Concurrency (Part II):
Mutual Exclusion, **Synchronization**, Deadlock, and Starvation

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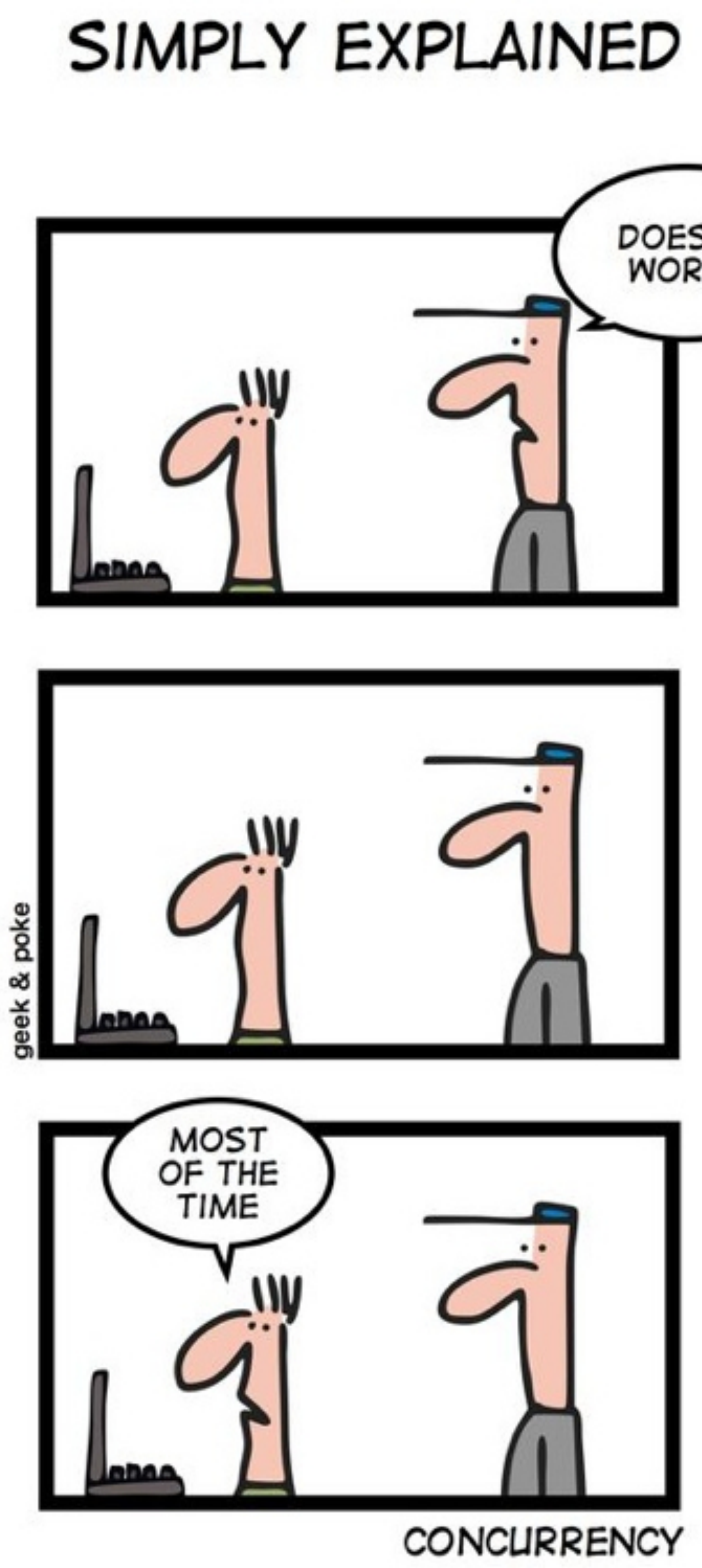
CSCI 460 Operating Systems
Fall 2019



–http://www.datamation.com/news/tech-comics-quantum-physics-2.html

Some slides & figures adapted from Stallings instructor resources.

