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Coordination CS 272 Software Development

Providing Consistency

- If multithreading...
 - If **sharing data** between threads...
 - If shared data not already thread safe...
 - must synchronize access to that data



Synchronization

- Using the **synchronized** keyword and intrinsic (or monitor) lock objects to protect blocks of code
- Using the **volatile** keyword to protect* variables
- Using wait() and notifyAll() to coordinate threads
- Using **conditional synchronization** via lock objects

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Synchronization

 Using the synchronized keyword and intrinsic (or monitor) lock objects to protect blocks of code

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Using conditional synchronization via lock objects

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Motivation

- Synchronization helps coordinate threads with shared resources and provide thread safety
- Sometimes need coordination for other reasons
 - Scanner needs to wait for console input...
 - Server needs to wait for incoming requests...
 - Main thread needs to wait for work to complete...



Example: Thread.join()

- public static void main(...) { 1.
- Thread worker = new Thread(); 2.
- 3. worker.start(); // assume long-running
- 4. worker.join();

https://www.cs.usfca.edu/~cs272/javadoc/api/java.base/java/lang/Thread.html#join()

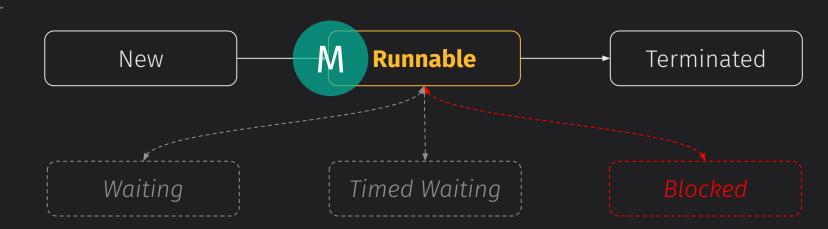
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5. }



1. public static void main(...) {

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- 3. worker.start();
- 4. worker.join();

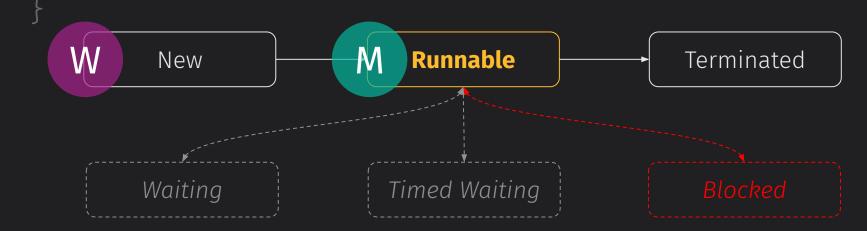


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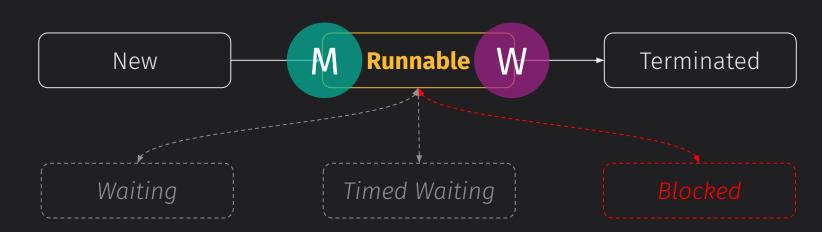


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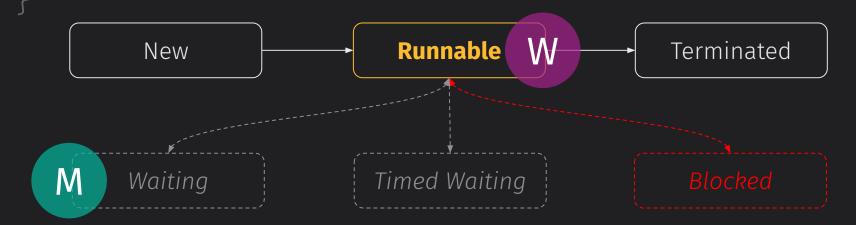


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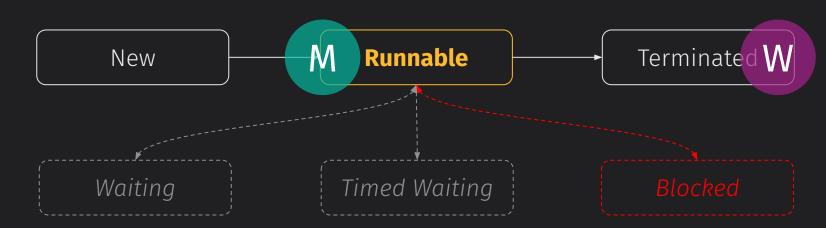


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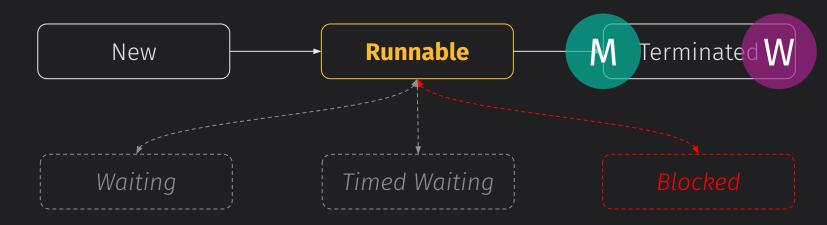


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Example: Thread.join()

- The calling thread **main** calls wait() to transition from **RUNNABLE** to the WAITING state
- The target thread **worker** calls notifyAll() when it transitions to TERMINATED state
- The calling thread **main** wakes up and transitions from WAITING back into its **RUNNABLE** state



Using Wait and Notify

- Must be called within a synchronized block of code on the intrinsic lock object
 - o synchronized (lock) { lock.wait(); }
 - o synchronized (this) { this.notify(); }
- The intrinsic lock object determines which wait() calls are woken up by notify() and notifyAll() calls



Using Intrinsic Locks

synchronized (hello) { hello.wait(); } synchronized (hello) { hello.notify(); } synchronized (hello) { hello.notifyAll(); }

synchronized (world) { world.wait(); } synchronized (world) { world.notify(); } synchronized (world) { world.notifyAll(); }

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Using wait(), wait(long), ...

- Current thread transitions from RUNNABLE to WAITING or TIMED WAITING state
- Releases intrinsic lock while waiting
- Waits until notified, timed out, interrupted, or... ????? igodot
 - A **spurious wakeup** can occur (rarely) Ο
 - Must wait in a while loop instead of if as a result! Ο

https://www.cs.usfca.edu/~cs272/javadoc/api/java.base/java/lang/Object.html#wait()

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Using notify(), notifyAll()

- Wakes up one or all threads waiting on lock Rarely use notify() since unable to choose thread Ο
- Awoken thread(s) attempt to acquire lock and transition back into RUNNABLE state
 - If unable to acquire lock, will be BLOCKED** until able Ο to acquire lock object

https://www.cs.usfca.edu/~cs272/javadoc/api/java.base/java/lang/Object.html#notify()

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Using Thread.sleep()

- Pauses execution temporarily
- Does not release locks (i.e. blocking)
- Often used to test code if attempting to cause blocking
- Most cases should use wait(...) with a time instead

https://docs.oracle.com/javase/tutorial/essential/concurrency/sleep.html

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Use Cases

- **Bounded Buffer**
 - Data structure for producer/consumer problems Ο
- Work Queue
 - Manages worker threads and work Ο
- Conditional Synchronization
 - Only block when certain conditions hold Ο



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