Module 04:
”Nonblocking Synchronization”

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Agenda

- **Introducing Nonblocking Synchronization**
- Interlocking
- Memory Barriers a.k.a. Fences
- Volatile

Thread Safety

"A program or method is said to be thread-safe if it has no indeterminacy in the face of any multithreading scenario"

What does Thread Safety mean?

- It's quite hard to give a precise (and still simple definition)

- "Produces predictable and consistent answers regardless of scheduling"

- Free of deadlocks
- Free of livelocks
- Free of resource starvation
- Free of race conditions
- …

- Best practice is to use locking (and perhaps) signaling to obtain thread safety

What is Nonblocking Synchronization?

- For extreme performance scenarios there are some very advanced options for avoiding blocking
- Often require very intricate knowledge of
  - CLR
  - CPU
  - Compiler optimizations

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Atomicity

- A single read or write of 32 bits (or less)
  - is always atomic on both 32-bit and 64-bit machines
- A single read or write of 64 bits (or more)
  - is not atomic on 32-bit machines
  - is atomic on 64-bit machines

```
int _x, _y;
long _z, l;
...
_x = 3;       ←———— Atomic
_z = 3;       ←———— Not atomic
l = _z;       ←———— Not atomic
_y += _x;     ←———— Not atomic
_x++;         ←———— Not atomic
```

- Locking essentially simulates atomicity for blocks of code

Interlocked

- Helper class to make these assignments atomic
- `Interlocked.`
    - `Read()` + `Add()`
    - `Increment()` + `Decrement()`
    - `Exchange()` + `CompareExchange()`

```
long _a;

Interlocked.Increment(ref _a);
Interlocked.Add(ref _a, 42);
Console.WriteLine(Interlocked.Read(ref _a));

Interlocked.Exchange(ref _a, 87);
Interlocked.CompareExchange(ref _a, 176, 87);
```

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A Simple Puzzle (or...?)

```
private int _answer = 42;
private bool _complete;

public void Access1()
{
    _answer = 87;
    _complete = true;
}

public void Access2()
{
    if (_complete)
    {
        Console.WriteLine(_answer); // <-- What is printed?
    }
}
```

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Safe Optimizations

- Safe optimizations for single-threaded programs:

- The compiler, CLR, or CPU may reorder your program's instructions to improve efficiency.
- The compiler, CLR, or CPU may cache variables such that assignments to variables won't be visible to other threads right away.

- Are these safe for multi-threaded programs also?

MemoryBarrier

- Manually suppress unsafe optimizations

```
public void Access1()
{
    _answer = 87;
    Thread.MemoryBarrier();
    _complete = true;
    Thread.MemoryBarrier();
}

public void Access2()
{
    Thread.MemoryBarrier();
    if (_complete)
    {
        Thread.MemoryBarrier();
        Console.WriteLine(_answer); // <-- 87 is printed!
    }
}
```

Full Memory Barriers

- At least all of these generate a full memory barrier:
  - `Thread.MemoryBarrier()`
  - Interlocked methods
  - `Thread.Sleep()` + `Thread.Join()` + `Thread.SpinWait()`
  - C# `lock` statement
  - `Monitor.Enter()` + `Monitor.Exit()`
  - Any event signaling and waiting
  - `Thread.VolatileRead()` + `Thread.VolatileWrite()`
  - `Task.Start()` + `Task.Wait()` + Task continuations

Module 02

Module 03

Up shortly

Later…

Agenda

- Introducing Nonblocking Synchronization
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- **Volatile**

Volatile

- The **`volatile`** keyword
  - Generates *Acquire-fence* on reads
    - prevents other reads/writes from being moved *before* the fence
  - Generates *Release-fence* on writes
    - a release-fence prevents other reads/writes from being moved *after* the fence
- Confused? That's quite understandable! ☺

```
volatile bool _complete;

public void Access1()
{
    _answer = 87;
    _complete = true;
}
public void Access2()
{
    if (_complete)
    {
        WriteLine(_answer);
    }
}
```

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What Volatile Means

	Hardware			CLR 2.0+	
Operation	Intel x86 & Intel64	IA 64	AMD64	Without Volatile	With Volatile
Read, Read	No	Yes	No	Yes	No
Read, Write	No	Yes	No	Yes	No
Write, Write	No	Yes	No	No	No
Write, Read	Yes, only if load and store are to different locations.	Yes	Yes, only if load and store are to different locations.	**Yes**	**Yes**

- No, volatile does NOT incur "latest is always read"!

