Practical Concurrent and Parallel Programming

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Plan for today

- A few notes on yesterdays feedback
- CPU caches and parallelism
- Visibility (of memory writes)
- Instance creation and synchronization

First feedback session

Reentrant

```
class Reentrant <T> {
  private List<T> myElements;

  public synchronized void add(T element){
    myElements.add( element ); }
  public synchronized void addAll(Collection<> col){
    for (T elem: col) {
      add( elem ); }
  }
}
```

Which of the following descriptions of `synchronized` is the correct?

- When a thread try to enter a synchronized method, it will try to obtain the lock. If the lock is already taken, it will wait.
- When a thread try to enter a synchronized method, it will try to obtain the lock. If the lock is already taken by an other thread, it will wait

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Reentrancy is implemented by associating with each lock an acquisition count and an owning thread.

Why synchronize just to read data?

```
class LongCounter {
 private long count = 0;
 public synchronized void increment() {
   count = count + 1;
 }
 public synchronized long get() {
   return count;
}} // TestLongCounter.java
```

Why needed? The synchronized keyword has **two** effects:

- *Mutual exclusion*: only one thread can hold a lock (execute a synchronized method or block) at a time
- *Visibility of memory writes*: All writes by thread A before releasing a lock (exit synchr) are visible to thread B after acquiring the lock (enter synchr)

Visibility is really important

```
class MutableInteger { WARNING: Useless
  private int value = 0;
  public void set(int value) { this.value = value; }
  public int get() { return value; }
}
```

- Looks OK, no need for synchronization?
- But thread t may loop forever in this scenario:

```
final MutableInteger mi = new MutableInteger();
Thread t = new Thread(() -> {
    while (mi.get() == 0) { } //Loop while zero
});
t.start();
mi.set(42);
```

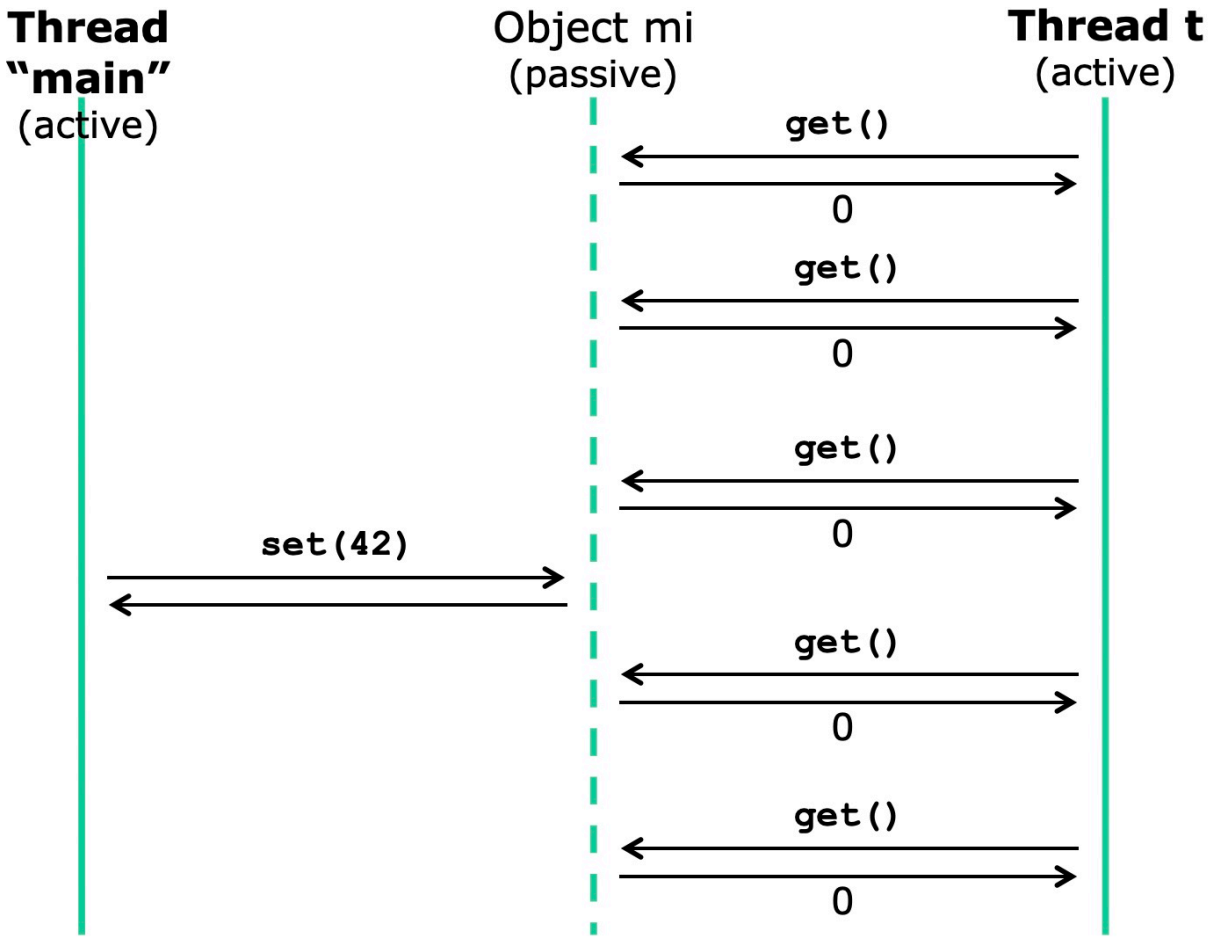
This write by thread ”main” may be forever invisible to thread t

