TECHNISCHE UNIVERSITÄT DRESDEN

Faculty of Computer Science Institute of Systems Architecture, Operating Systems Group

THREADS

MICHAEL ROITZSCH

RECAP

MICROKERNEL

- kernel:
  - provides system foundation
  - usually runs in privileged CPU mode
- microkernel:
  - kernel provides mechanisms, no policies
  - most functionality implemented in user mode, unless dictated otherwise by
    - security
    - performance

TECHNISCHE UNIVERSITÄT DRESDEN

ABSTRACTIONS

Resource	Mechanism
CPU	Thread
Memory	Task
Communication	IPC, IRQ
Platform	Virtual Machine

Rights

Capabilities

VIRTUAL MACHINE

- provides an exclusive instance of a full system platform
- may be a synthetic platform (bytecode)
- full software implementations
- hardware-assisted implementations in the kernel (hypervisor)
- see virtualization lecture on Dec 13th

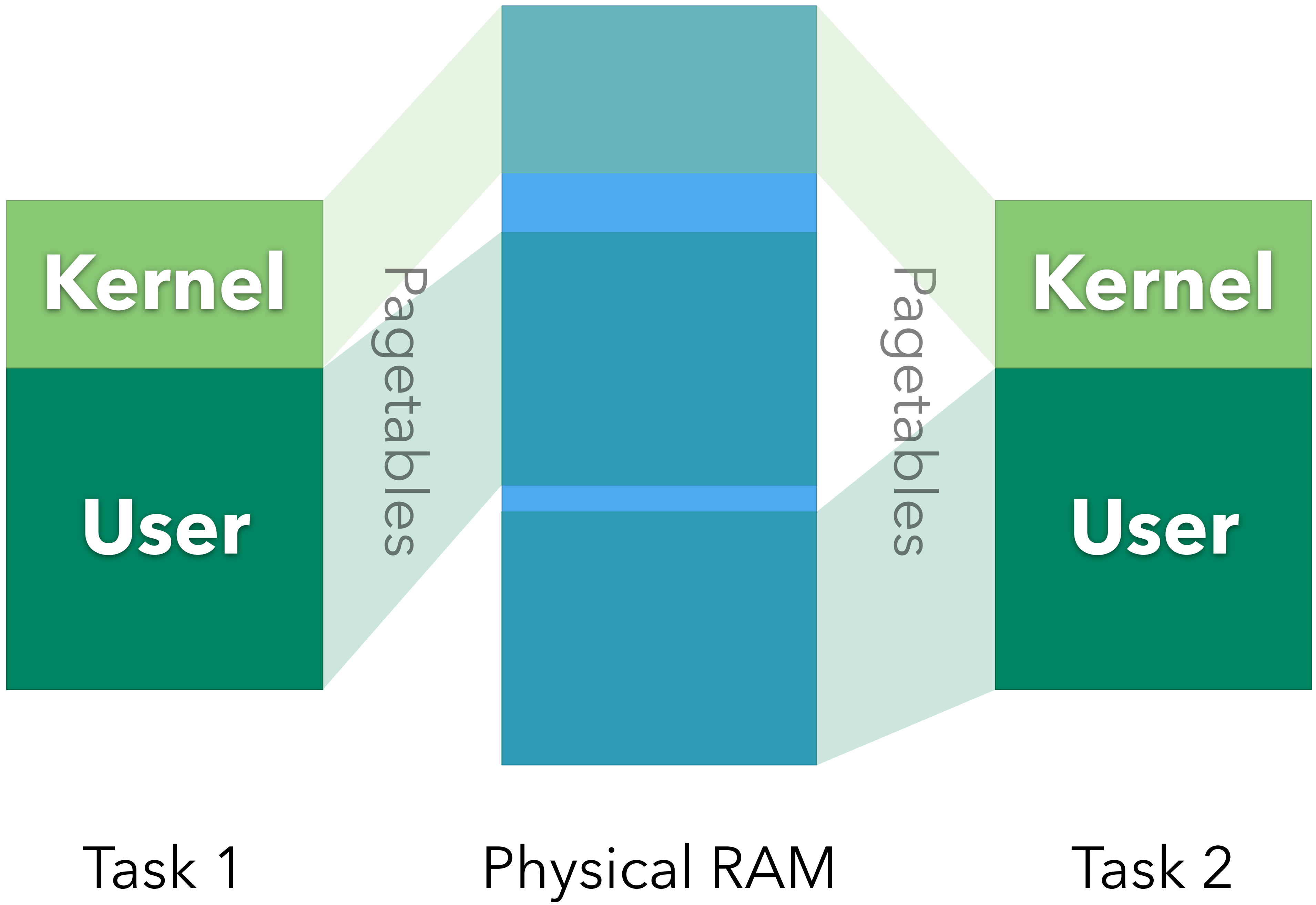
IPC

- inter-process communication
- between threads
- two-way agreement, synchronous
- memory mapping with flexpages
- see communication lecture last week

TASK

- (virtual) address space
- unit of memory management
- provides spatial isolation
- common memory content can be shared
  - shared libraries
  - kernel
- see memory lecture next week

