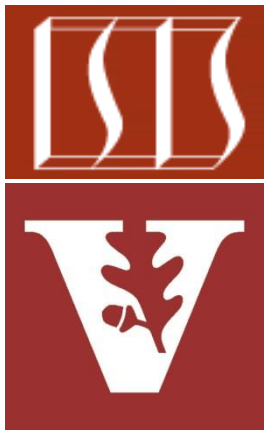
Java ReentrantLock (Part 4)



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Learning Objectives in this Part of the Lesson

- Understand how the concept of mutual exclusion in concurrent programs
- Recognize how Java ReentrantLock provides mutual exclusion to concurrent programs
- Know the key methods defined by the Java ReentrantLock class
- Learn how to use ReentrantLock in Java programs

Class ArrayBlockingQueue<E>

java.lang.Object
  java.util.AbstractCollection<E>
    java.util.AbstractQueue<E>
      java.util.concurrent.ArrayBlockingQueue<E>

Type Parameters:

`E - the type of elements held in this collection`

All Implemented Interfaces:

`Serializable, Iterable<E>, Collection<E>, BlockingQueue<E>, Queue<E>`

```
public class ArrayBlockingQueue<E>
extends AbstractQueue<E>
implements BlockingQueue<E>, Serializable
```

A bounded blocking queue backed by an array. This queue orders elements FIFO (first-in-first-out). The *head* of the queue is that element that has been on the queue the longest time. The *tail* of the queue is that element that has been on the queue the shortest time. New elements are inserted at the tail of the queue, and the queue retrieval operations obtain elements at the head of the queue.

This is a classic "bounded buffer", in which a fixed-sized array holds elements inserted by producers and extracted by consumers. Once created, the capacity cannot be changed. Attempts to `put` an element into a full queue will result in the operation blocking; attempts to `take` an element from an empty queue will similarly block.

This class supports an optional fairness policy for ordering waiting producer and consumer threads. By default, this ordering is not guaranteed. However, a queue constructed with fairness set to `true` grants threads access in FIFO order. Fairness generally decreases throughput but reduces variability and avoids starvation.

Using Reentrant Lock in Java

Using ReentrantLock in Java

- ArrayBlockingQueue is a blocking bounded FIFO queue

```
public class ArrayBlockingQueue<E>
    extends AbstractQueue<E>
implements BlockingQueue<E>,
    java.io.Serializable {
```

Class ArrayBlockingQueue<E>

java.lang.Object
  java.util.AbstractCollection<E>
    java.util.AbstractQueue<E>
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See docs.oracle.com/javase/8/docs/api/java/util/concurrent/ArrayBlockingQueue.html

Using ReentrantLock in Java

- ArrayBlockingQueue is a blocking bounded FIFO queue

```
public class ArrayBlockingQueue<E>
    extends AbstractQueue<E>
implements BlockingQueue<E>,
    java.io.Serializable {
```

Class AbstractQueue<E>

java.lang.Object
  java.util.AbstractCollection<E>
    java.util.AbstractQueue<E>

Type Parameters:

E - the type of elements held in this collection

All Implemented Interfaces:

Iterable<E>, Collection<E>, Queue<E>

Direct Known Subclasses:

ArrayBlockingQueue, ConcurrentLinkedQueue, DelayQueue, LinkedBlockingDeque, LinkedBlockingQueue, LinkedTransferQueue, PriorityBlockingQueue, PriorityQueue, SynchronousQueue

---

```
public abstract class AbstractQueue<E>
extends AbstractCollection<E>
implements Queue<E>
```

This class provides skeletal implementations of some Queue operations. The implementations in this class are appropriate when the base implementation does *not* allow null elements. Methods add, remove, and element are based on offer, poll, and peek, respectively, but throw exceptions instead of indicating failure via false or null returns.

See docs.oracle.com/javase/8/docs/api/java/util/AbstractQueue.html

Using ReentrantLock in Java

- ArrayBlockingQueue is a blocking bounded FIFO queue

```
public class ArrayBlockingQueue<E>
    extends AbstractQueue<E>
    implements BlockingQueue<E>,
        java.io.Serializable {
```

Interface BlockingQueue<E>

Type Parameters:

E - the type of elements held in this collection

All Superinterfaces:

Collection<E>, Iterable<E>, Queue<E>

All Known Subinterfaces:

BlockingDeque<E>, TransferQueue<E>

All Known Implementing Classes:

ArrayBlockingQueue, DelayQueue, LinkedBlockingDeque, LinkedBlockingQueue, LinkedTransferQueue, PriorityBlockingQueue, SynchronousQueue