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Joe Duffy's Bizarre Example

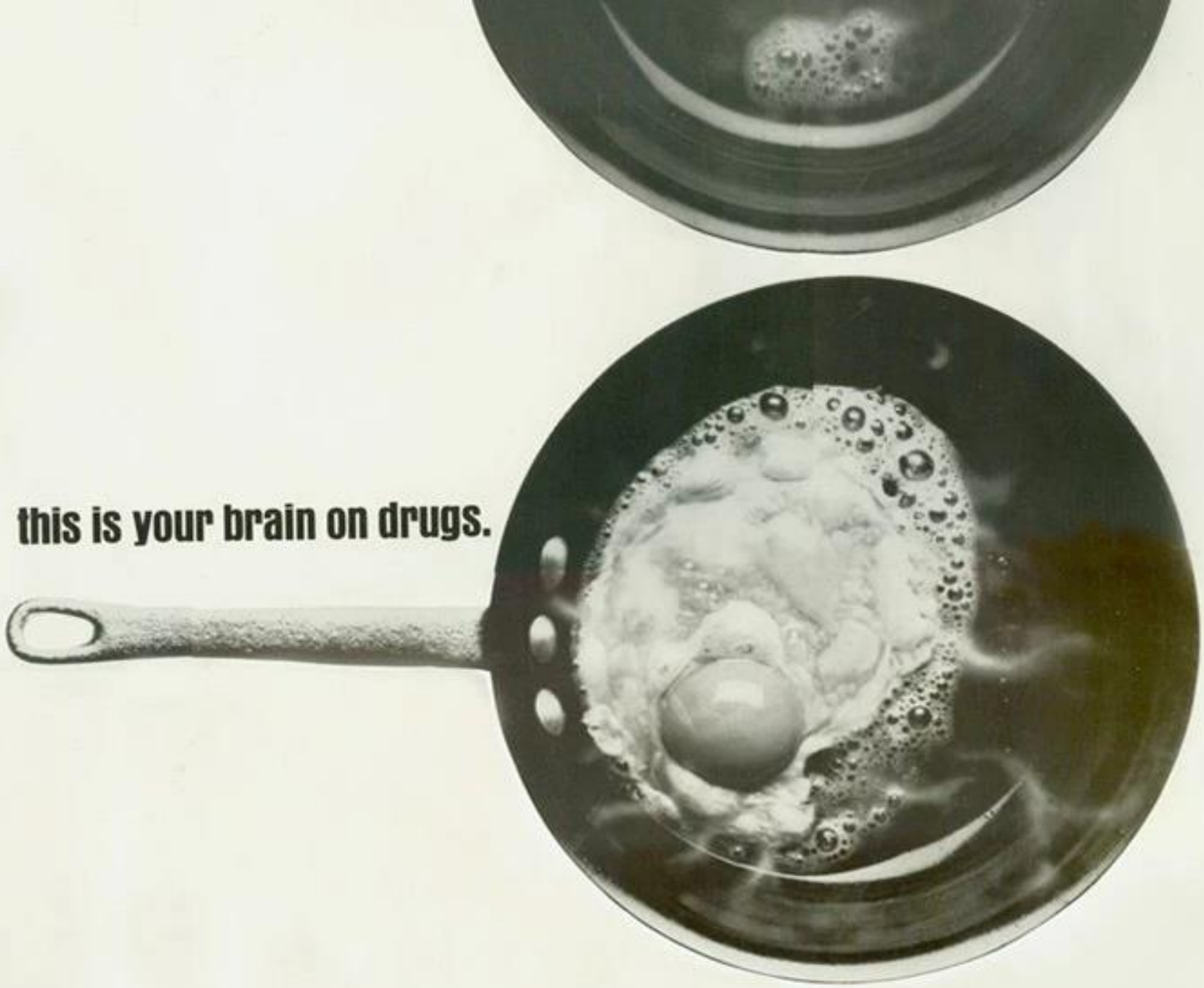
- May end up as a == 0 and b == 0

```
volatile int x, y;

public void Access1()
{
    x = 1;              // Volatile write (release-fence)
    int a = y;          // Volatile read (acquire-fence)
    Console.WriteLine(a);
}

public void Access2()
{
    y = 1;              // Volatile write (release-fence)
    int b = x;          // Volatile read (acquire-fence)
    Console.WriteLine(b);
}
```