SHARED KERNEL

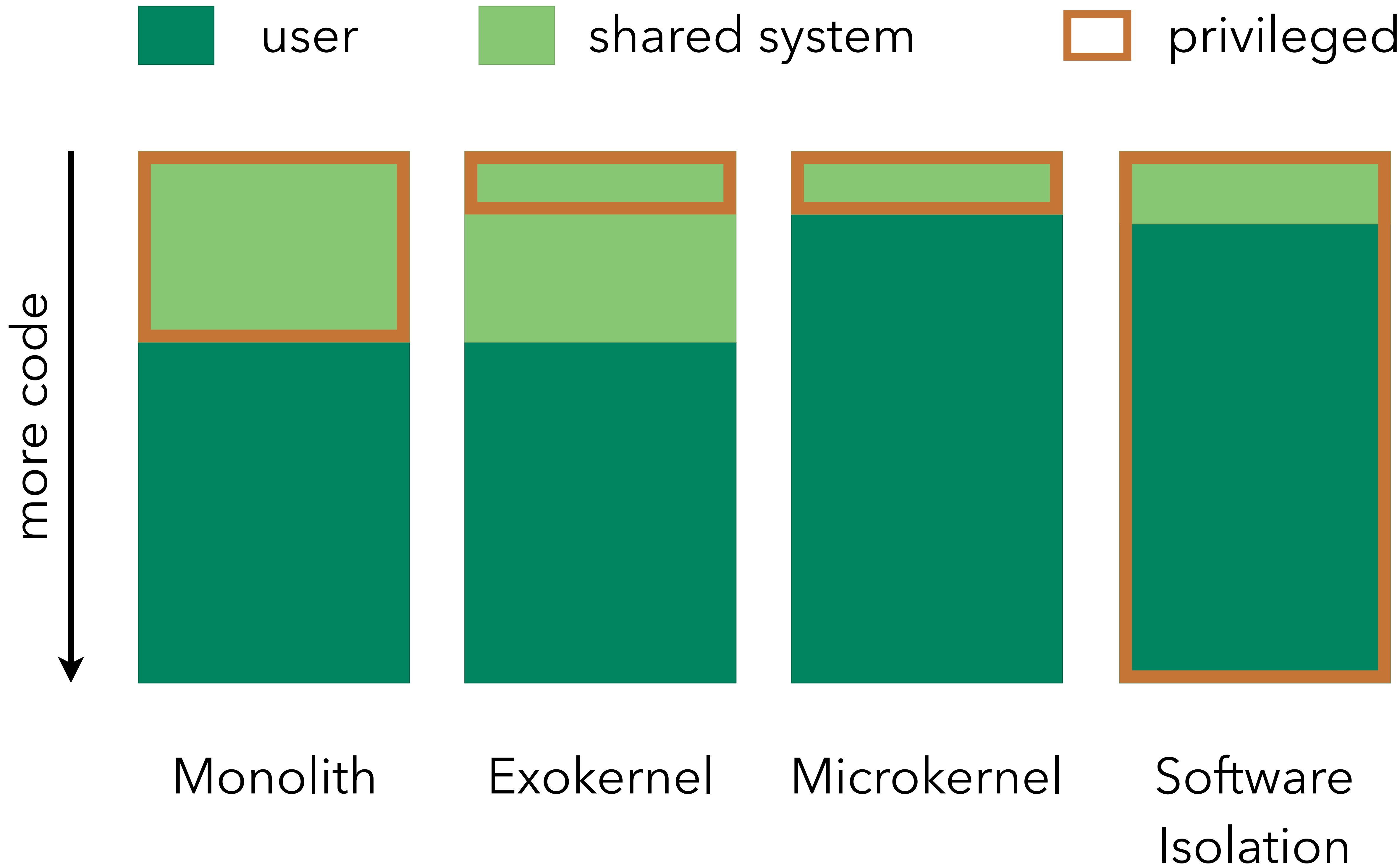


KERNEL AS

User Address Space

Kernel Address Space

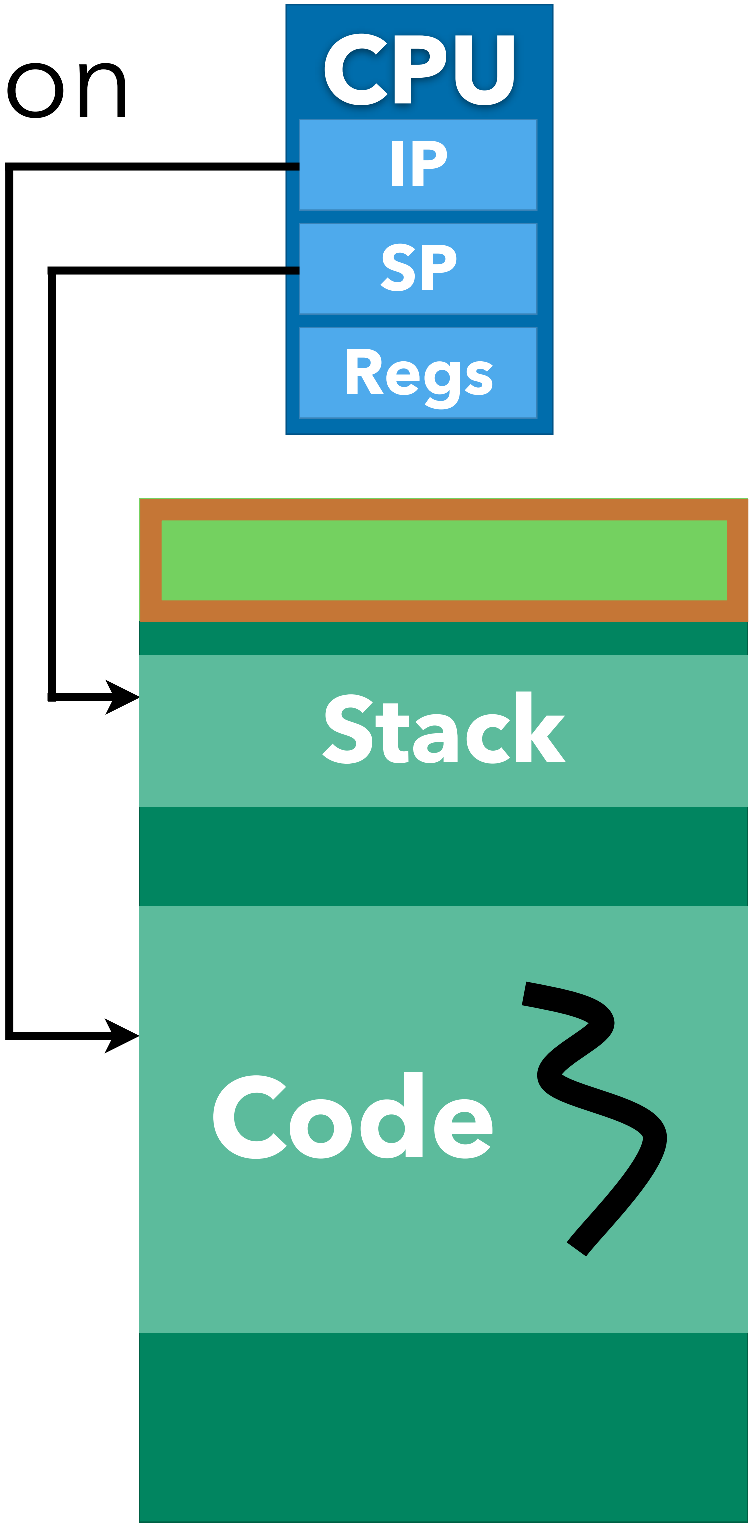
ALTERNATIVES



THREADS

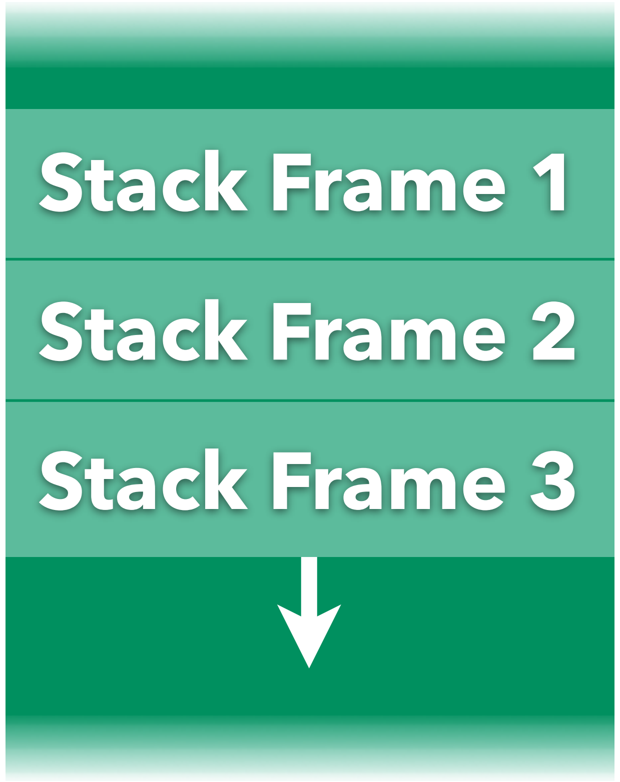
BASICS

- abstraction of code execution
- unit of scheduling
- provides temporal isolation
- typically requires a stack
- thread state:
  - instruction pointer
  - stack pointer
  - CPU registers, flags