---

```
public interface BlockingQueue<E>
extends Queue<E>
```

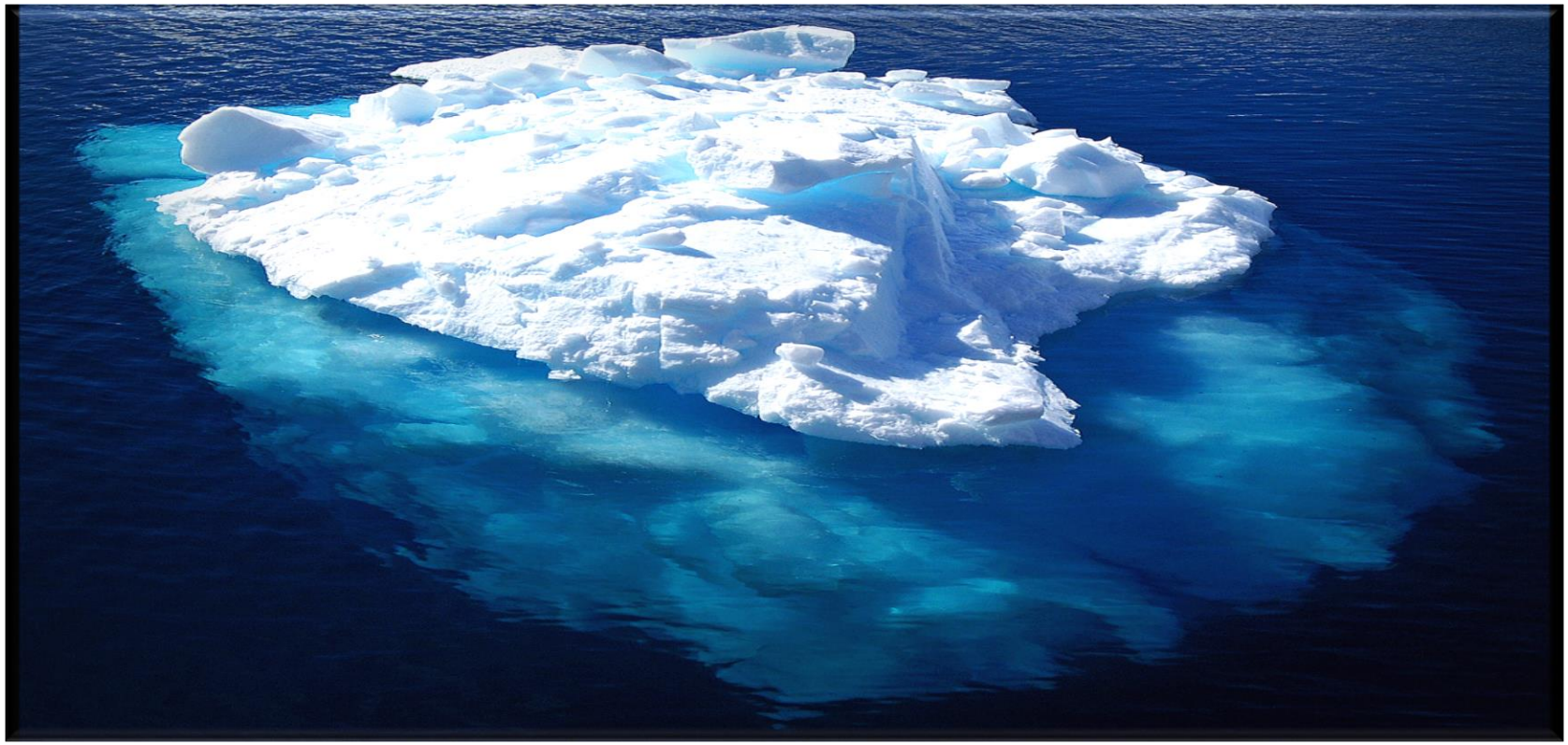
A Queue that additionally supports operations that wait for the queue to become non-empty when retrieving an element, and wait for space to become available in the queue when storing an element.

See docs.oracle.com/javase/8/docs/api/java/util/concurrent/BlockingQueue.html

Using ReentrantLock in Java

- ArrayBlockingQueue is a blocking bounded FIFO queue

```
public class ArrayBlockingQueue<E>
      extends AbstractQueue<E>
   implements BlockingQueue<E>,
        java.io.Serializable {
...
```



We'll consider both the interface & implementation of ArrayBlockingQueue

Using ReentrantLock in Java

- ArrayBlockingQueue is a blocking bounded FIFO queue

ReentrantLock used in lieu of Java's built-in monitor objects due to their limitations

```
public class ArrayBlockingQueue<E>
             extends AbstractQueue<E>
           implements BlockingQueue<E>,
                java.io.Serializable {
    ...
    // Main lock guarding all access
    final ReentrantLock lock;
    ...
    // The queued items
    final Object[] items;

    // items indices for next take
    // or put calls
    int takeIndex;
    int putIndex;

    // Number of elements in the queue
    int count;
```

See www.dre.vanderbilt.edu/~schmidt/C++2java.html#concurrency

Using ReentrantLock in Java

- ArrayBlockingQueue is a blocking bounded FIFO queue

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public class ArrayBlockingQueue<E>
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```

Object state that's being protected by the lock

Using ReentrantLock in Java

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    int takeIndex;
    int putIndex;