Volatile Reads and Writes

- volatile ~ Thread.VolatileRead + Thread.VolatileRead

```
class Thread
{
    ...
    public static void VolatileWrite( ref int address, int value)
    {
        MemoryBarrier(); address = value;
    }

    public static int VolatileRead (ref int address)
    {
        int num = address; MemoryBarrier(); return num;
    }
}
```


this is your brain on drugs.

Best Practices for Synchronization

- Do
  - Use lock
  - Use Monitors
  - Use Events and Handles
  - Use Interlocked

- Don’t
  - Use **`volatile`**
  - Use **`Thread.VolatileRead()`** or **`Thread.VolatileWrite()`**
  - Use explicit memory barriers

Summary

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- Volatile

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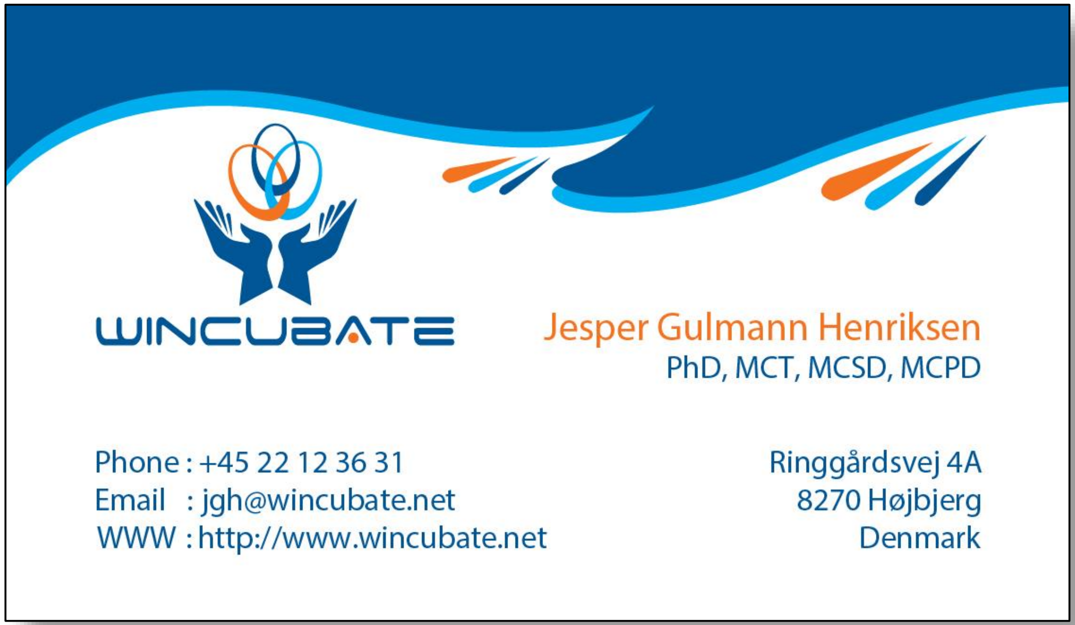

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