STACK

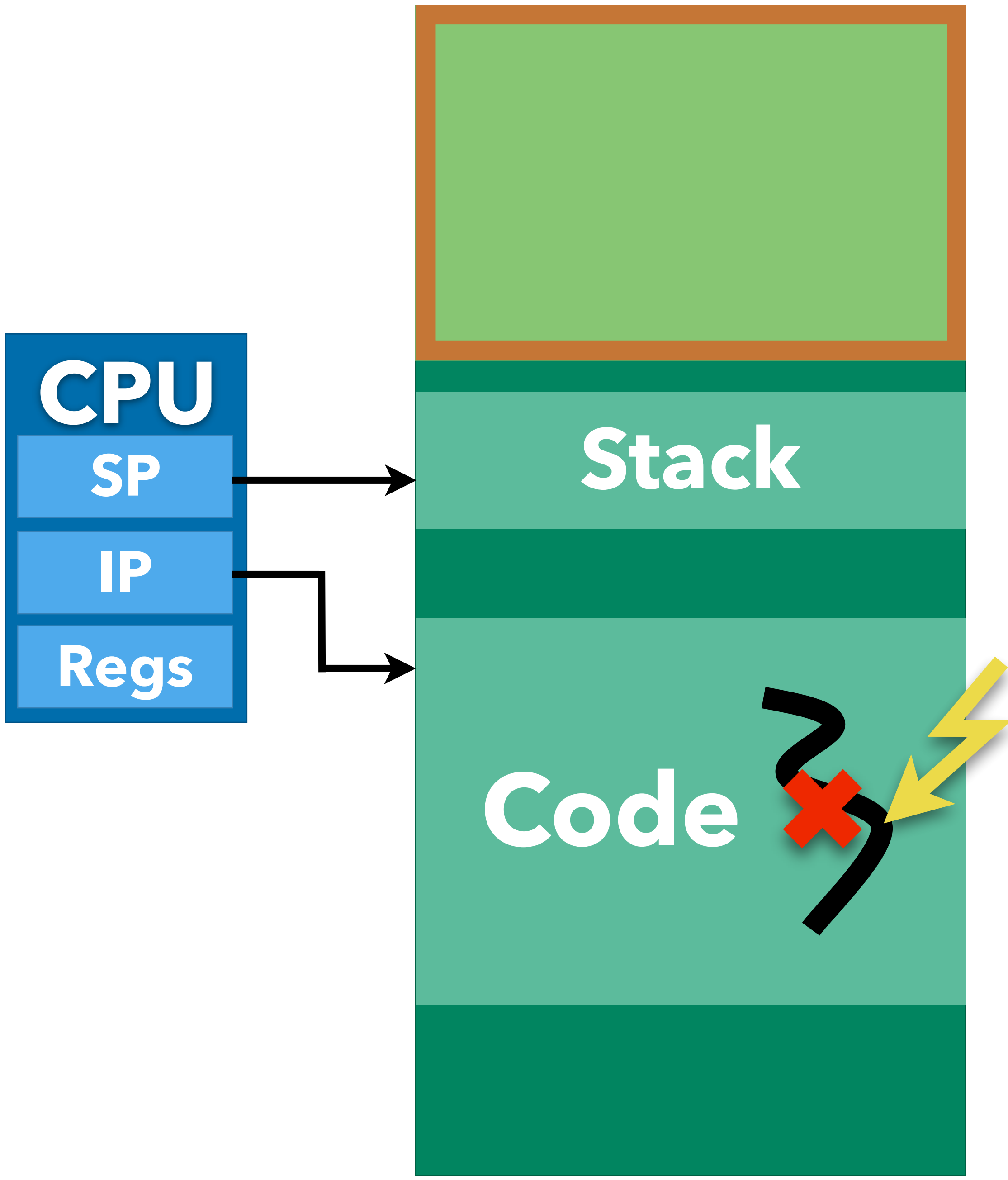
- storage for function-local data
  - local variables
  - return address
- one stack frame per function
- grows and shrinks dynamically
- grows from high to low addresses



