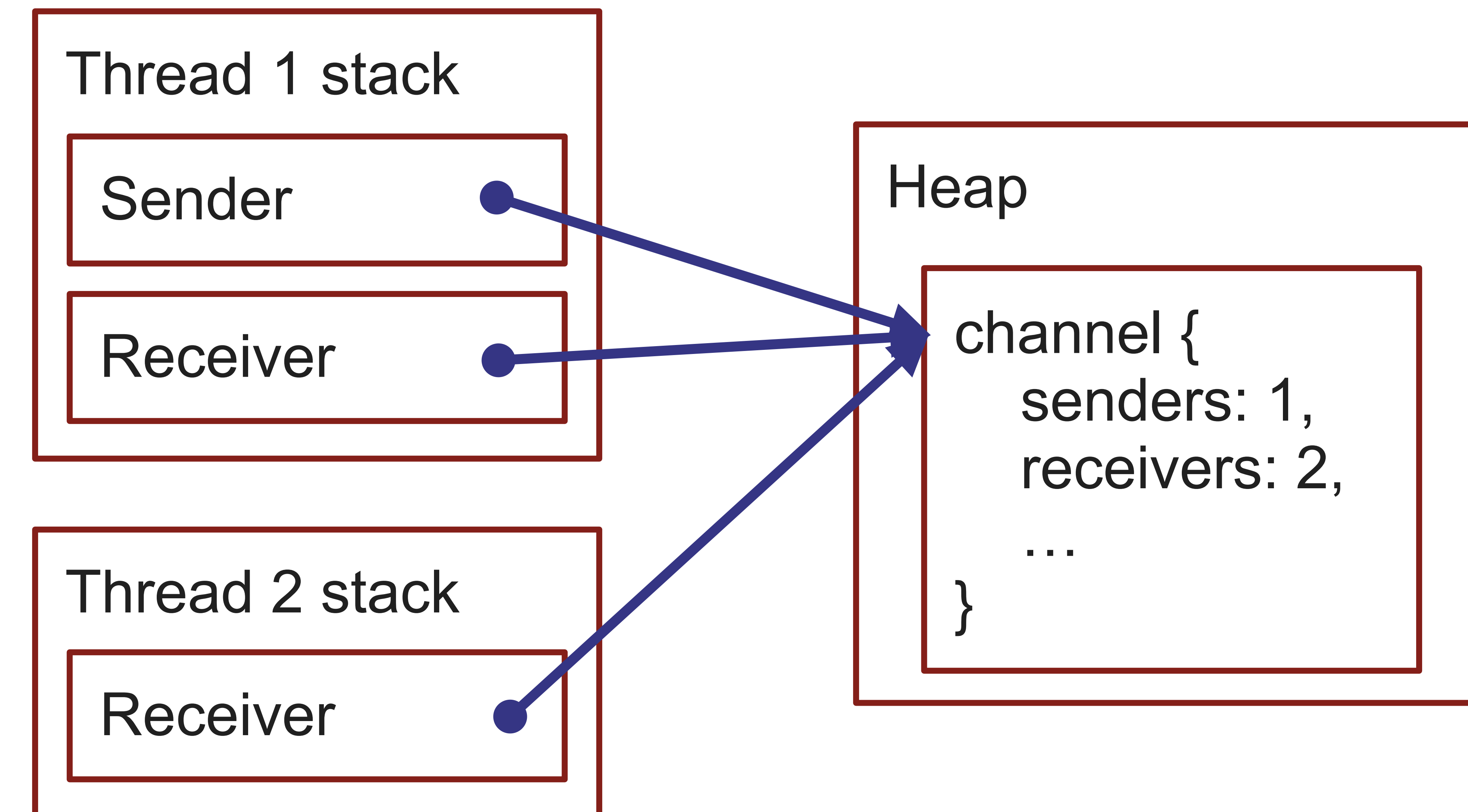
```

Read until recv() returns Err (i.e. until the channel is closed)



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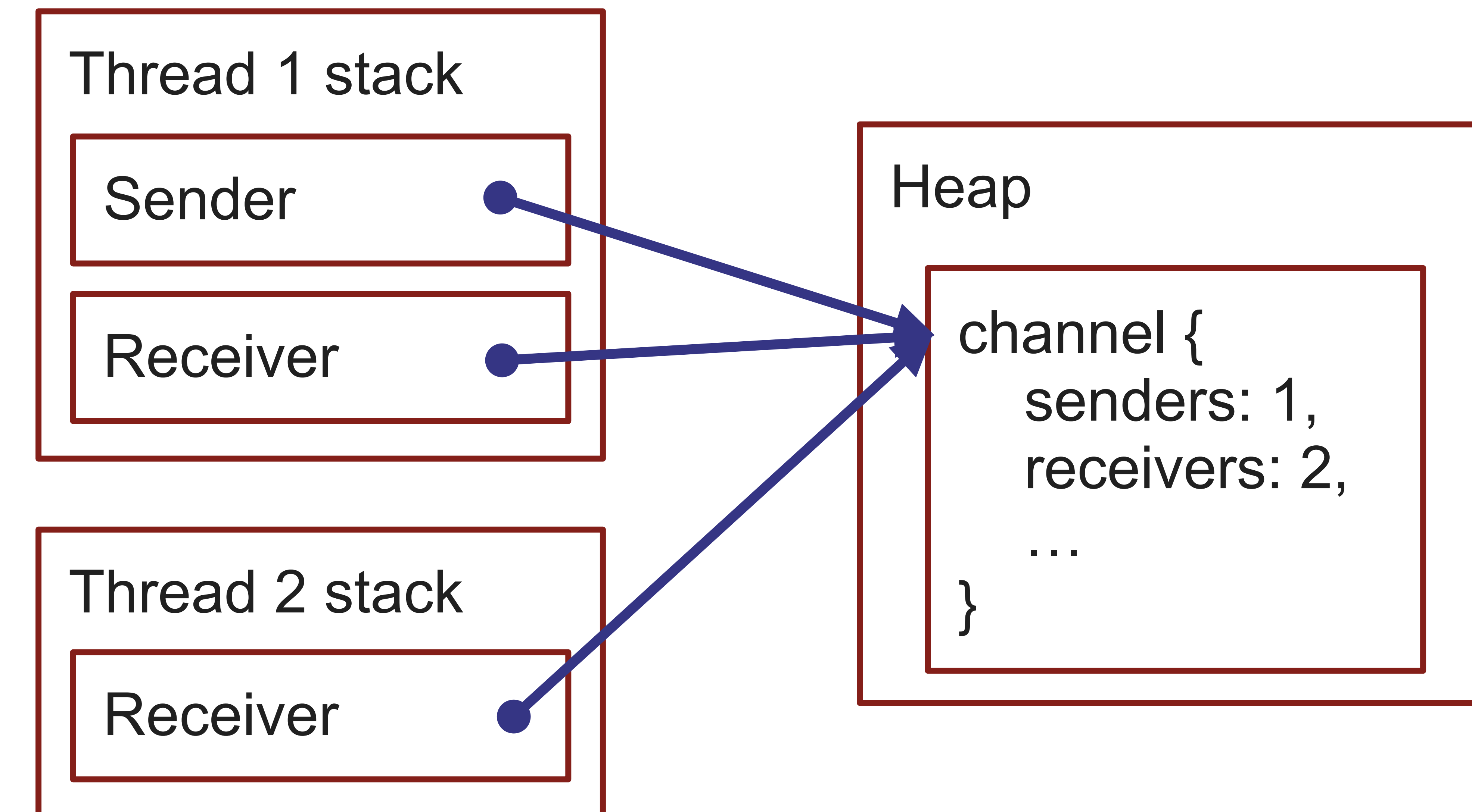

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    