    // Number of elements in the queue
    int count;
```

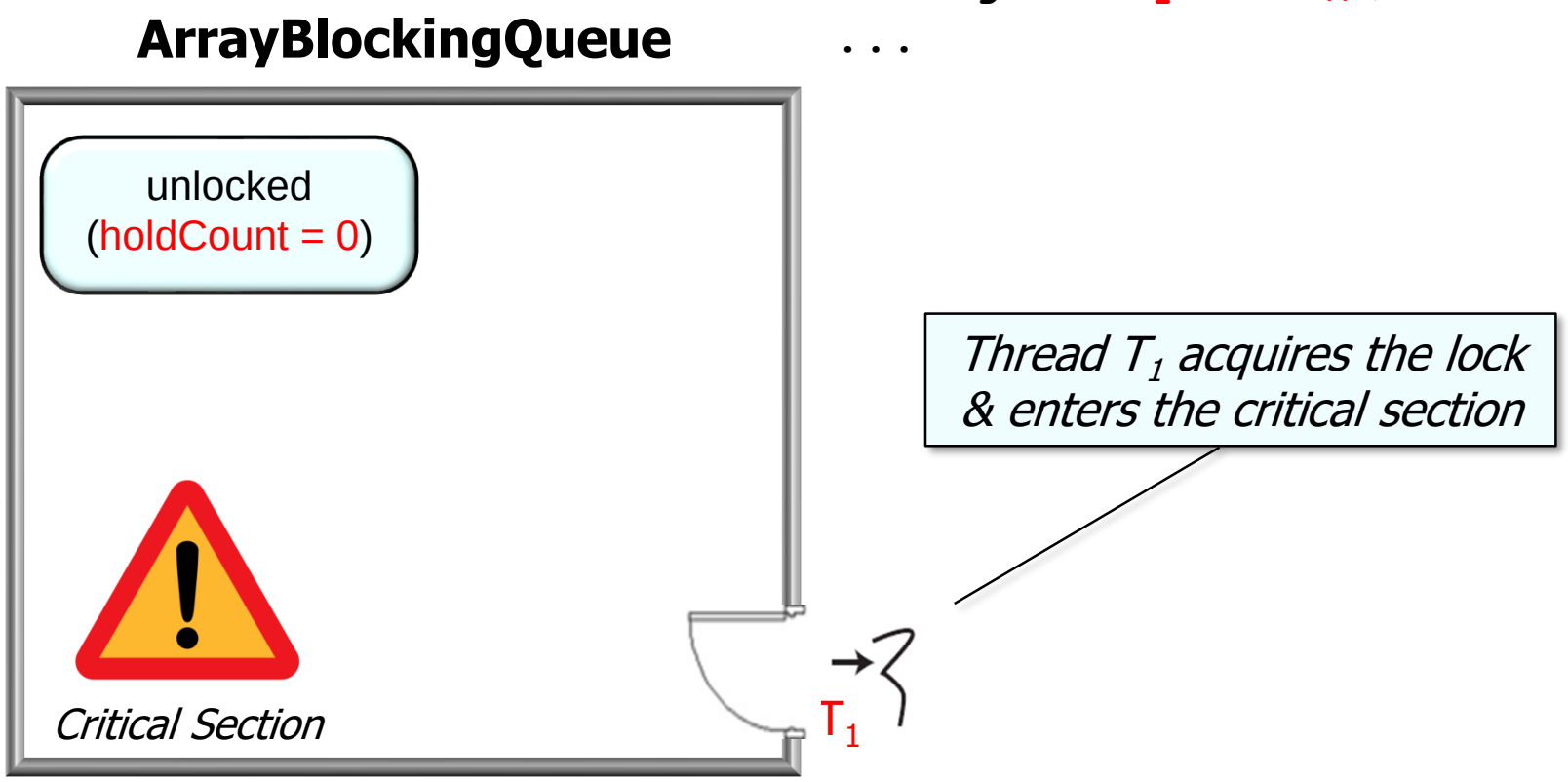
Fields needn't be defined as volatile since ReentrantLock handles all of the atomicity, visibility, & ordering issues

See docs.oracle.com/javase/8/docs/api/java/util/concurrent/locks/Lock.html

Using ReentrantLock in Java

- ArrayBlockingQueue is a blocking bounded FIFO queue