KERNEL'S VIEW

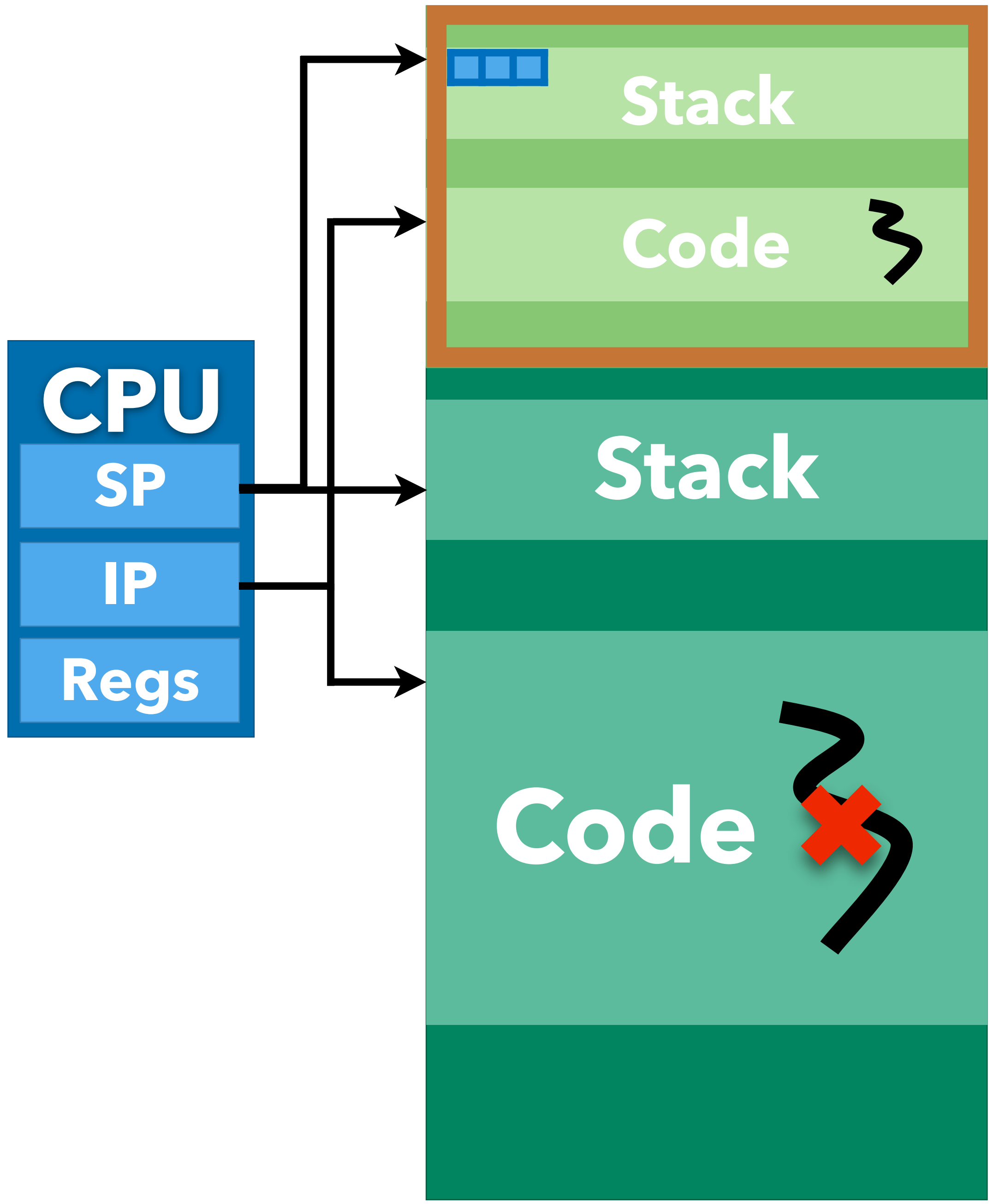
- maps user-level threads to kernel-level threads
  - often a 1:1 mapping
  - threads can be implemented in userland
- assigns threads to hardware
- one kernel-level thread per logical CPU
- with hyper-threading and multicore, we have more than one hardware thread

KERNEL ENTRY



- thread can enter kernel:
- voluntarily
  - system call
- forced
  - interrupt
  - exception

KERNEL ENTRY



- IP and SP point into kernel
- user CPU state stored in TCB
  - old IP and SP
  - registers
  - flags
  - FPU state
  - MMX, SSE, AVX

TCB

- thread control block
- kernel object, one per thread
- stores thread's userland state while it is not running
- untrusted parts can be stored in user space
  - separation into KTCB (kernel TCB) and UTCB (user TCB)
  - UTCB also holds system call parameters

KERNEL EXIT

- once the kernel has provided its services, it returns back to userland
- by restoring the saved user IP and SP
- the same thread or a different thread
- the old thread may be blocking now
  - waiting for some resource
- returning to a different thread might involve switching address spaces

SCHEDULING

BASICS

- scheduling describes the decision, which thread to run on a CPU at a given time
- When do we schedule?
  - current thread blocks or yields
  - time quantum expired
- How do we schedule?
  - RR, FIFO, RMS, EDF
  - based on thread priorities

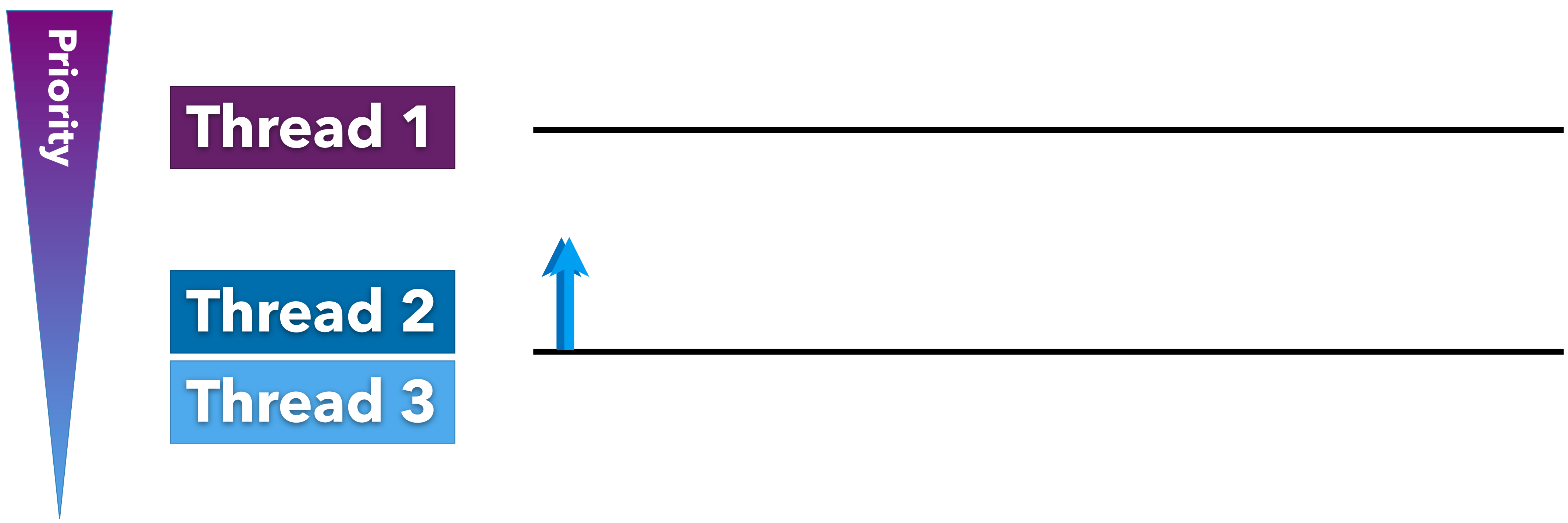
POLICY

- scheduling decisions are policies
- should not be in a microkernel
- L4 used to have facilities to implement scheduling in user land
  - each thread has an associated preempter
  - kernel sends an IPC when thread blocks
  - preempter tells kernel where to switch to
- no efficient implementation yet
- scheduling is the only in-kernel policy in L4

- scheduling in L4 is based on thread priorities
- time-slice-based round robin within the same priority level
- kernel manages priority and timeslice as part of the thread state
- see scheduling lecture on Nov 8th

