Examples of Java “Happens-Before” Relationships

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Learning Objectives in this Part of the Lesson

- Understand what “happens-before” relationships mean in Java
- Recognize how Java Thread methods support “happens-before” relationships
Learning Objectives in this Part of the Lesson

- Understand what “happens-before” relationships mean in Java
- Recognize how Java Thread methods support “happens-before” relationships
- Know how Java collections support “happens-before” relationships
Java Thread “Happens-Before” Relationships
Java Thread “Happens-Before” Relationships

- Methods in the Java Thread class establish “happen-before” relationships

See docs.oracle.com/javase/8/docs/api/java/lang/Thread.html
Java Thread “Happens-Before” Relationships

- Methods in the Java Thread class establish “happen-before” relationships.
- Starting a thread “happens-before” the run() hook method of the thread is called.

Java Thread “Happens-Before” Relationships

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```java
Thread threadB =
    new Thread(() ->
        System.out.println("hello world"));

threadB.start();
```

```java
<<Java Class>>
G Thread

yield():void
currentThread():Thread
sleep(long):void
sleep(long,int):void
Thread()
Thread(Runnable)
Thread(String)
start():void
run():void
exit():void
interrupt():void
interrupted():boolean
isInterrupted():boolean
isAlive():boolean
setPriority(int):void
getPriority():int
join(long):void
join(long,int):void
join():void
setDaemon(boolean):void
isDaemon():boolean
```
Java Thread “Happens-Before” Relationships

• Methods in the Java Thread class establish “happen-before” relationships
  
• Starting a thread “happens-before” the run() hook method of the thread is called

```java
Thread threadB =
    new Thread(() ->
        System.out.println("hello world"));

threadB.start();
```

Create & start threadB from within threadA
Java Thread “Happens-Before” Relationships

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- Starting a thread “happens-before” the run() hook method of the thread is called

```java
Thread threadB =
    new Thread(() ->
        System.out.println("hello world");
    threadB.start();
```

This lambda expression plays the role of the run() hook method!
Methods in the Java Thread class establish “happen-before” relationships

Starting a thread “happens-before” the run() hook method of the thread is called

```java
Thread threadB =
    new Thread(() ->
        System.out.println("hello world"));

threadB.start();
...
```

threadA’s call to the threadB.start() method (& associated changes it made to any shared state) will “happen before” threadB’s run() hook method is called
Java Thread “Happens-Before” Relationships

- Methods in the Java Thread class establish “happen-before” relationships
- Starting a thread “happens-before” the run() hook method of the thread is called

```java
Thread threadB =
    new Thread(() ->
        System.out.println
            ("hello world"));

threadB.start();
```

Likewise, the state of threadB will be consistent & visible before the run() hook method begins to execute
Java Thread “Happens-Before” Relationships

- Methods in the Java Thread class establish “happens-before” relationships
  - Starting a thread “happens-before” the run() hook method of the thread is called
  - The termination of a thread “happens-before” a join() with the terminated thread
Methods in the Java Thread class establish “happen-before” relationships

- Starting a thread “happens-before” the run() hook method of the thread is called
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```java
Thread threadB =
    new Thread(() ->
        System.out.println("hello world"));

threadB.start();

...

threadB.join();
```
Methods in the Java Thread class establish “happen-before” relationships

- Starting a thread “happens-before” the run() hook method of the thread is called
- The termination of a thread “happens-before” a join() with the terminated thread

```java
Thread threadB =
    new Thread(() ->
        System.out.println("hello world"));
threadB.start();
...
threadB.join();
```

*threadB terminates after its lambda expression run() processing completes*
Java Thread “Happens-Before” Relationships

• Methods in the Java Thread class establish “happen-before” relationships
  • Starting a thread “happens-before” the run() hook method of the thread is called
  • The termination of a thread “happens-before” a join() with the terminated thread

```java
Thread threadB = 
    new Thread(() -> 
        System.out.println("hello world");
    )
    threadB.start();

...

threadB.join();
```

threadA waiting on join() only resumes its processing after threadB terminates
Java Thread “Happens-Before” Relationships

- Methods in the Java Thread class establish “happen-before” relationships
  - Starting a thread “happens-before” the run() hook method of the thread is called
  - The termination of a thread “happens-before” a join() with the terminated thread

```java
Thread threadB = new Thread(() ->
    System.out.println("hello world"));
threadB.start();
...
threadB.join();
```

After join() returns threadA must see all changes made to shared state by threadB that “happened before” it exited
Java Collections “Happens-Before” Relationships
Java Collections “Happens-Before” Relationships

- Methods in java.util.concurrent package classes also establish “happen-before” relationships

See docs.oracle.com/javase/8/docs/api/java/util/concurrent/package-summary.html#MemoryVisibility
Java Collections “Happens-Before” Relationships

- Methods in java.util.concurrent package classes also establish “happen-before” relationships
- The release of a monitor lock “happens-before” every subsequent acquire on the same lock