```
ArrayBlockingQueue<String> q = new
  ArrayBlockingQueue<String>(10);
...
// Called by thread T1
String s = q.take();
...
```

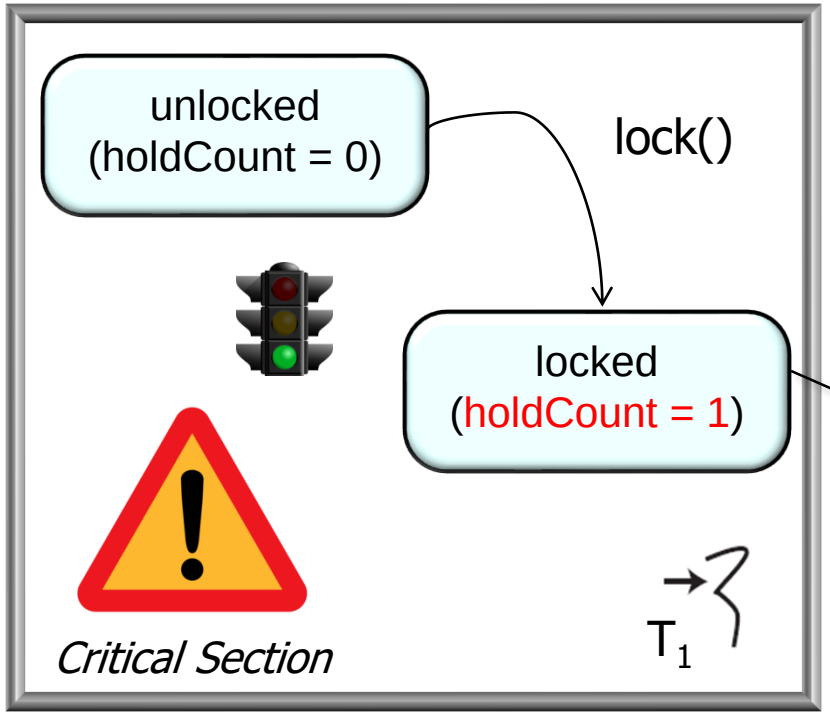


Using ReentrantLock in Java

- ArrayBlockingQueue is a blocking bounded FIFO queue

```
public class ArrayBlockingQueue<E>
        extends AbstractQueue<E>
    implements BlockingQueue<E>,
            java.io.Serializable {
  ...
  public E take() ... {
    final ReentrantLock lock
      = this.lock;
    lock.lockInterruptibly();
    ...
```

ArrayBlockingQueue

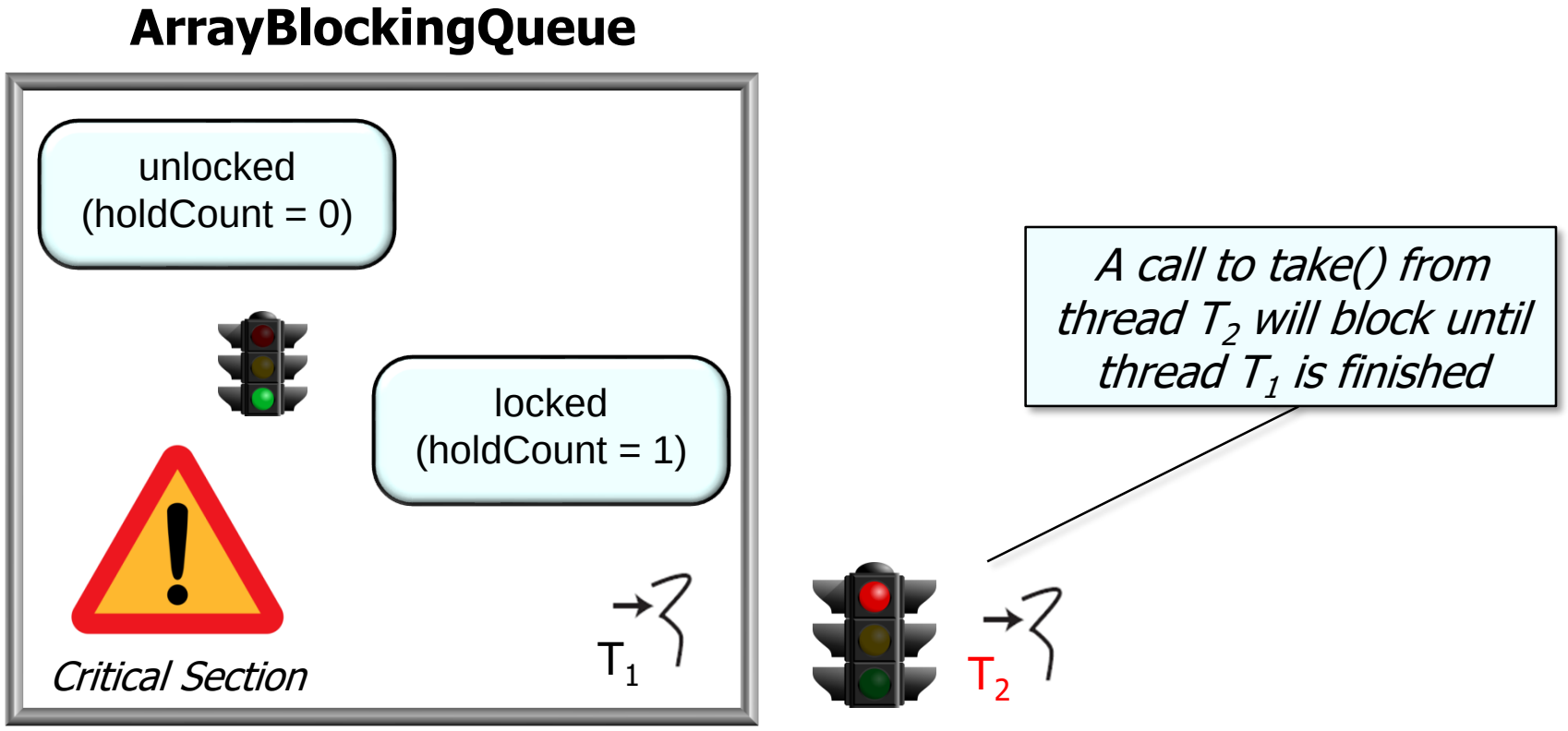


The lock's hold count is incremented by 1

Using ReentrantLock in Java

- ArrayBlockingQueue is a blocking bounded FIFO queue