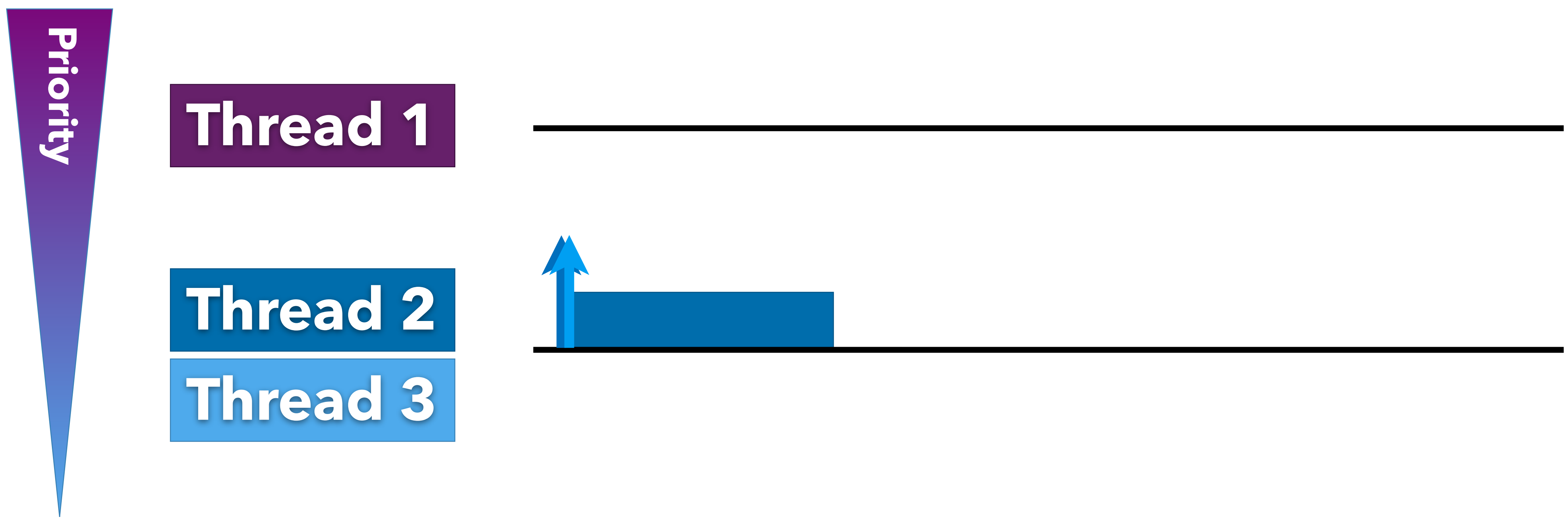
EXAMPLE

- thread 1 is a high priority driver thread, waiting for an interrupt (blocking)
- thread 2 and 3 are ready with equal priority



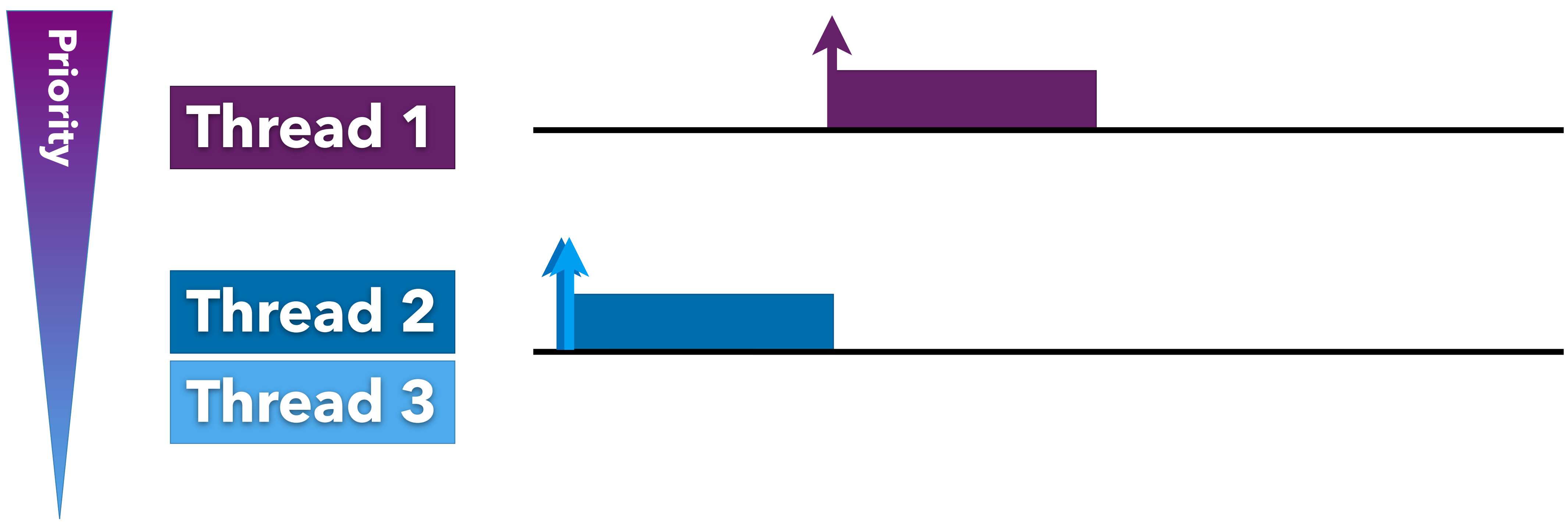
EXAMPLE

- 1 hardware thread
- kernel fills time slices of threads 2 and 3
- scheduler selects 2 to run



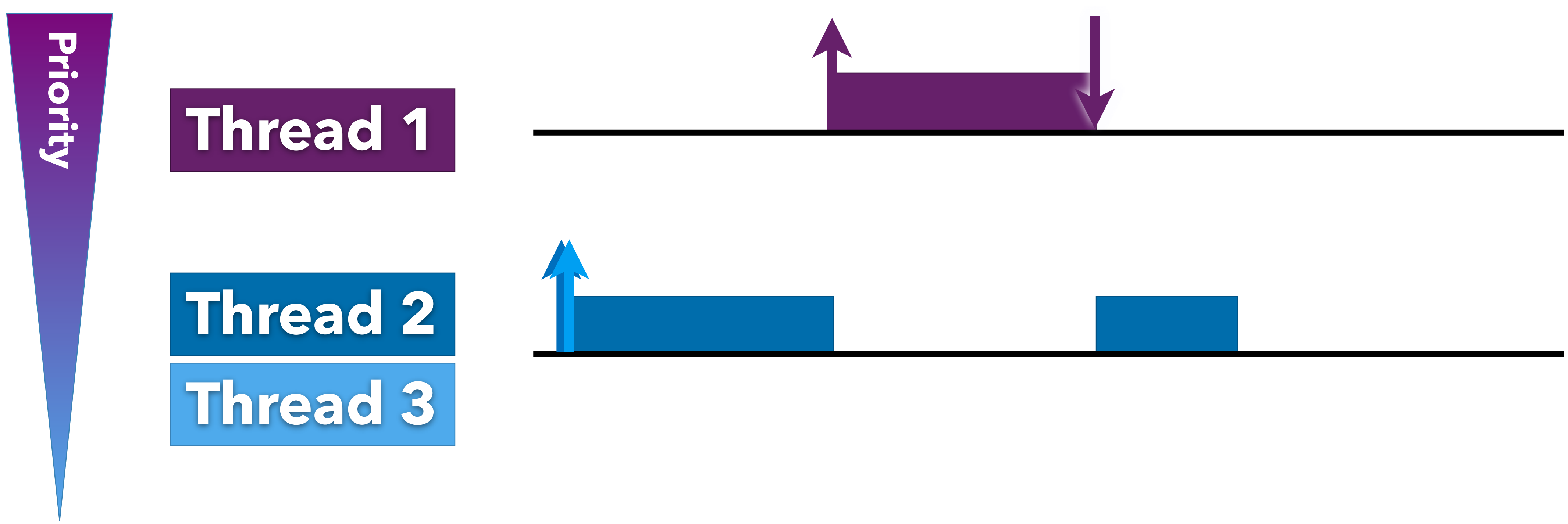
EXAMPLE

- device interrupt arrives
- thread 2 is forced into the kernel, where it unblocks thread 1 and fills its time slice
- switch to thread 1 preempts thread 2



