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Coordination

CS 272 Software Development

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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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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()

```
1. public static void main( ... ) {
2.     Thread worker = new Thread();
3.     worker.start(); // assume long-running
4.     worker.join();
5. }
```

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

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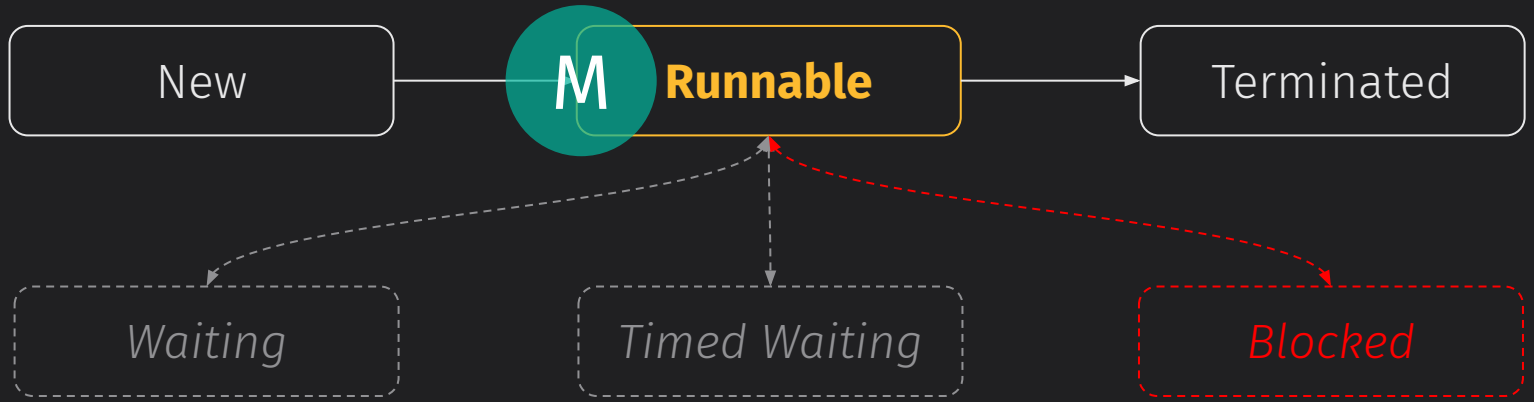

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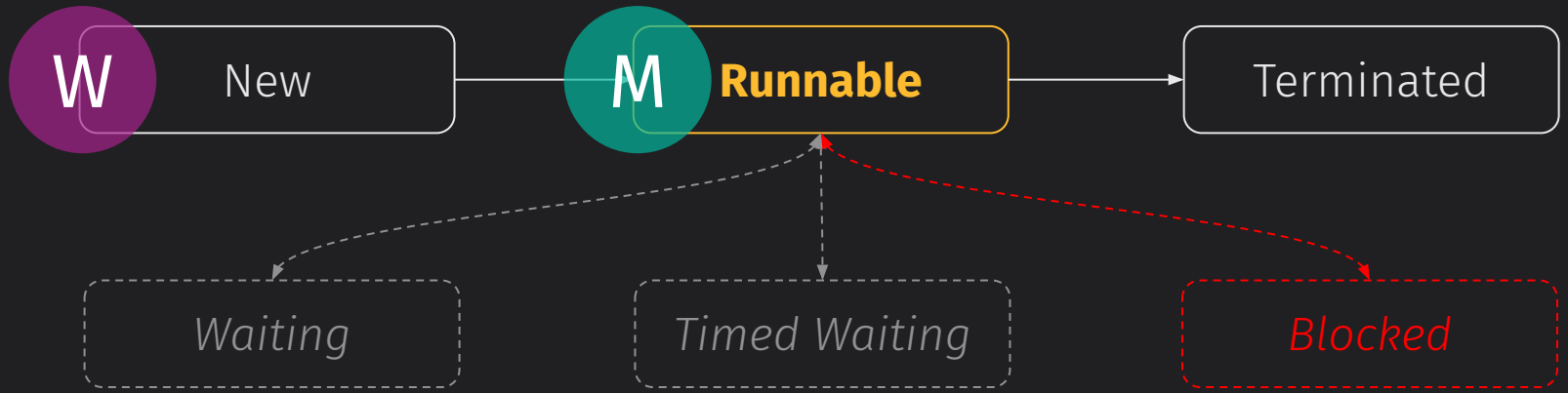