```
...
// Called by thread T2
String s = q.take();
...
```



Using ReentrantLock in Java

- ArrayBlockingQueue is a blocking bounded FIFO queue

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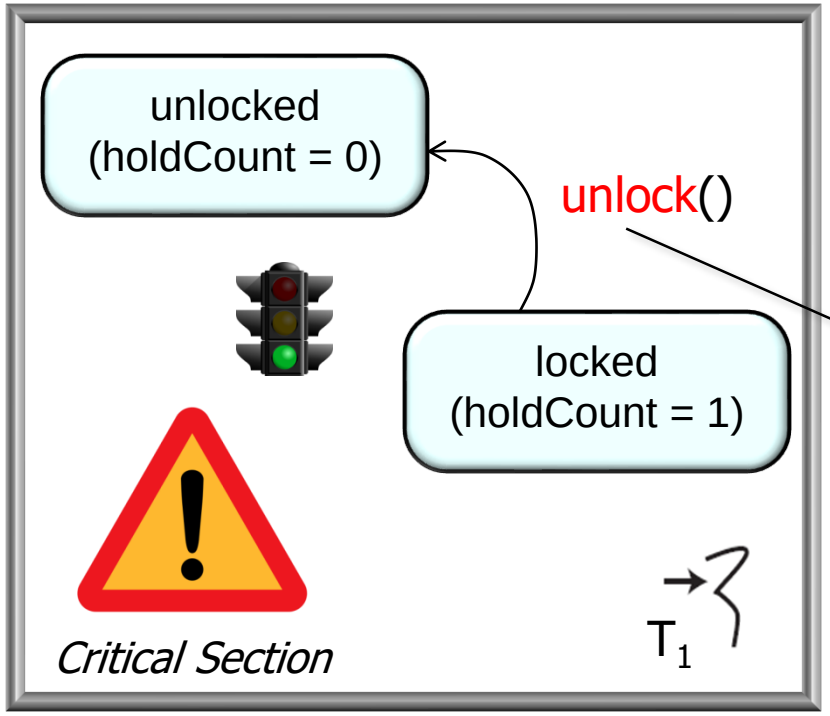
  ...
  public E take() ... {
    final ReentrantLock lock
      = this.lock;
    lock.lockInterruptibly();
    try { ...
    } finally {
      lock.unlock();
    }
    ...
```