Why can the other thread not see the write of 42?

It is because of the caching done inside a modern CPU.

Lets just spend 5 min on this video.

42 is just written to main's cache



Reordering of instructions

```
public class PossibleReordering {
    static int x = 0, y = 0;
    static int a = 0, b = 0;
    public static void main(String[] args) throws InterruptedException {
        Thread one = new Thread(() -> {
            a = 1; x = b; });
        Thread other = new Thread(() {
            b = 1; y = a; });
        one.start(); other.start();
        one.join(); other.join();
        System.out.println("( " + x + "," + y + ")");
    }
}
```

We can get (0,1), (1,0), and (1,1)

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- The Java compiler can *reorder* instructions with no data-dependencies
- Memory caching can make assignments to field-variables appear out of order.

Aside - why would java reorder statements???

```
a = ...
b = ...
//stuff that change a
//stuff that change b
a++;
b++;
```

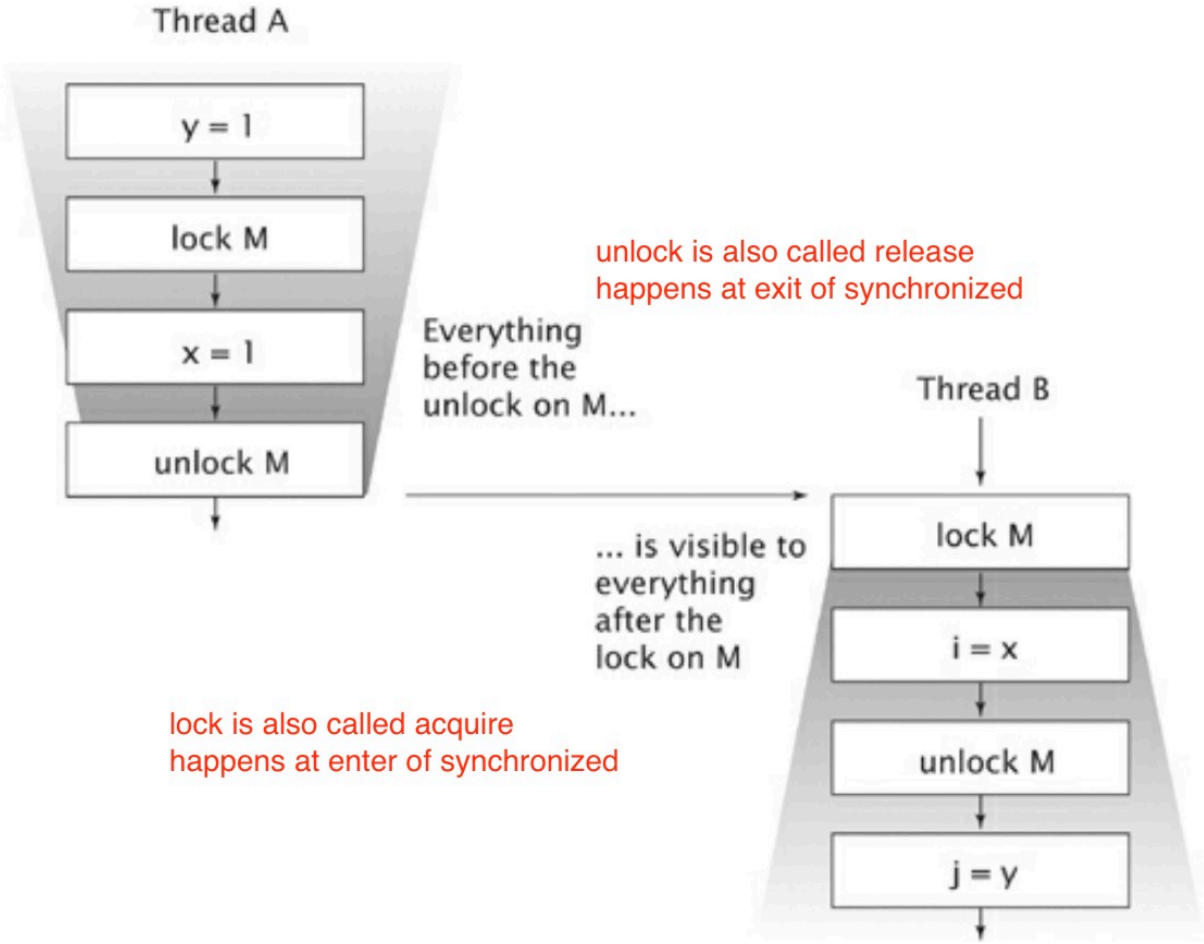
Sometimes it can yield better performance to let the JVM JIT compiler allow to change this to:

```
a = ...
//stuff that change a
a++;
b = ...
//stuff that change b
b++;
```

Because this can allow variable `a` to remain in one of the cpu registers, and not be written to memory until the end

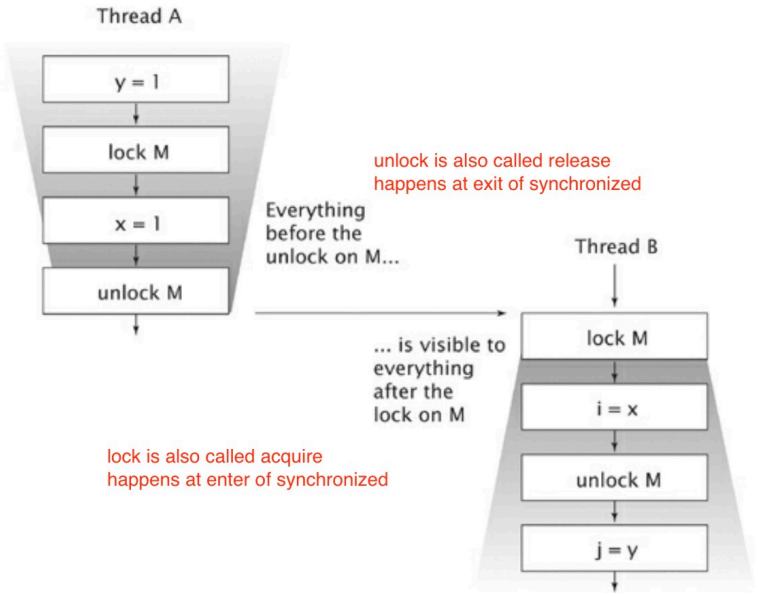
Visibility by synchronization

One solution is to use `synchronized`



MutableInteger - synchronization

```
class MutableInteger {
  private int value = 0;
  public synchronized void set(int value) { this.value = value; }
  public synchronized int get() { return value; }
}
```