**Thread A**
```
synchronized (lock) {
    .......... 
}
```
**Thread B**
```
synchronized (lock) {
    .......... 
}
```

- e.g., a ReentrantLock or exiting a synchronized method/statement

Java Collections “Happens-Before” Relationships

- Methods in java.util.concurrent package classes also establish “happen-before” relationships
- The release of a monitor lock “happens-before” every subsequent acquire on the same lock

// Thread A
class ArrayBlockingQueue<E> {
    ... { ... 
        public void put(E e) { ... {
            ... 
            final ReentrantLock lock = this.lock;
            lock.lockInterruptibly();
            try { ... }
            finally { 
                lock.unlock();
            }
        }
    }
}

// Thread B
class ArrayBlockingQueue<E> {
    ... { ... 
        public E take() { ... {
            final ReentrantLock lock = this.lock;
            lock.lockInterruptibly();
            try { ... }
            finally { 
                lock.unlock();
            }
        }
    }
}
Java Collections “Happens-Before” Relationships

- Methods in `java.util.concurrent` package classes also establish “happen-before” relationships
- The release of a monitor lock “happens-before” every subsequent acquire on the same lock

```
// Thread A
class ArrayBlockingQueue<E> {
    ... { ... }
    public void put(E e) { ...
        final ReentrantLock lock = this.lock;
        lock.lockInterruptibly();
        try { ... }
        finally { lock.unlock(); }
    }
}

// Thread B
class ArrayBlockingQueue<E> {
    ... { ... }
    public E take() { ...
        final ReentrantLock lock = this.lock;
        lock.lockInterruptibly();
        try { ... }
        finally { lock.unlock(); }
    }
}
```

Consider the `put()` & `take()` methods in `ArrayBlockingQueue`
Java Collections “Happens-Before” Relationships

• Methods in java.util.concurrent package classes also establish “happen-before” relationships

• The release of a monitor lock “happens-before” every subsequent acquire on the same lock

```java
// Thread A
class ArrayBlockingQueue<E> { ...
    public void put(E e) {... {
        ...
        final ReentrantLock lock = this.lock;
        lock.lockInterruptibly();
        try {
            ...
        } finally {
            lock.unlock();
        }
    }
}

// Thread B
class ArrayBlockingQueue<E> { ...
    public E take() {... {
        final ReentrantLock lock = this.lock;
        lock.lockInterruptibly();
        try {
            ...
        } finally {
            lock.unlock();
        }
    }
}
```

Actions prior to "releasing" the ReentrantLock must happen-before actions subsequent to a successful "acquiring" of this lock

See earlier lessons on “Java ReentrantLock” & “Java ConditionObject"
Methods in java.util.concurrent package classes also establish “happen-before” relationships

- The release of a monitor lock “happens-before” every subsequent acquire on the same lock
- Actions in a thread prior to placing an object into any concurrent collection “happen-before” actions subsequent to the access or removal of that element from the collection in another thread

```java
Map<String, String> concurrentMap = new ConcurrentHashMap<>();

// Thread t1
concurrentMap.put("key", "value");

// Thread t2
String value = concurrentMap.get("key");
```

See upcoming lesson on “Java Concurrent Collections”
Java Collections “Happens-Before” Relationships

- Methods in java.util.concurrent package classes also establish “happen-before” relationships
  - The release of a monitor lock “happens-before” every subsequent acquire on the same lock
  - Actions in a thread prior to placing an object into any concurrent collection “happen-before” actions subsequent to the access or removal of that element from the collection in another thread

```java
Map<String, String> concurrentMap = new ConcurrentHashMap<>();

// Thread t1
concurrentMap.put("key", "value");

// Thread t2
String value = concurrentMap.get("key");
```

Consider a ConcurrentHashMap that supports concurrent retrievals & high expected concurrency for updates

See docs.oracle.com/javase/8/docs/api/java/util/concurrent/ConcurrentHashMap.html
Java Collections “Happens-Before” Relationships

• Methods in java.util.concurrent package classes also establish “happen-before” relationships

• The release of a monitor lock “happens-before” every subsequent acquire on the same lock

• Actions in a thread prior to placing an object into any concurrent collection “happen-before” actions subsequent to the access or removal of that element from the collection in another thread

Map<String, String> concurrentMap = new ConcurrentHashMap<>();

// Thread t1
concurrentMap.put("key", "value");

// Thread t2
String value = concurrentMap.get("key");

Placing a “key/value” element into a ConcurrentHashMap must happen-before accessing or removing this element from the map
Java Collections “Happens-Before” Relationships

- Java’s class libraries are responsible for ensuring these “happens-before” relationships are preserved
Java Collections “Happens-Before” Relationships

• Java’s class libraries are responsible for ensuring these “happens-before” relationships are preserved

You don’t need to understand all the nitty-gritty details of Java’s memory model – you just need to understand how to use synchronizers properly!
End of Examples of “Happens-Before” Relationships