ArrayBlockingQueue



When thread T_1 finishes in take() it unlocks the lock

Using ReentrantLock in Java

- ArrayBlockingQueue is a blocking bounded FIFO queue

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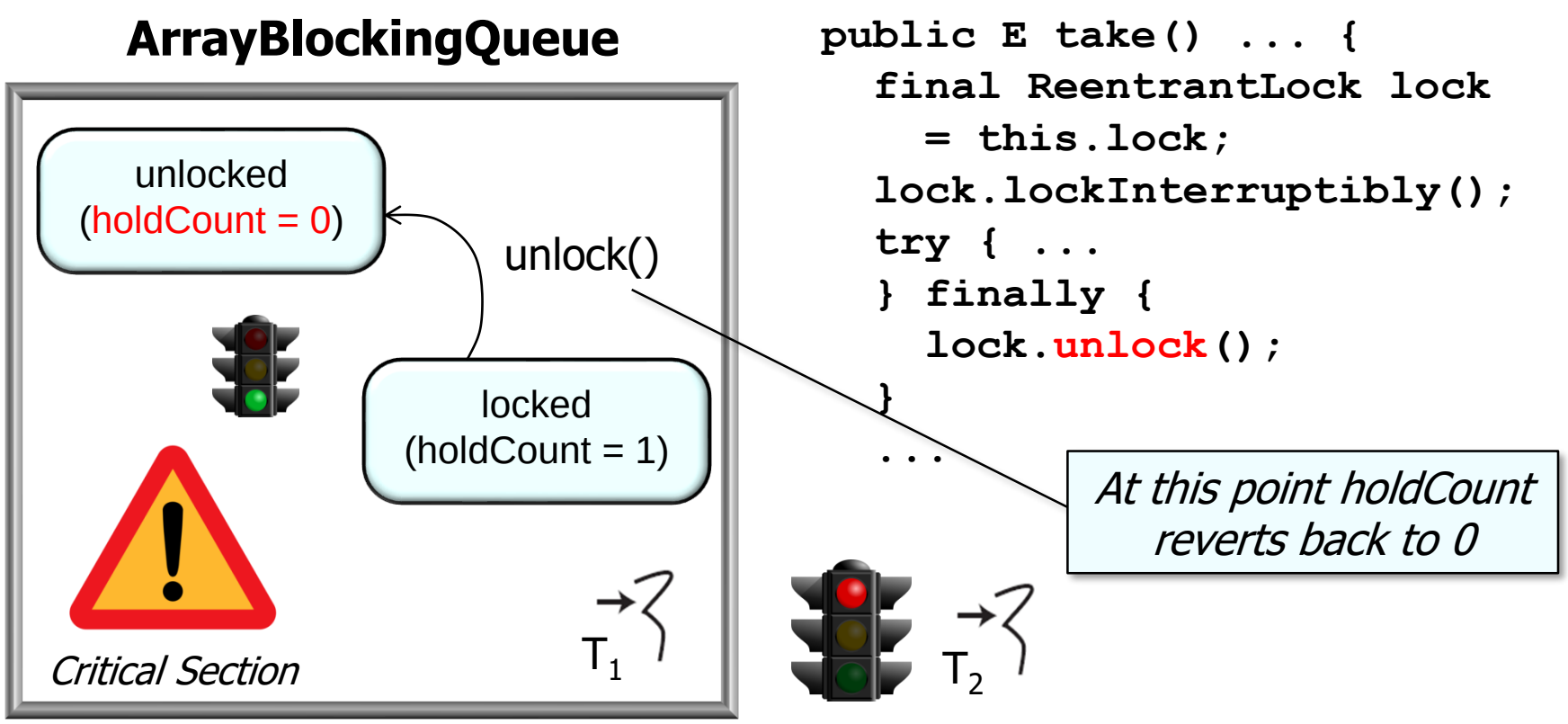
...
public E take() ... {
  final ReentrantLock lock
    = this.lock;
  lock.lockInterruptibly();
  try { ...
  } finally {
    lock.unlock();
  }
  ...
```



Using ReentrantLock in Java

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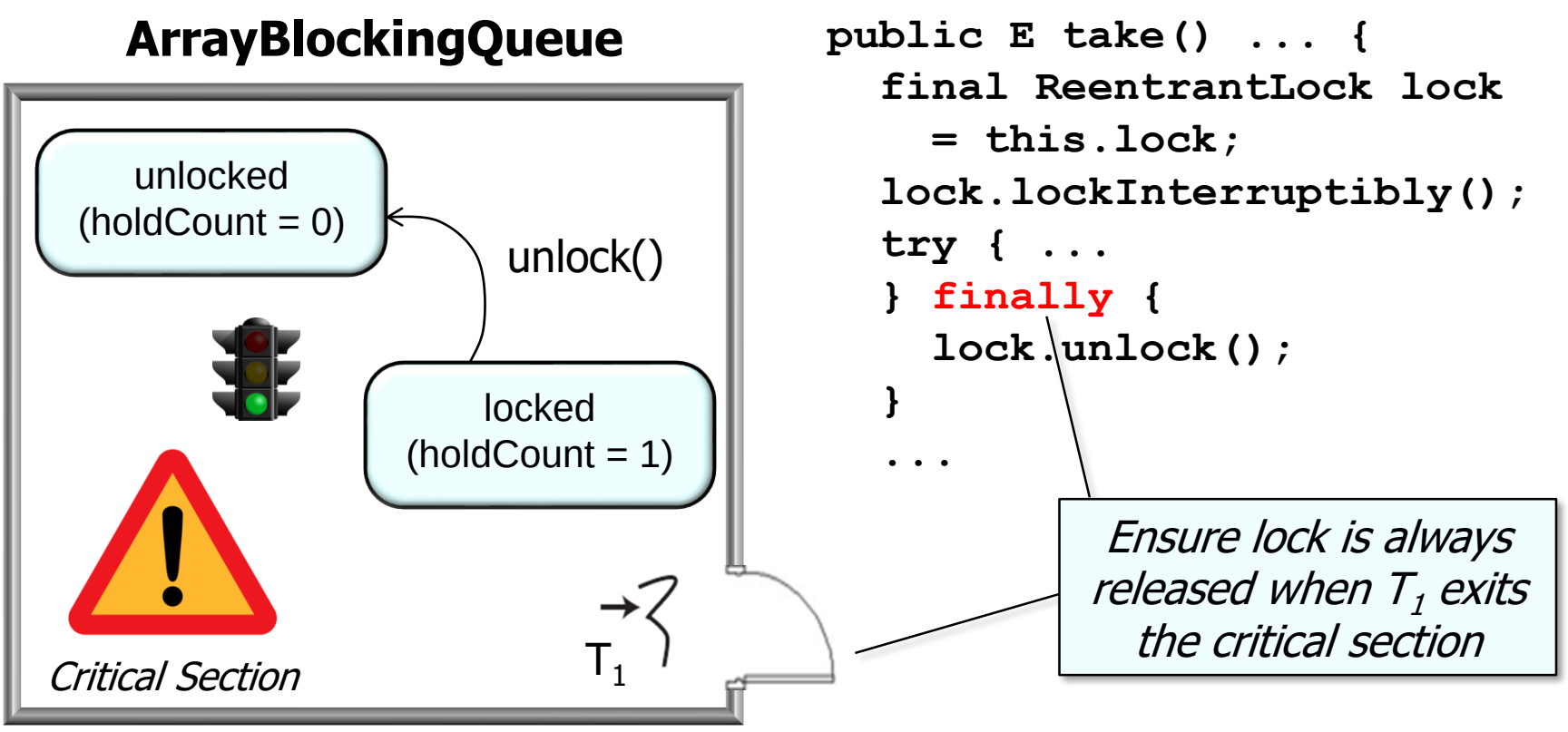
  lock.lockInterruptibly();
  try { ...
  } finally {
    lock.unlock();
  }
  ...
```