Some slides adapted from Adam Bates's F'18 CS423 course @ UIUC
https://courses.engr.illinois.edu/cs423/sp2018/schedule.html

Goals for Today

Learning Objectives

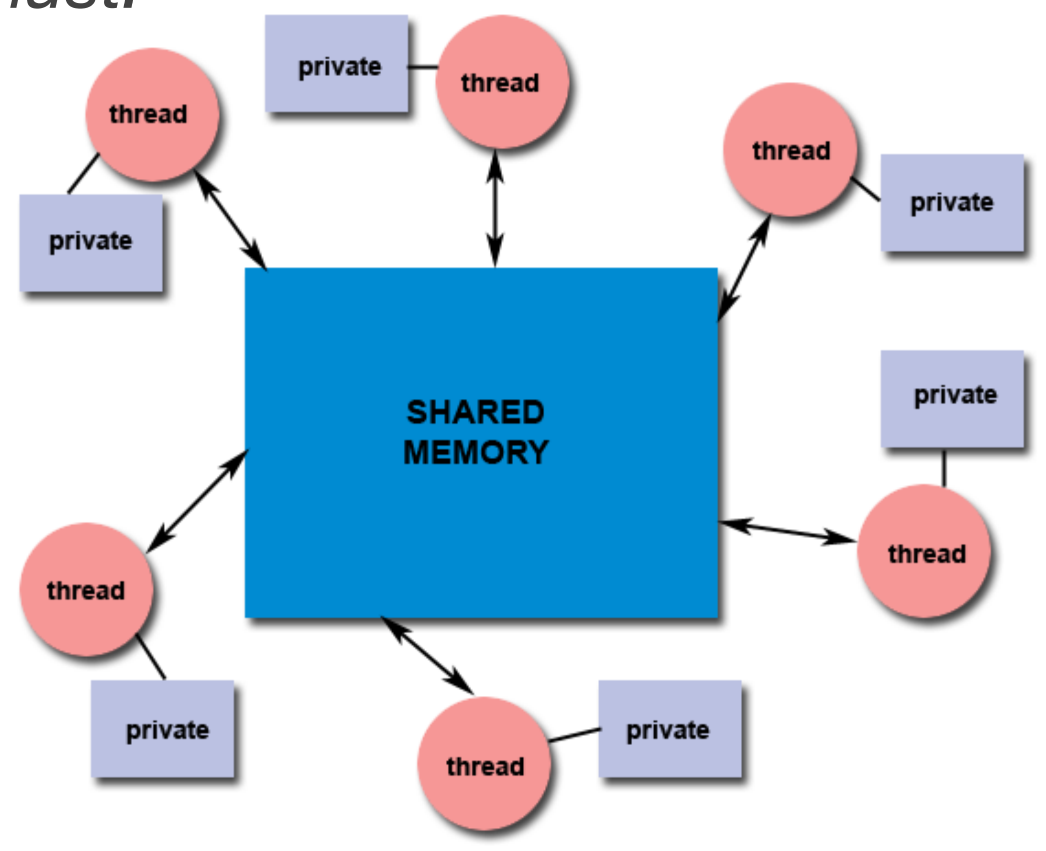
- Dive a bit deeper into core topics in concurrency
- Discuss common mechanisms for achieving mutual exclusion & synchronization

Announcements

- **Schedule Updates**
    - Exam #1 — delayed…
        - …career fair…
        - topics to include everything up through concurrency (at least… possibly scheduling as well…)
    - Exam #2 — topics will include:
        - (Scheduling)
        - Memory Management & Virtual Memory
        - File Systems & I/O
        - Selected OS Security Topics
    - No Exam #3!
- **Homework 2** (Chapters 3-4) DUE 10/11 *—trust me, you don't need that long!*
- **Homework 3** (Chapters 5-6) DUE 10/18
- **Programming Assignment 1** (Concurrency + C programming/pthreads) — should be posted by Friday

Recap: Concurrency & Solutions for Mutual Exclusion

*To acheive correct & meaningful solutions to concurrency problems, **mutual exclusion** is a must!*