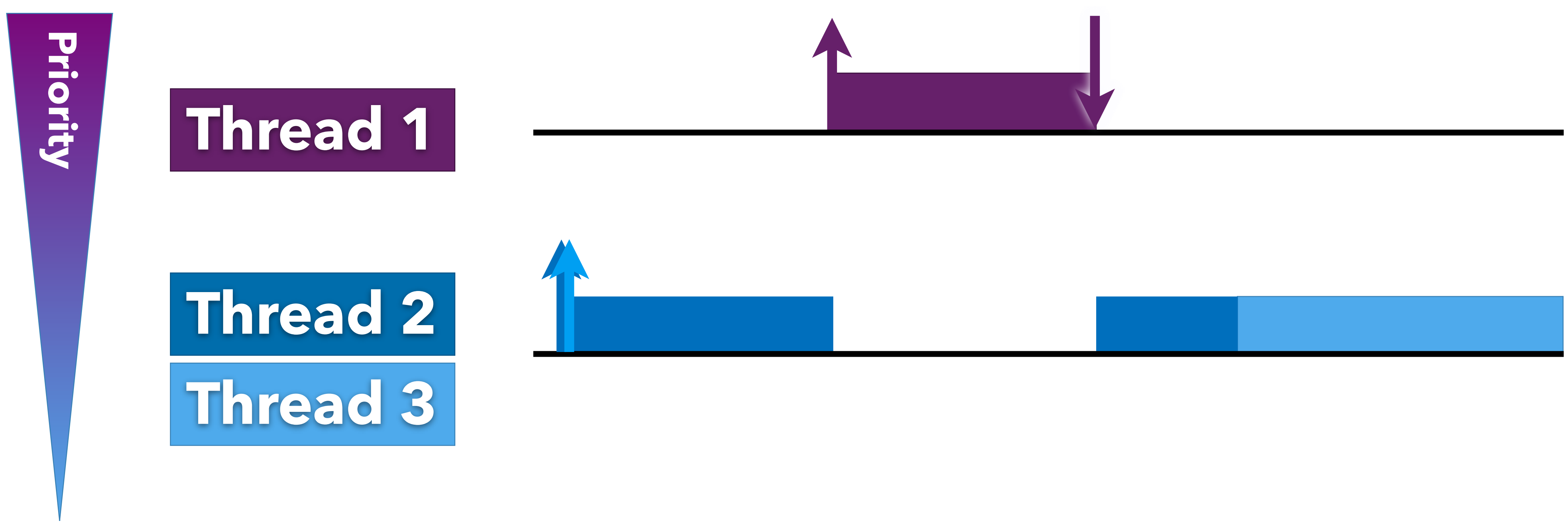
EXAMPLE

- thread 1 blocks again (interrupt handled, waiting for next)
- thread 2 has time left

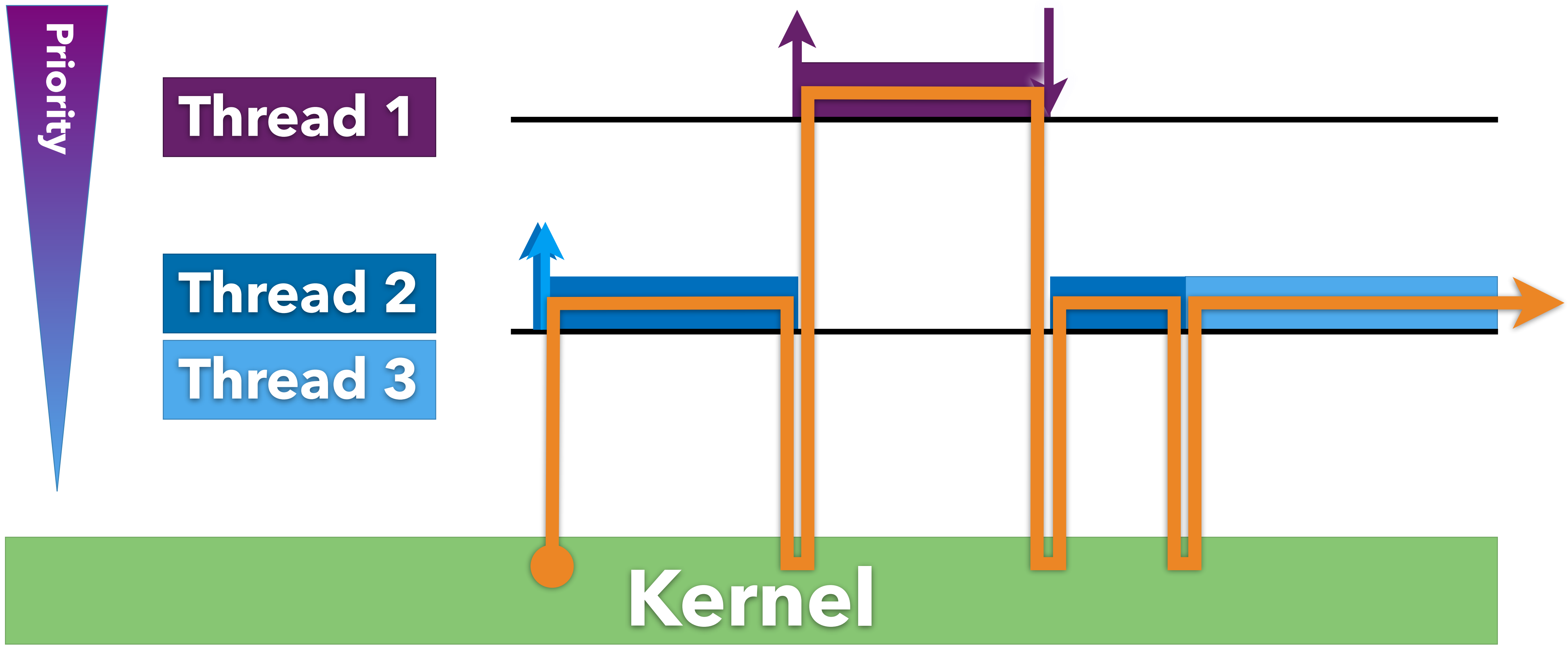


EXAMPLE

- thread 2's time slice has expired
- timer interrupt forces thread 2 into kernel
- scheduler selects the next thread on the same priority level (round robin)