See tutorials.jenkov.com/java-concurrency/locks.html#finally

Using ReentrantLock in Java

- ArrayBlockingQueue is a blocking bounded FIFO queue

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    lock.lockInterruptibly();
    ...
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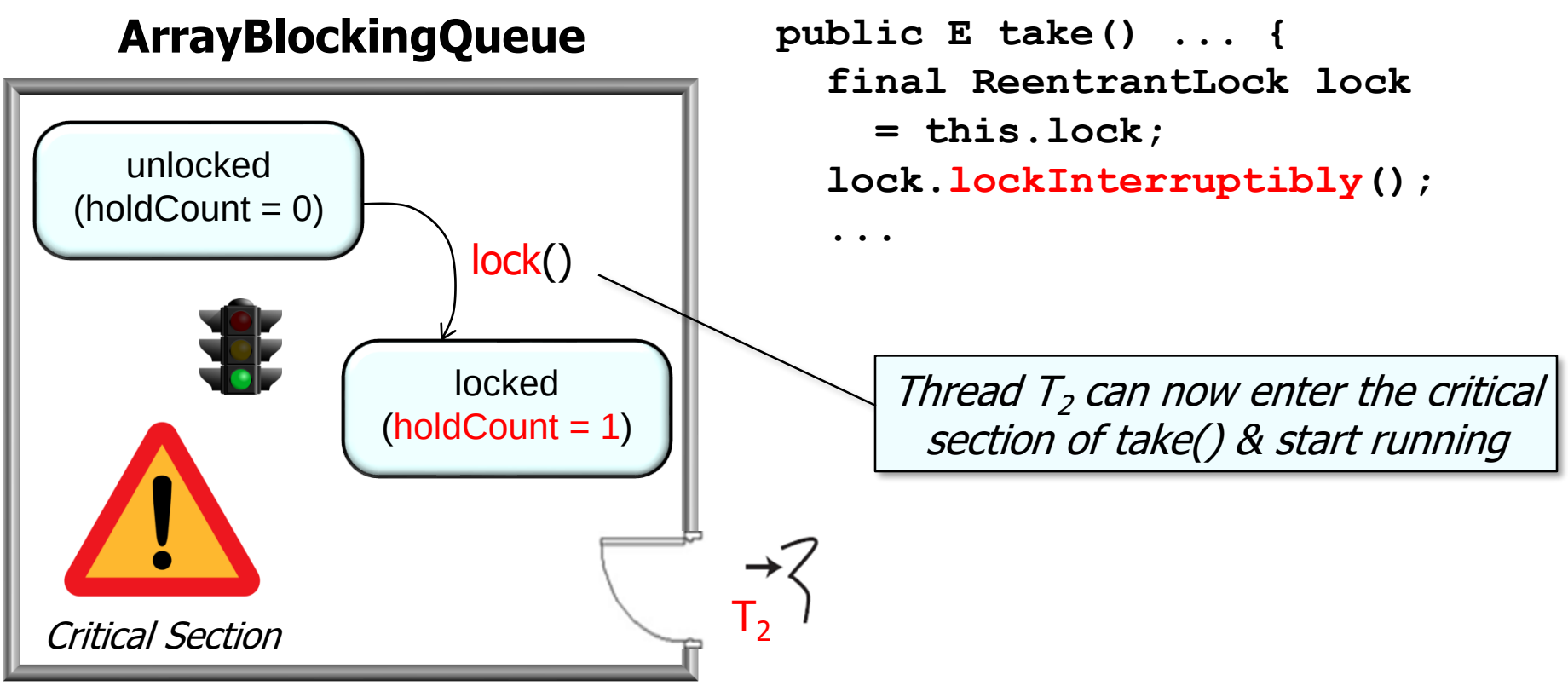
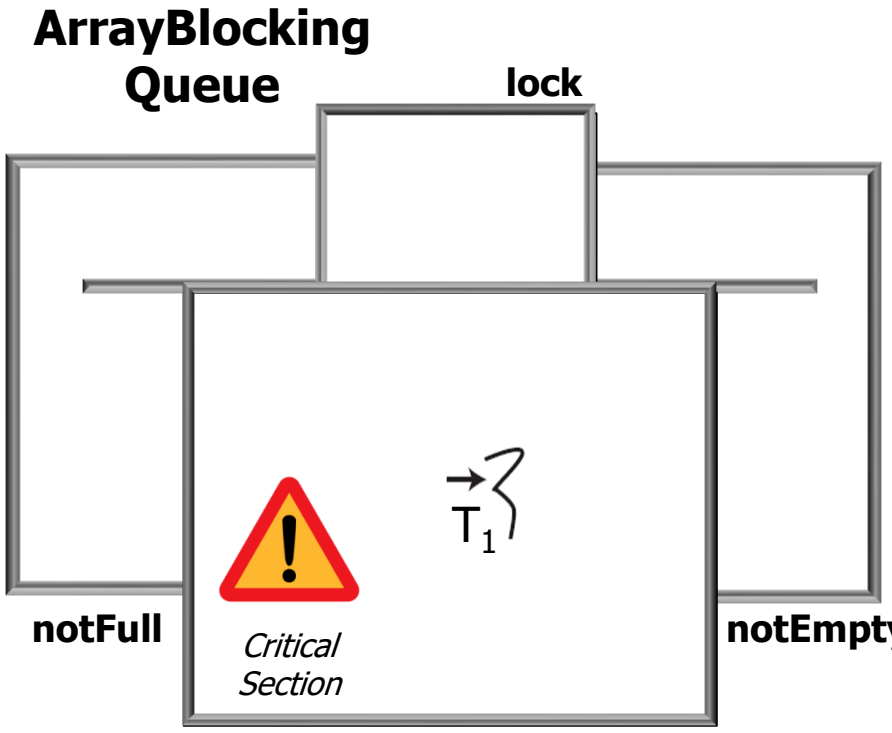


