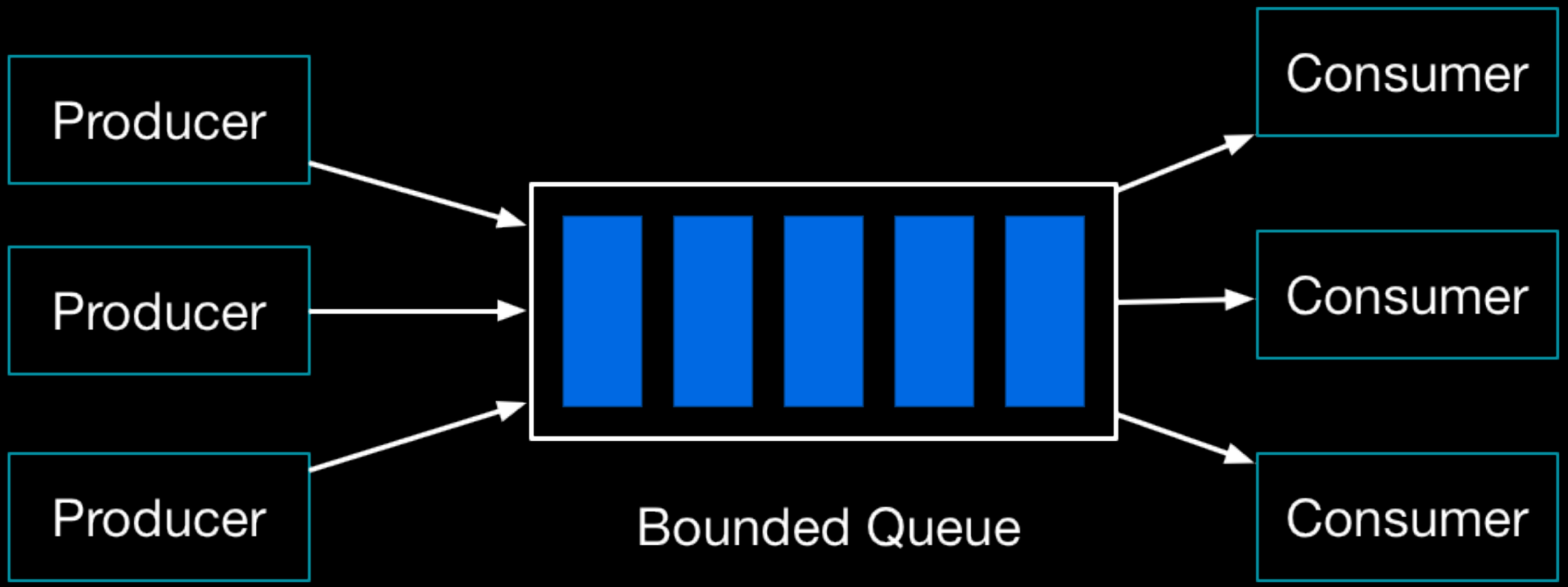
Monitor Mechanism

Producer -> Consumer



Consumer Events

"Consumer will be blocked while queue is empty"

Question:

How do the blocked consumers know when the queue becomes non-empty

Answer:

1. Keeps spinning and tests the queue
2. Blocked consumer will be notified when queue changed

Condition

- It can be alias of expression: `!queue.isEmpty`
- Must be `protected` to prevent race condition
- Must be read `exclusively` by Consumer
- Must be write `exclusively` be Producer

Race condition

```
take(){
   //Spinning while queue is empty
   while(queue.isEmpty){
   }
   queue.remove()
}

put(e){
   queue.add(e)
}
```

With Lock

```
take(){
  synchronized(this){
    //Spinning while queue is empty
    while(queue.isEmpty){

    }
    queue.remove()
  }
}

put(e){
  synchronized(this){
    queue.add(e)
  }
}
```

But deadlock

- Take: acquired lock & waits for condition from put
- Put: waits for a lock which acquired from put

=> take should release `lock` to let `put` change the condition

Spinning with lock

```
take(){
  acquireLock()
  while(queue.isEmpty) {
    releaseLock()
    Thread.yield()
    acquireLock()
  }
  queue.remove()
  releaseLock()
}

put(e){
  acquireLock()
  queue.add(e)
  releaseLock()
}
```

Spinning Approach

- Consistent result
- But waste of CPU Cycles

Condition Variable

A condition that thread can
- `wait`: waits until condition occurs
- `signal`: wakes up one of waiting threads
- `broadcast`: wakes up all waiting threads

All operations must be executed when acquired lock

wait(condition, lock)

1. Release lock
2. Sleep until `condition` is signalled
3. When awaken up, re-acquire lock again

signal(condition, lock)

- Caller must hold `lock`
- Wakes up one of waiting threads

broadcast(condition, lock)

- Caller must hold `lock`
- Wakes up all waiting threads

Hoare Monitor

- Waking up waiting thread immediately
- Implicitly transfer the lock
- Awaken thread does not have to check the condition
- Hard to implement

Mesa Monitor

- Signaling is just a hint
- Awaken thread must re-acquire lock
- Awakened thread must re-check condition

Java Monitor

- Mesa style
- Every Java object is Monitor
- `wait` <-> `wait`
- `signal` <-> `notify`
- `broadcast` <-> `notifyAll`

With Java Monitor

```
take(){
  synchronized(this){
    while(queue.isEmpty)
      this.wait()
    queue.remove()
  }
}

put(e){
  synchronized(this){
    queue.add(e)
    this.notify()
  }
}
```

Notes

`wait`, `notify`, `notifyAll` must be called within `synchronized`