it's really only one hardware thread being multiplexed



SYNCHRONIZATION

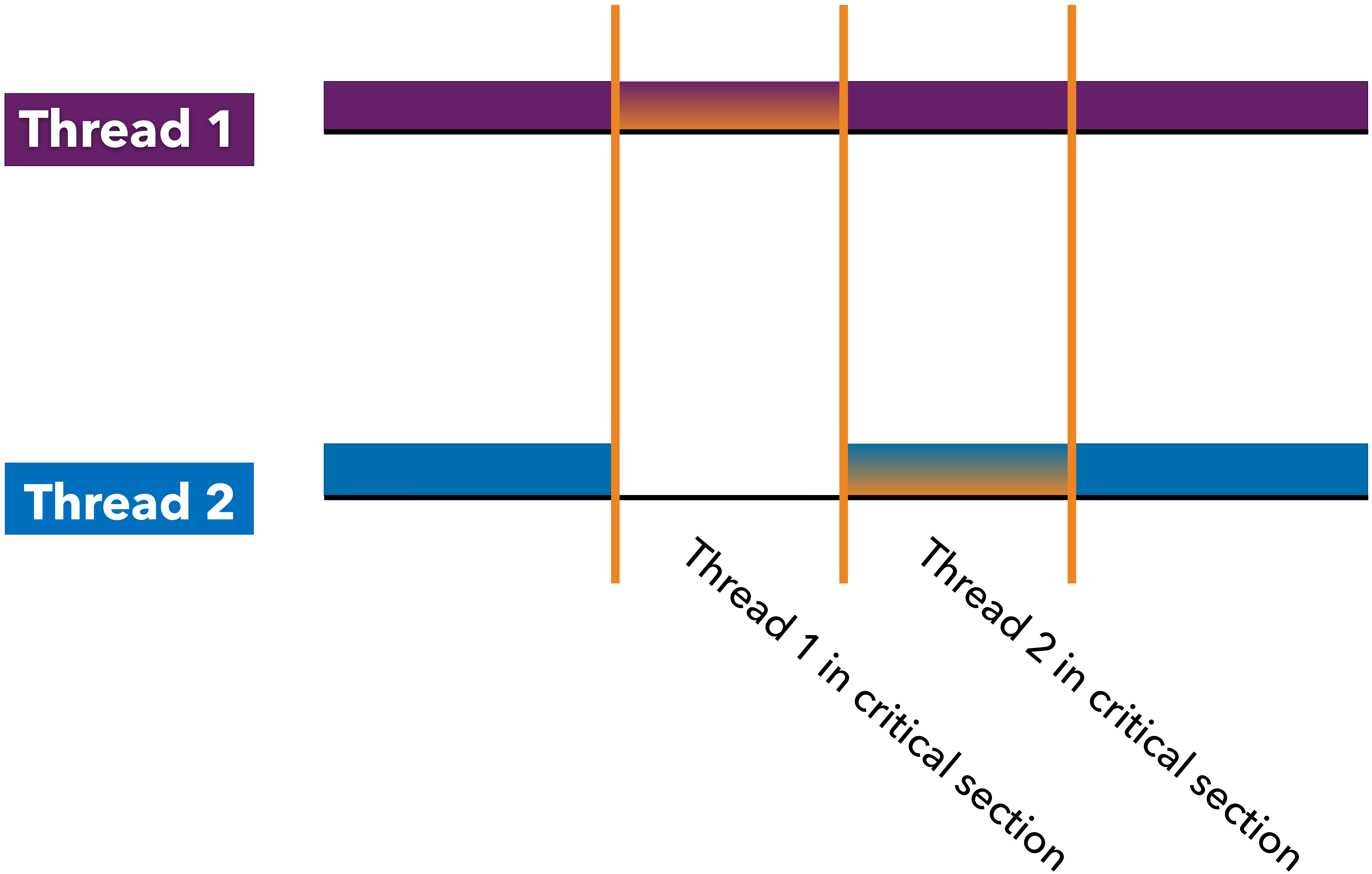
BASICS

- synchronization used for
  - mutual exclusion
  - producer-consumer-scenarios
- traditional approaches that do not work
  - spinning, busy waiting
  - disabling interrupts