Software Support

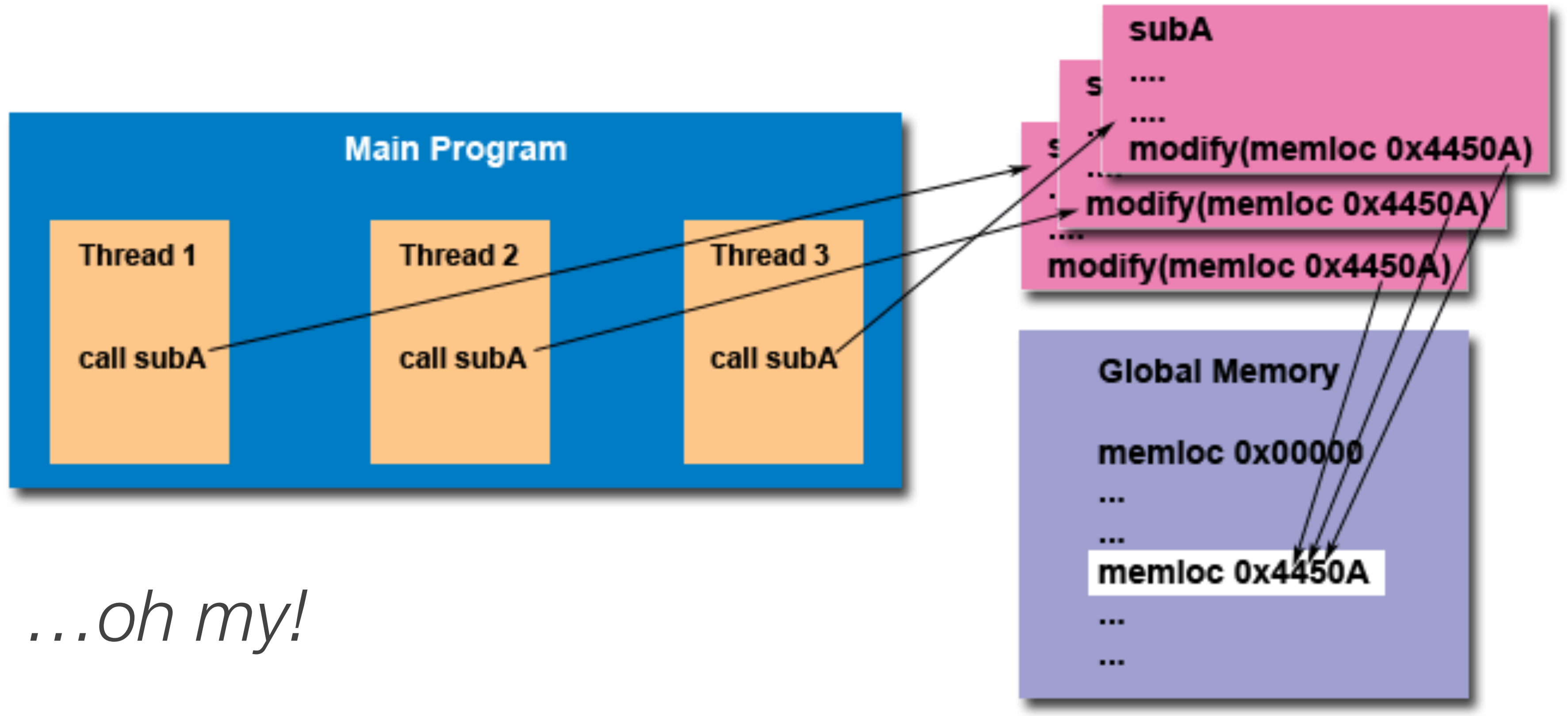
- *Assume elementary mutual exclusion at the memory access level; serialized by "memory arbiter"*
- Decker's Algorithm, Peterson's Algorithm

Hardware Support

- Interrupt Disabling
  - **Disadvantages:** inhibits processor's ability to interleave processes; doesn't work across processors.
- Special Machine Instructions
  - **Compare&Swap:** compare values => if values are the same, swap!
  - **Exchange (XCHG):** exchanges the contents of a register w/ that of a memory location
  - **Advantages:** simple & easy to implement; can be used on multi-processor machines
  - **Disadvantages:** possibly expensive busy-waiting; starvation & deadlock are still possibe

Programming Language Mechanisms

- Examples using pthreads
- Semaphores, Monitors, Condition Variables, Message Passing, Mutexes (Locks), *…oh my!*