let stdin = std::io::stdin();
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        sender
            .send(num)
            .expect("Tried writing to channel, but there are no receivers!");
    }
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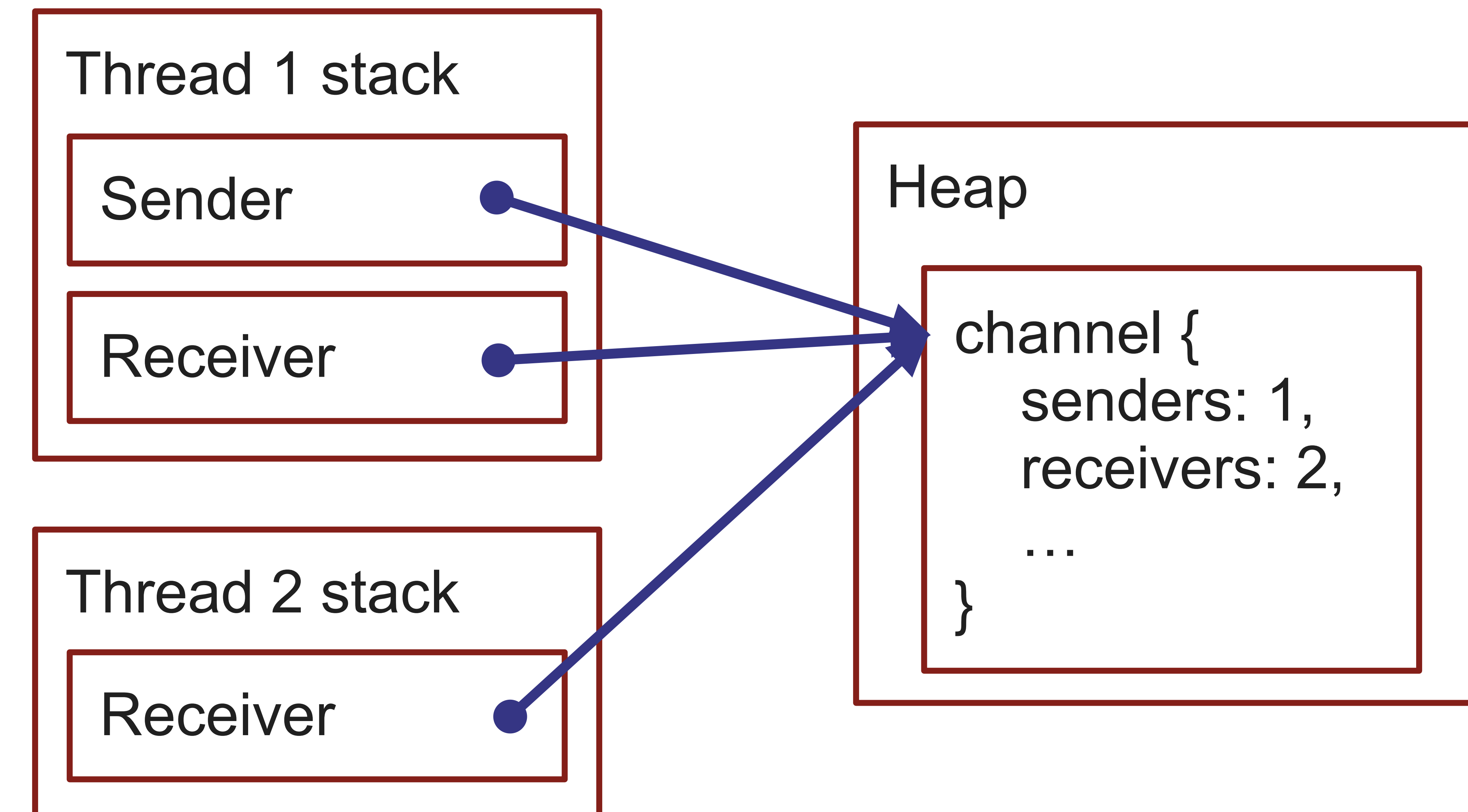

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    drop(sender);
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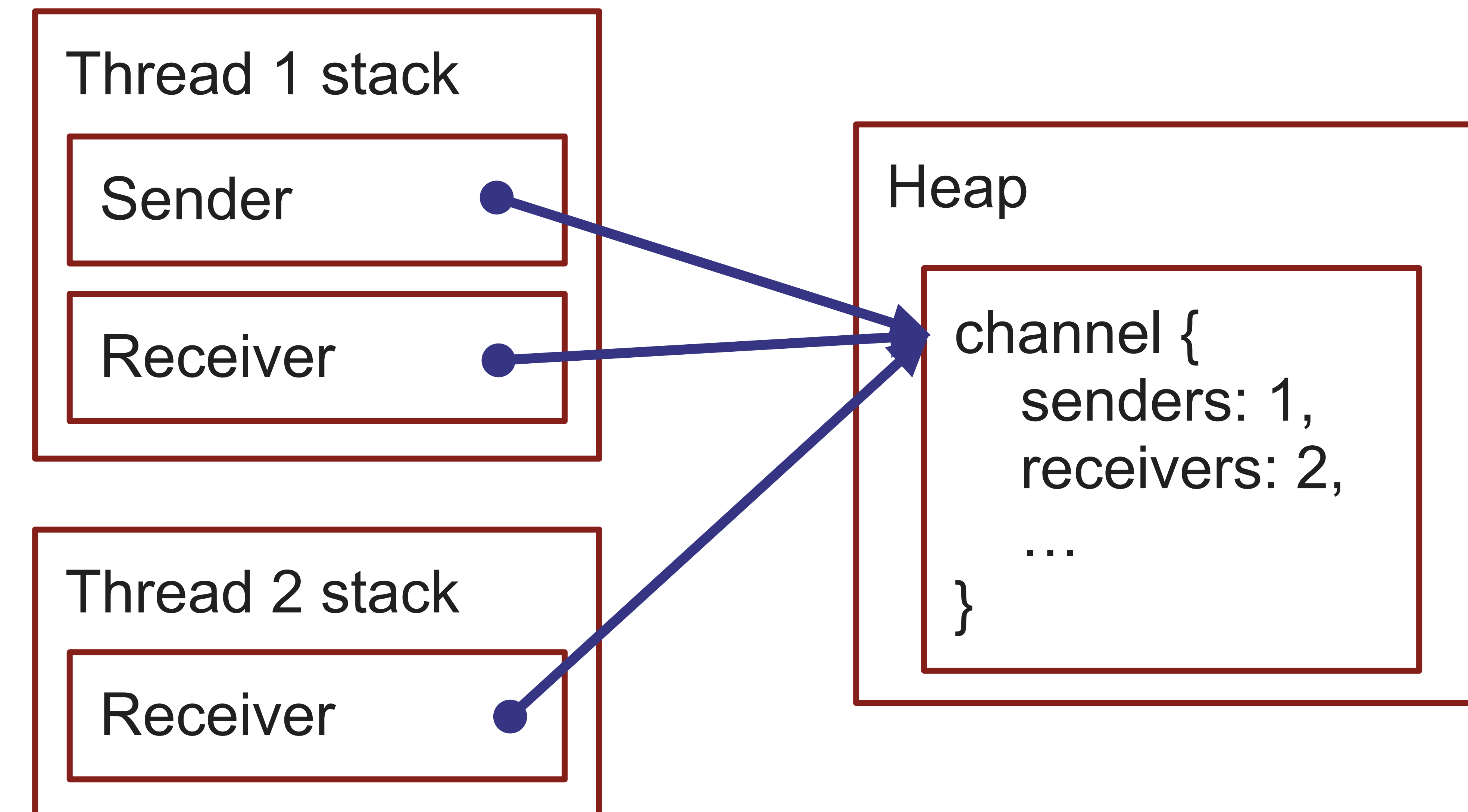