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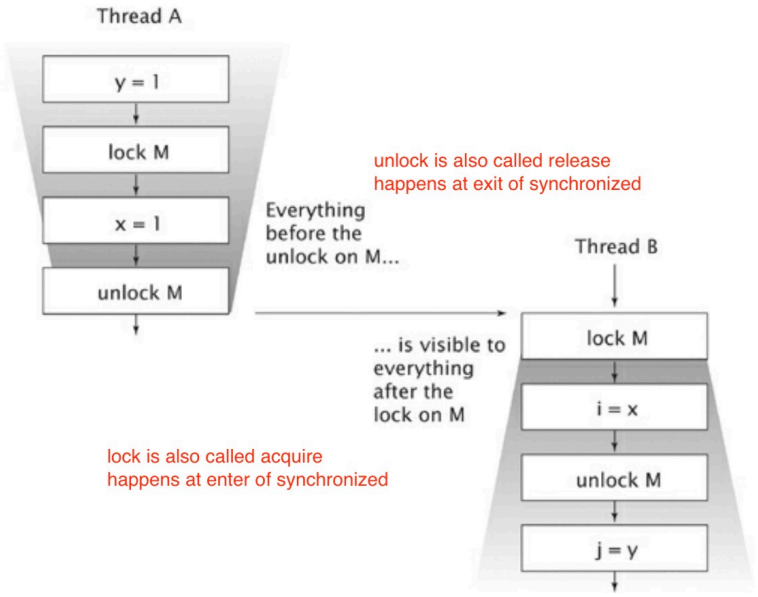

Why is the synchronized keyword needed for `get()`?

The volatile field modifier

The volatile field modifier can be used to ensure visibility (but not mutual exclusion)

```
class MutableInteger {
  private volatile int value = 0;
  public void set(int value) { this.value = value; }
  public int get() { return value; }
}
```

- Volatile variable rule: A write to a volatile field *happens-before* every subsequent read of that same field.

Goetz advice on volatile

Use volatile variables only when they simplify your synchronization policy; avoid it when verifying correctness would require subtle reasoning about visibility.

Locking can guarantee both visibility and atomicity; volatile variables can only guarantee visibility.

- Rule 1: Use locks (synchronized)
- Rule 2: If circumstances are right, and you are an expert, maybe use volatile instead
- Rule 3: There are few experts

Ways to ensure visibility

- Unlocking followed by locking the same lock
- Writing a volatile field and then reading it
- Calling one method on a concurrent collection and another method on same collection – java.util.concurrent.*
- Calling one method on an atomic variable and then another method on same variable – java.util.concurrent.atomic.*
- Finishing a constructor that initializes final or volatile fields Calling t.start() before anything in thread t Anything in thread t before t.join() returns

(Java Language Specification 8 §17.4, and the Javadoc for concurrent collection classes etc, give the full and rather complicated details)

Break

Publishing an object

- What is the problem of making an object, and telling other threads about the object
- Some examples that do not work
- Text book has examples of how it can go wrong

Unsafe publication

Listing 16.3. Unsafe Lazy Initialization. ***Don't do this.***

```
@NotThreadSafe
public class UnsafeLazyInitialization {
    private static Resource resource;

    public static Resource getInstance() {
        if (resource == null)
            resource = new Resource(); // unsafe publication
        return resource;
    }
}
```

Problems:

- two threads might get into a *race-condition* from the test to the assignment
- Due to caching, you can a Resource which is not initialized (because the fields were not yet written)

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Would it help to make `resource` volatile?

Safe publication

Initialization must *happen-before* publication

If you just want to make it work, use 'synchronized' for `getInstance()`.

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Other ways to publish thread-safely:

- Initializing an object reference from a static initializer;
- Storing a reference to it into a volatile field or AtomicReference;
- Storing a reference to it into a final field of a properly constructed object; or
- Storing a reference to it into a field that is properly guarded by a lock.
- Inserting a reference into a `ThreadSafe` datastructure.

Immutable objects

- What are they?
- And how can it go wrong in publishing them too

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- And how can it go wrong in publishing them too

An object is immutable if:

- Its state cannot be modifled after construction;
- All its flelds are final and
- It is properly constructed.

Safe ways to publish objects

We need to assure that initialization *happens-before* publication.

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That is, somewhere the code should be `synchronized`.