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Learning Objectives in this Part of the Lesson

• Understand the concept of mutual exclusion in concurrent programs

See en.wikipedia.org/wiki/Mutual_exclusion
Learning Objectives in this Part of the Lesson

• Understand the concept of mutual exclusion in concurrent programs
• Note a human-known use of mutual exclusion
Overview of Mutual Exclusion Locks
Overview of Mutual Exclusion Locks

- A mutual exclusion lock (mutex) defines a “critical section”

A critical section is a group of instructions or region of code that must be executed atomically.

See [en.wikipedia.org/wiki/Critical_section](en.wikipedia.org/wiki/Critical_section)
Overview of Mutual Exclusion Locks

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- Ensures only one thread can run in a block of code at a time
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  - Ensures only one thread can run in a block of code at a time
    - The thread enters the critical section after acquiring the lock
  - This thread runs without fear of other threads corrupting shared mutable state
Overview of Mutual Exclusion Locks

• A mutual exclusion lock (mutex) defines a “critical section”
  • Ensures only one thread can run in a block of code at a time
  • Other threads are kept “at bay”
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Other threads must obey the locking protocol or chaos will ensue!!
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  - Ensures only one thread can run in a block of code at a time
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  - Prevent corruption of shared mutable state that can be set/get by concurrent operations
- Race conditions could occur if multiple threads run within a critical section

Race conditions arise when a program depends on the sequence or timing of threads for it to operate properly

See en.wikipedia.org/wiki/Race_condition
Overview of Mutual Exclusion Locks

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- Ensures only one thread can run in a block of code at a time
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- After a thread leaves a critical section another thread can enter & start running
  - After acquiring the lock another thread enters the critical section
  - This thread has exclusive access to shared mutable state within critical section
Overview of Mutual Exclusion Locks

- A mutex is typically implemented in hardware via atomic operations

Atomic operations appear to occur instantaneously & either change the state of the system successful or have no effect

See en.wikipedia.org/wiki/Linearizability
Overview of Mutual Exclusion Locks

- A mutex is typically implemented in hardware via atomic operations
- Implemented in Java via the compareAndSwap*() methods in the Unsafe class

Concurrency

And few words about concurrency with Unsafe. compareAndSwap methods are atomic and can be used to implement high-performance lock-free data structures.

For example, consider the problem to increment value in the shared object using lot of threads.

First we define simple interface Counter:

```java
interface Counter {
    void increment();
    long getCount();
}
```

Then we define worker thread CounterClient, that uses Counter:

```java
class CounterClient implements Runnable {
    private Counter c;
    private int num;

    public CounterClient(Counter c, int num) {
        this.c = c;
        this.num = num;
    }

    @Override
    public void run() {
        for (int i = 0; i < num; i++) {
            c.increment();
        }
    }
}
```

See earlier discussion of "Java Atomic Classes & Operations"
Human Known Use of Mutual Exclusion Locks
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- A human known use of mutual exclusion locks is an airplane restroom protocol
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Person can only enter if the restroom is vacant.
Human Known Use of Mutual Exclusion Locks

- A human known use of mutual exclusion locks is an airplane restroom protocol.

Person atomically enters & locks the door.
Human Known Use of Mutual Exclusion Locks

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Other people who want to use the restroom must wait while it’s in use
Human Known Use of Mutual Exclusion Locks

• A human known use of mutual exclusion locks is an airplane restroom protocol

This protocol is “fully-bracketed,” i.e., person who locks must be the same as the person who unlocks
A human known use of mutual exclusion locks is an airplane restroom protocol.

Once the restroom is vacant another person can enter.
End of Introduction to Java ReentrantLock