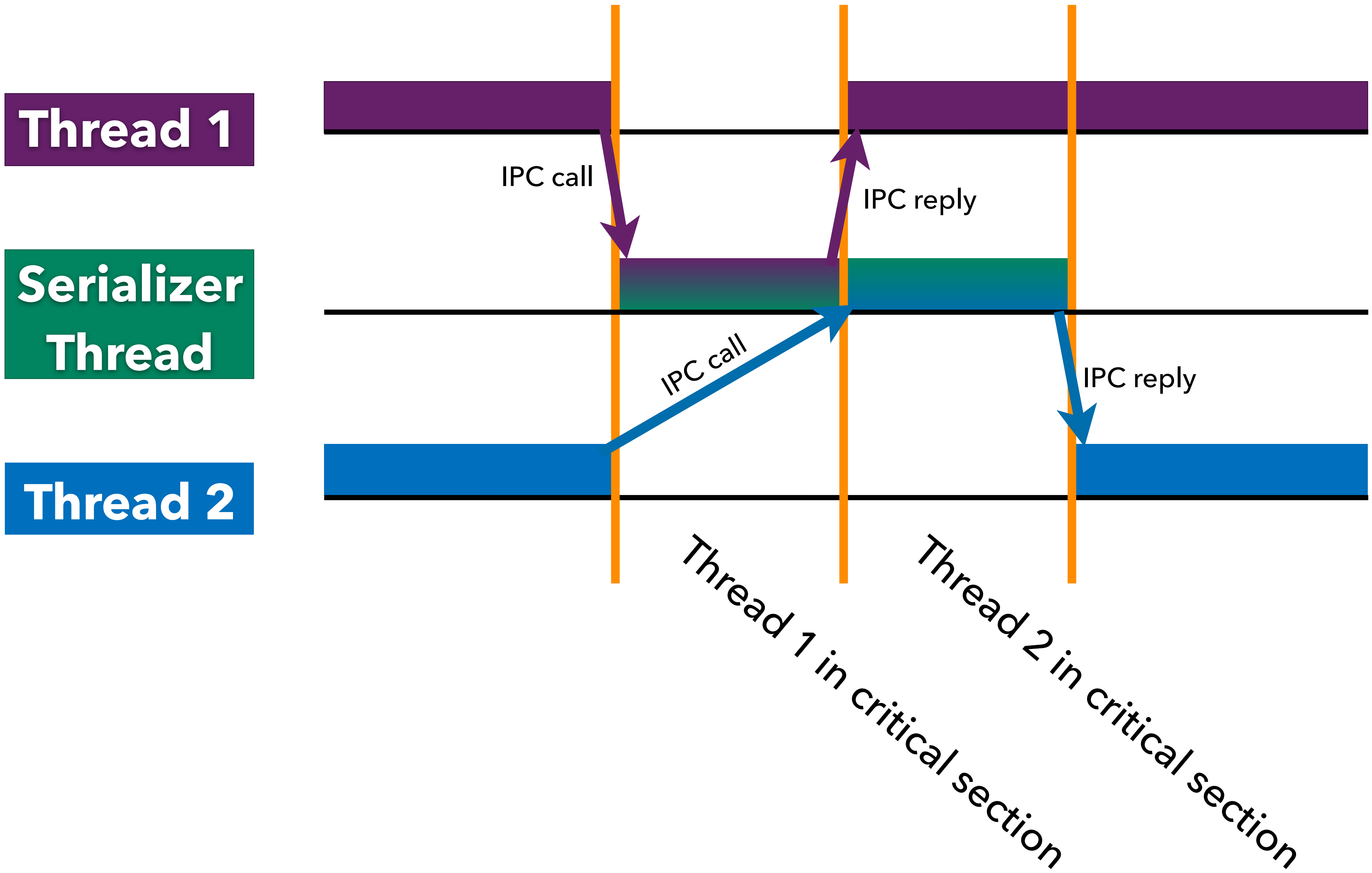
ATOMIC OPS

- for concurrent access to data structures
- use atomic operations to protect manipulations
- only suited for simple critical sections

EXPECTATION



SOLUTION

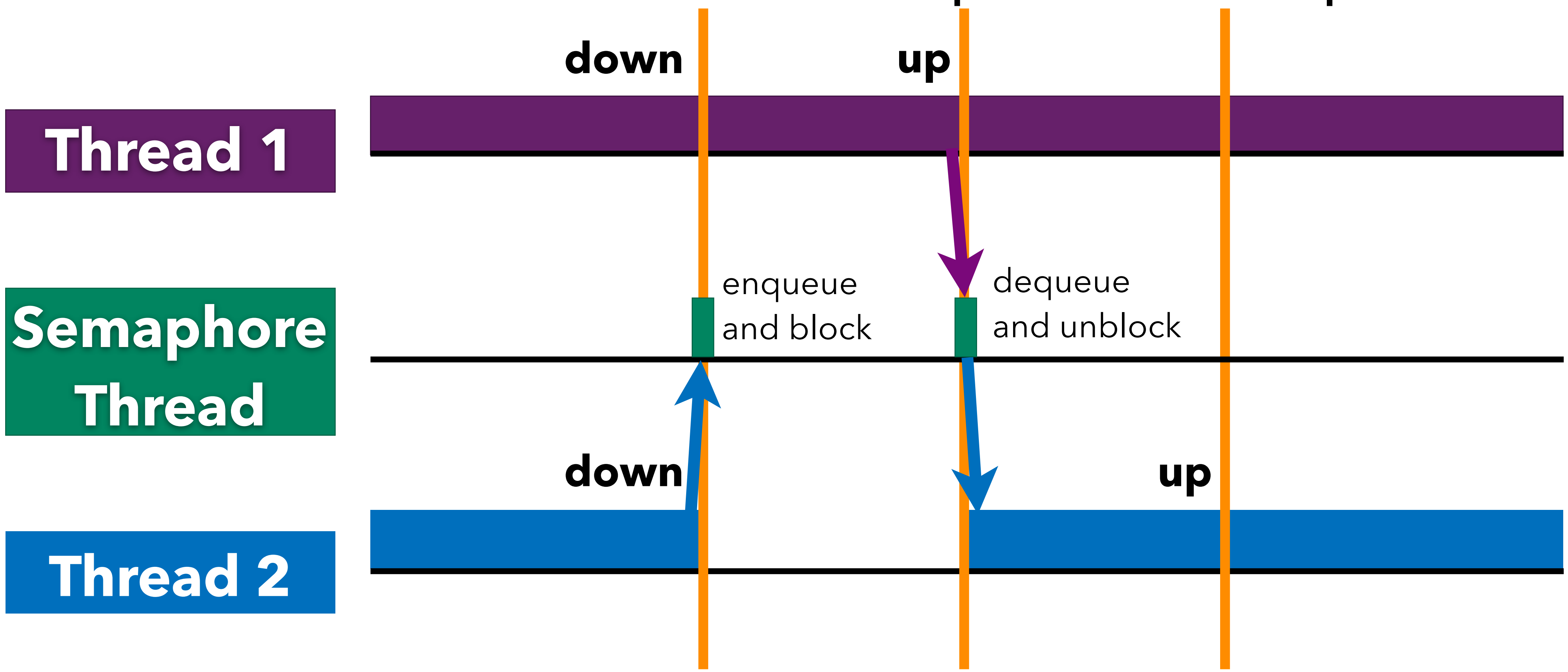

Thread 1
Serializer Thread
Thread 2
IPC call
IPC reply
IPC call
IPC reply
Thread 1 in critical section
Thread 2 in critical section

SEMAPHORES

- serializer and atomic operations can be combined to a nice counting semaphore
- semaphore
  - shared counter for correctness
  - wait queue for fairness
  - down (P) and up (V) operation
  - semaphore available iff counter > 0

SEMAPHORES

- counter increments and decrements using atomic operations
- when necessary, call semaphore thread to block/unblock and enqueue/dequeue



BENEFITS

- cross-task semaphores, when counter is in shared memory
- IPC only in the contention case
  - good for mutual exclusion when contention is rare
  - for producer-consumer-scenarios, contention is the common case
- solution for small critical sections in scheduling lecture

NOVA

INTRODUCTION

- NOVA is a research microhypervisor developed by Udo Steinberg
- explore technologies for a small and robust platform that hosts:
  - legacy operating systems
  - native NOVA applications
- designed for virtualization and manycore

KERNEL STYLES

Process-Style	Interrupt-Style
one kernel stack per thread	one kernel stack per CPU
context switch: switch to kernel stack of target thread	context switch: save kernel state of current thread, discard stack, restore state of target thread
target thread resumes at last context switch point	target thread resumes with empty kernel stack in continuation function
kernel state retained on stack at switch time	kernel state must be explicitly serialized
can switch anytime	lower thread overhead
Fiasco, Linux	**NOVA, (xnu)**

RECAP

- repeated basic microkernel concepts
  - paradigm, resource abstractions
- closer look on threads
  - TCB, kernel entry
- scheduling
  - time slices, priorities, preemption
- synchronization
  - atomic ops, serializer thread, semaphore
- next up: memory