—*https://computing.llnl.gov/tutorials/pthreads/*

➜ ***Famous Problems:*** *Producer/Consumer Problem, Dining Philosopers Problem*

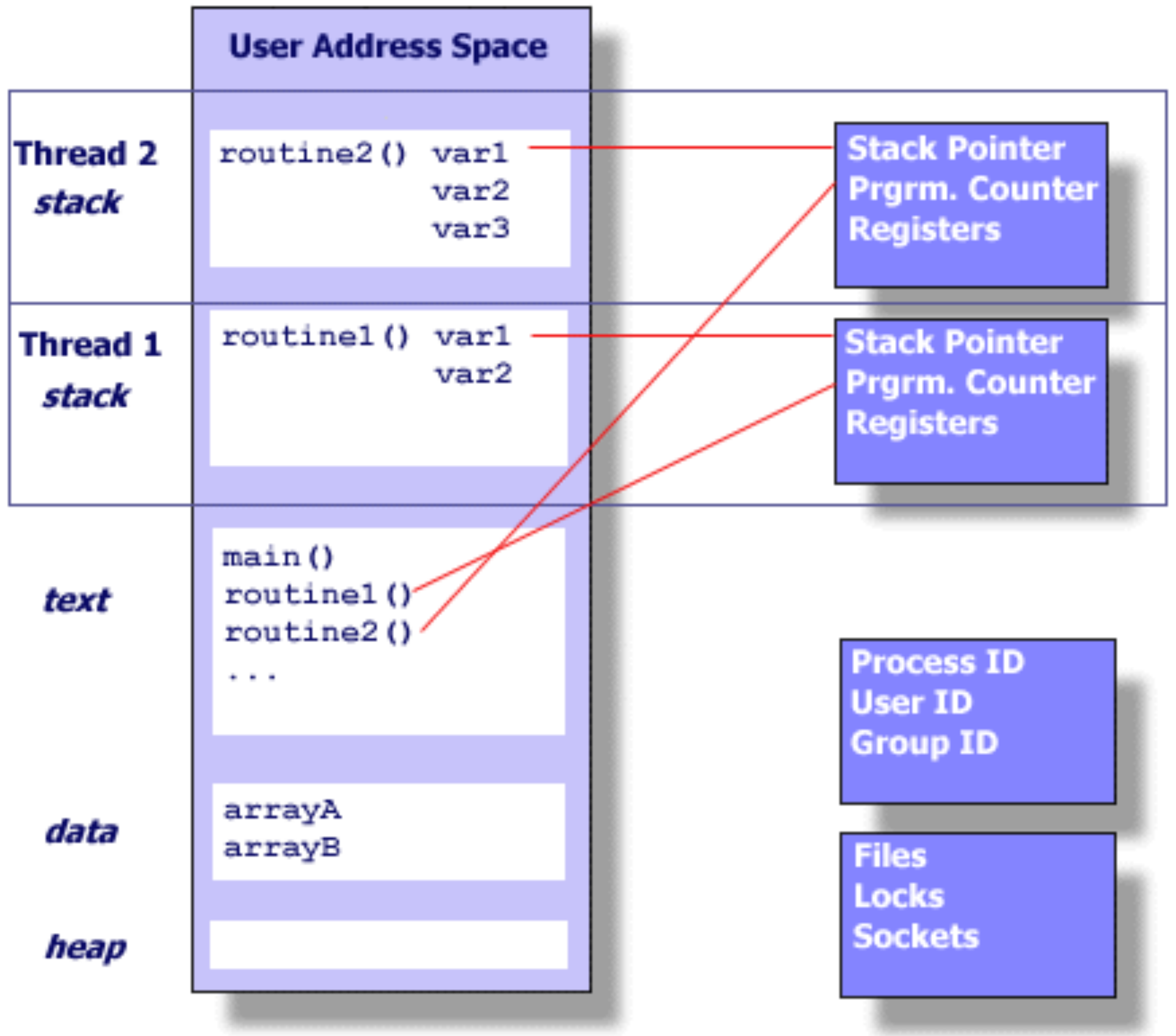
Programming w/ pthreads

A good write-up on pthreads: https://computing.llnl.gov/tutorials/pthreads/

- **pthreads** (POSIX Threads)
  - *defines a set of C programming language types, functions and constants.*
  - *is implemented with a pthread.h header and a thread library.*
  - *includes mutexes, condition variables, etc.*
- *E.g., A typical sequence in the use of a* ***mutex*** *is as follows:*

  ➔ *Create and initialize a mutex variable*
  ➔ *Create and start several threads*
  - ➔ *Several threads attempt to lock the mutex (only 1 succeeds and "owns" the lock)*
  - ➔ *The owner thread performs some set of actions*
  - ➔ *The owner unlocks the mutex*
  - ➔ *Another thread acquires the mutex and repeats the process*

  ➔ *Finally, the mutex is destroyed*



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NOTE: *When several threads compete for a mutex, the losers block at that call (there does exist a non-blocking call: "trylock")*

NOTE: *It is the programmer's responsibility to make sure* ***every thread*** *that needs to use a mutex does so.*
For example, if 10 threads are updating the same data, but only one uses a mutex, the data can still be corrupted!

Programming w/ pthreads

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Most of class featured in-class demo:

- <Code Walk-Through - **`threads01.c`** & **`threads02.c`**>
- What happens if I ***vary the number of threads***?
  - 1 vs. 2 vs. 5 vs. 10 vs. ….
- What happens if the ***target number is small***?
  - 100 vs. 1000000000000
- What happens if we ***don't wait*** for the threads to complete?
- What happens if I compile & run on ***different machines*** (e.g., naitive machine/OS vs. my local Linux VM)?
- ***Why*** are these things happening?!
  - NOTE: make sure you (re-)build the executable whereever you are going to run it….
  - `objdump -d t1`
- With proper (simple) synchronization, why does the program appear to execute ***slower***?