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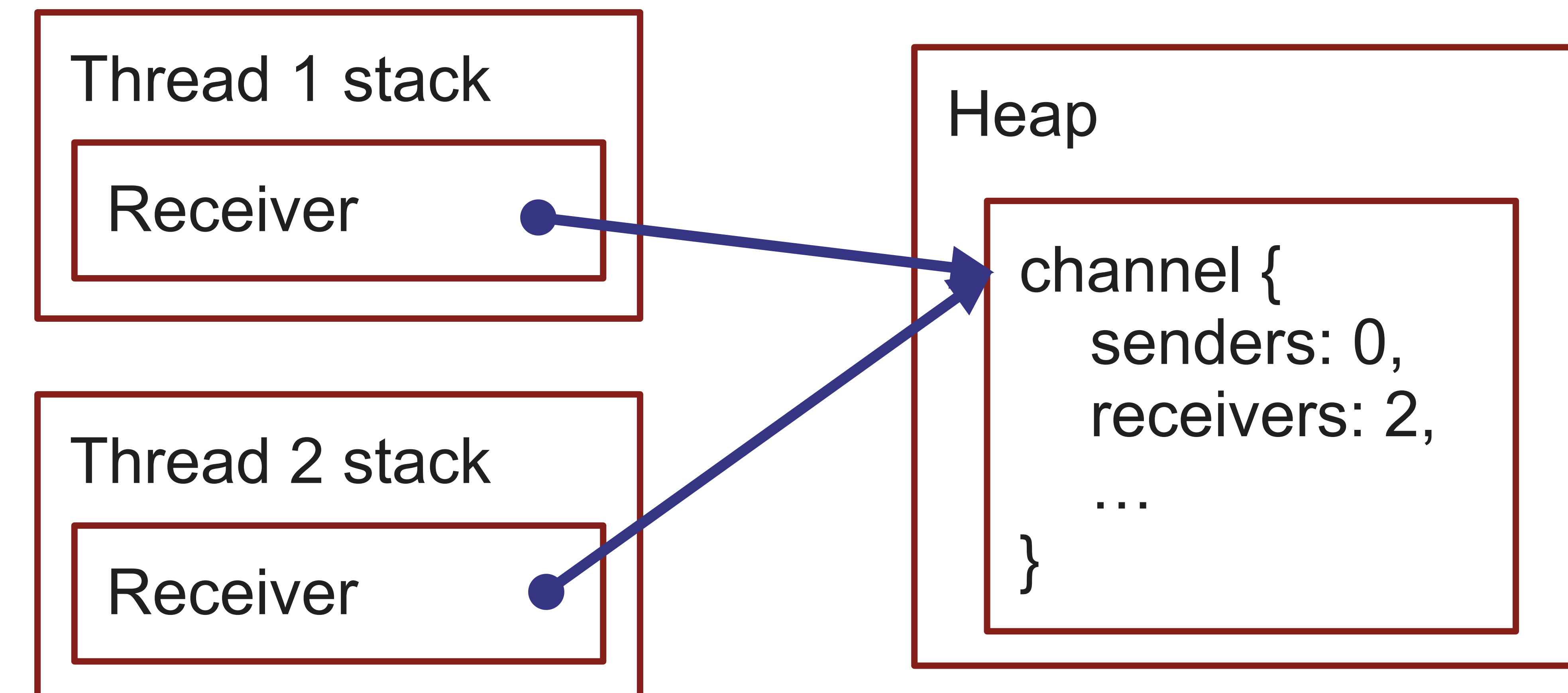

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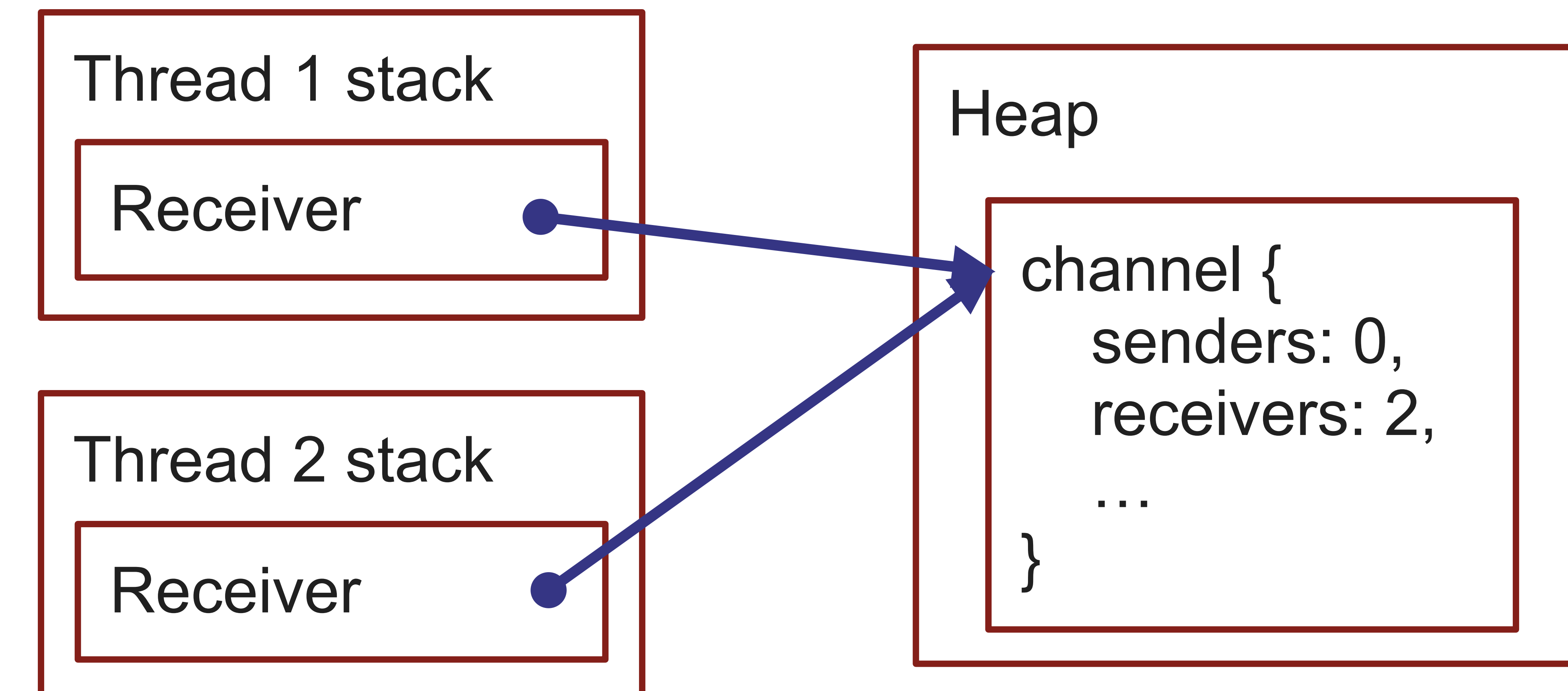

Channel is closed! Worker threads will break out of while loop