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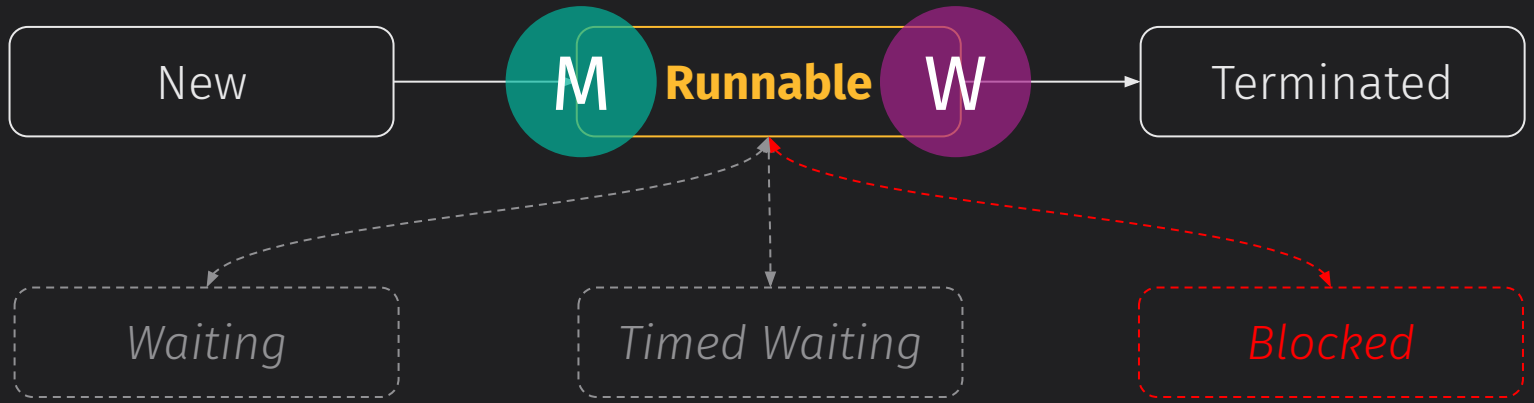

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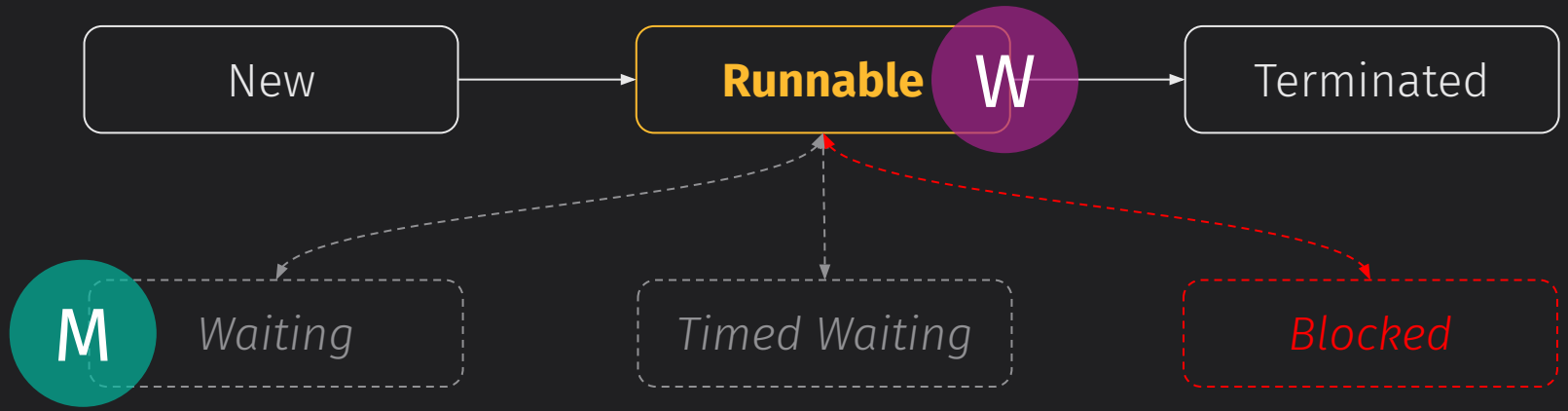