Using ReentrantLock in Java

- ArrayBlockingQueue needs to use more than ReentrantLock to implement its semantics




```
public class ArrayBlockingQueue<E>
             extends AbstractQueue<E>
           implements BlockingQueue<E>,
                      java.io.Serializable {
...
public E take() ... {
  final ReentrantLock lock
    = this.lock;
  lock.lockInterruptibly();
  try {
    while (count == 0)
      notEmpty.await();
    return extract();
  } finally {
    lock.unlock();
  }
}
```

A Java ConditionObject is used to coordinate multiple threads

Upcoming lesson on "*Java ConditionObject*" shows more on ArrayBlockingQueue

Using ReentrantLock in Java

- ArrayBlockingQueue needs to use more than ReentrantLock to implement its semantics

```
public class ArrayBlockingQueue<E>
             extends AbstractQueue<E>
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  lock.lockInterruptibly();
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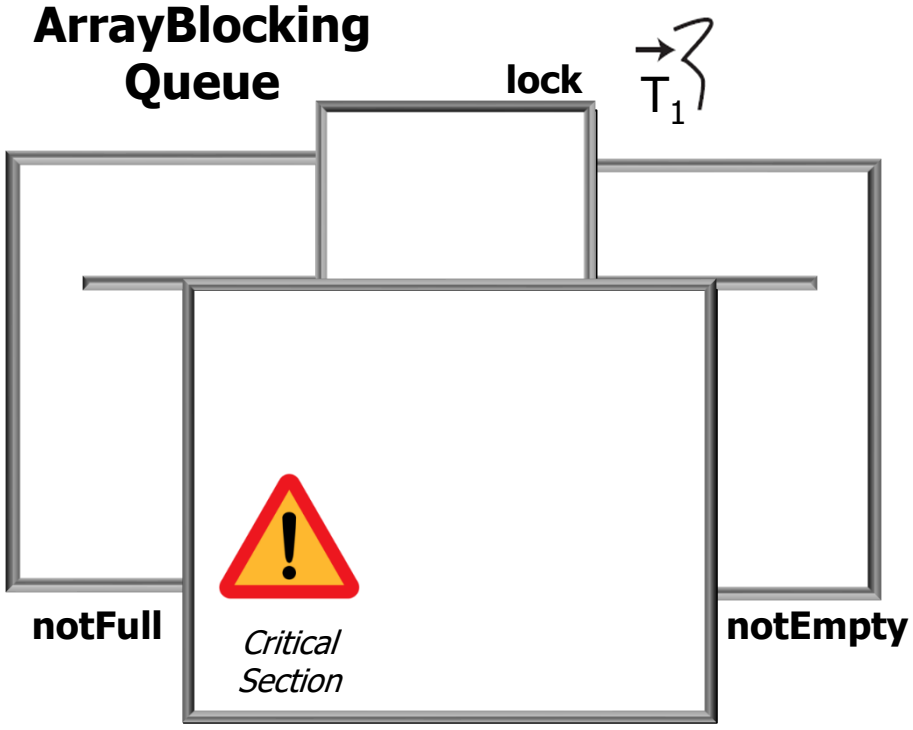
    return extract();
  } finally {
    lock.unlock();
  }
}
```



These mechanisms implement Guarded Suspension & Monitor Object patterns

See en.wikipedia.org/wiki/Guarded_suspension & www.dre.vanderbilt.edu/~schmidt/PDF/monitor.pdf

End of Java ReentrantLock (Part 4)