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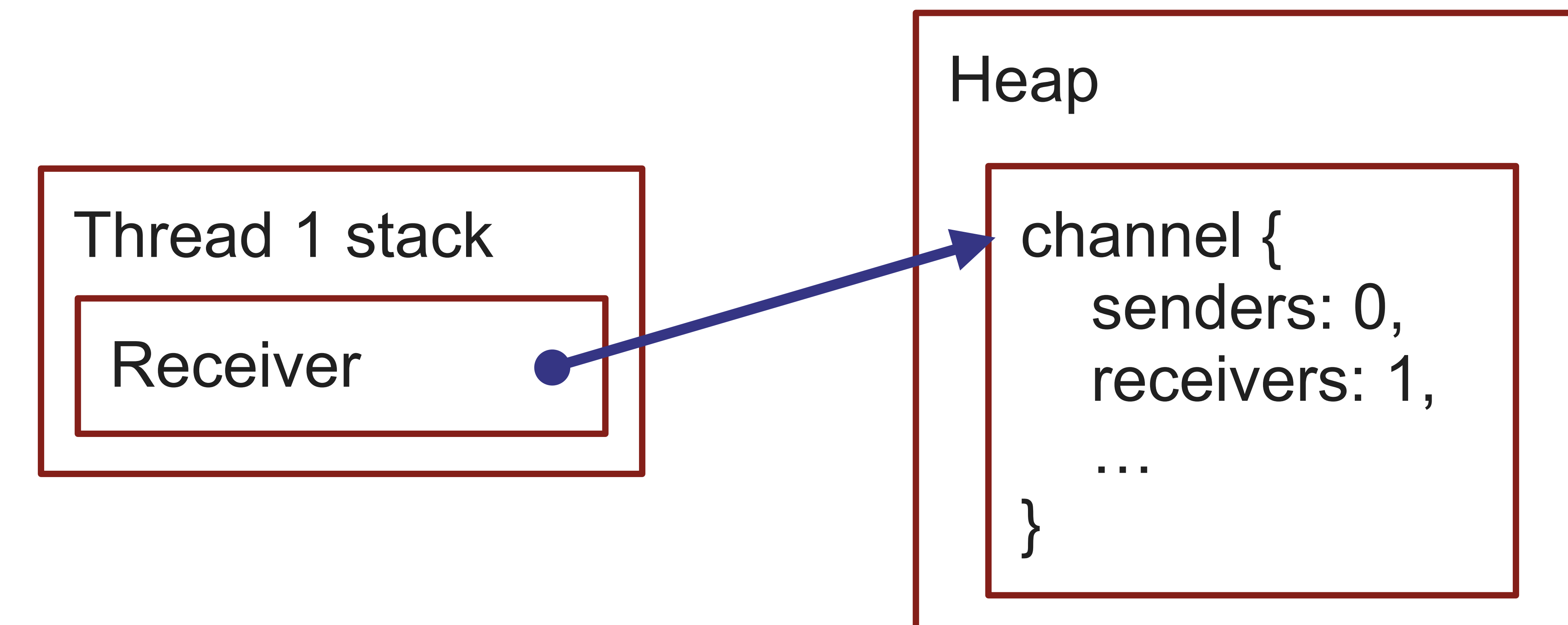

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        sender
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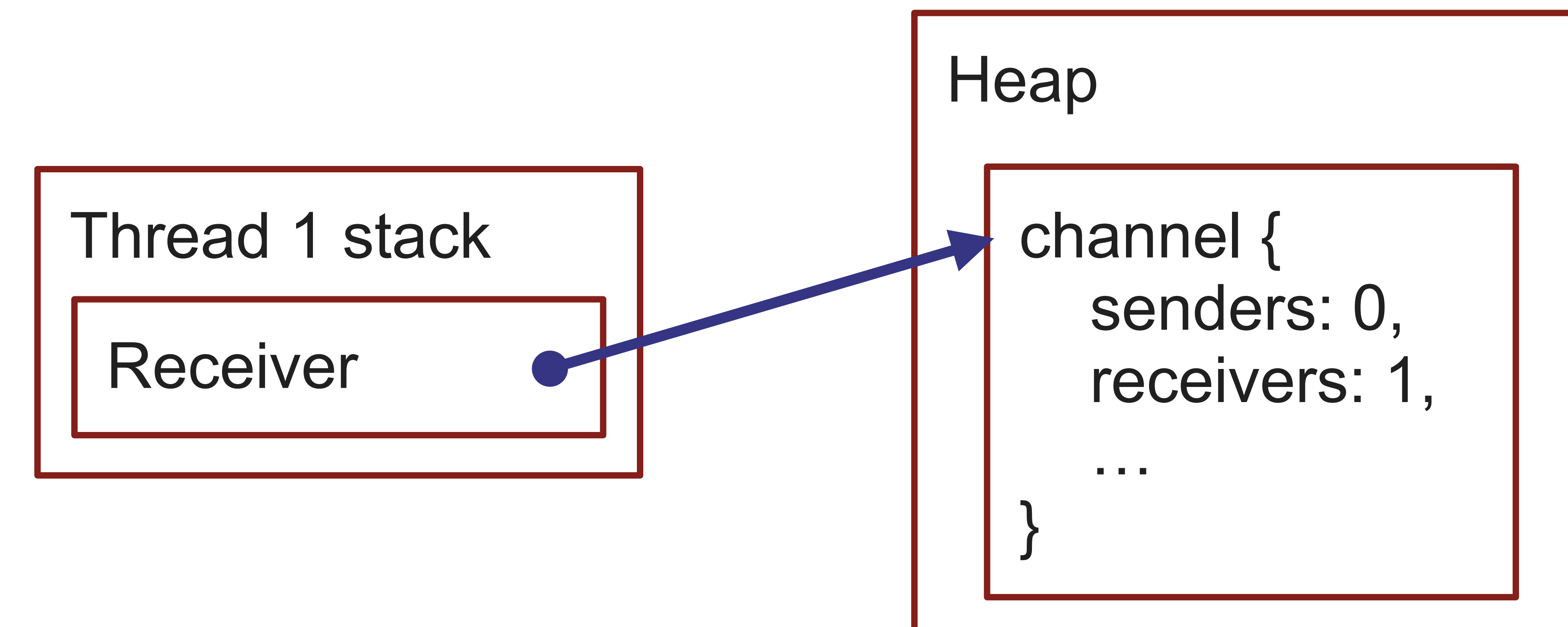
            .expect("Tried writing to channel, but there are no receivers!");
    }

    drop(sender);

    for thread in threads {
        thread.join().expect("Panic occurred in thread");
    }
}
```



Pick the right tool for the job

- Using channels is often much simpler and safer than using mutexes + CVs
  - Even in Rust, mutexes can still cause problems if you lock/unlock at the wrong times
- However, channels aren't always the best choice
  - Not very well suited for global values (e.g. caches or global counters)