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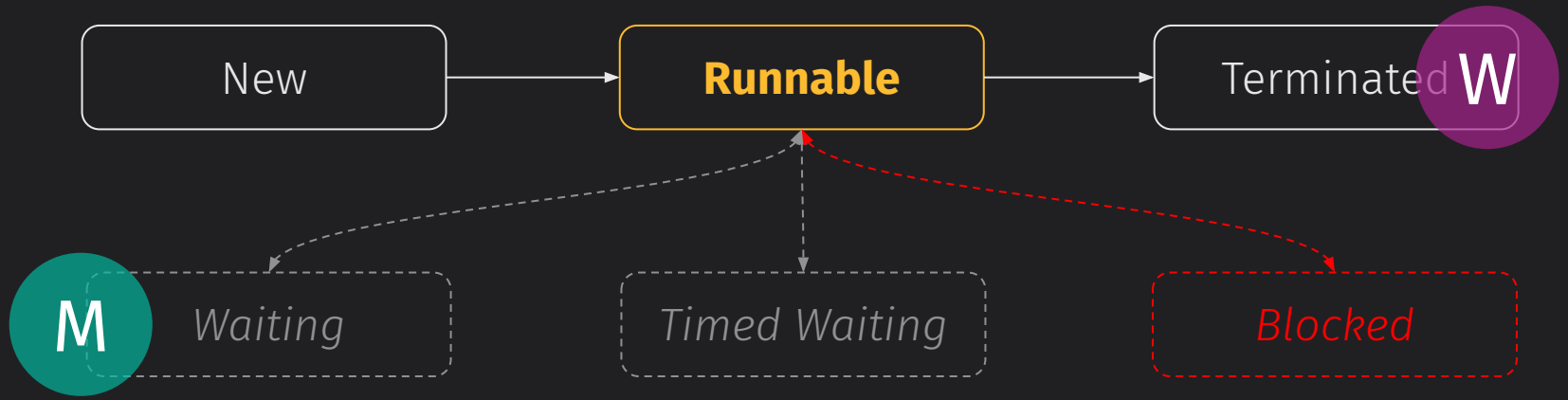

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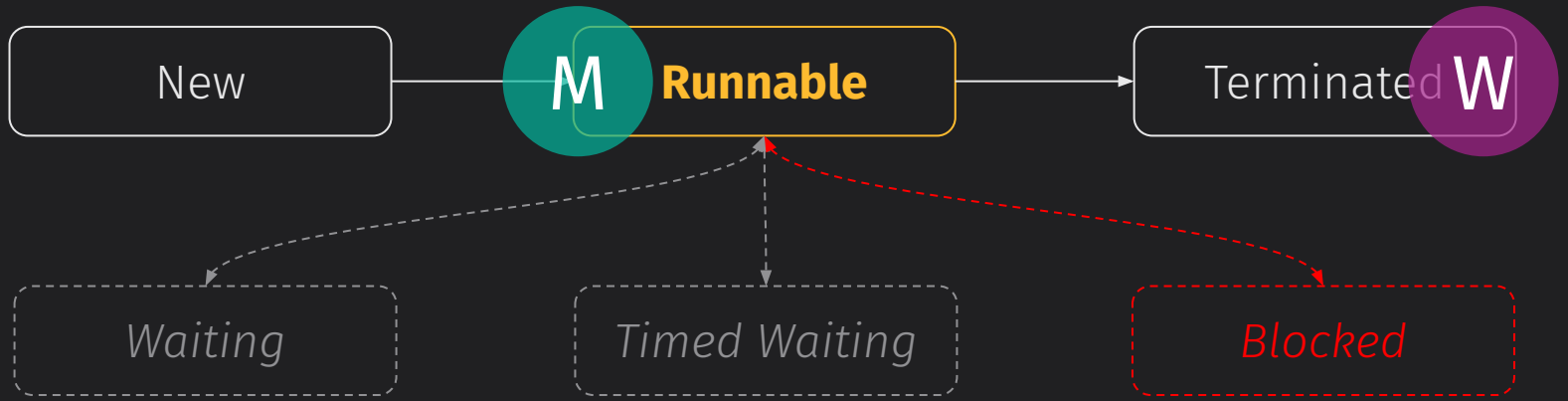

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Example: Thread.join()

- 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
  - `synchronized (lock) { lock.wait(); }`
  - `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(); }
```

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... ?????
  - A **spurious wakeup** can occur (rarely)
  - Must wait in a while loop instead of if as a result!

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

Using notify(), notifyAll()

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

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

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

Use Cases

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

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