TECHNISCHE UNIVERSITÄT DRESDEN

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THREADS

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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

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

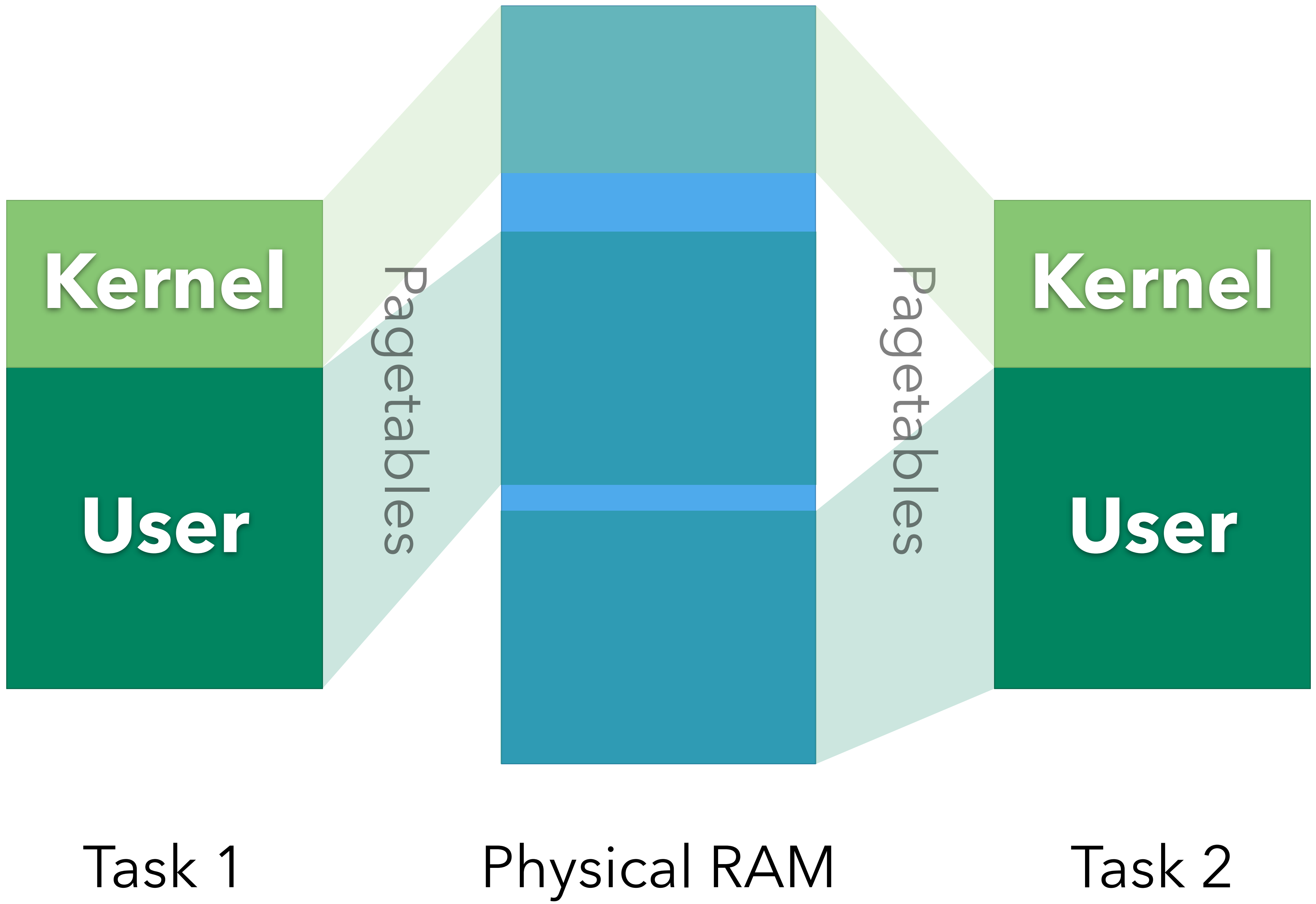
IPC

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

TASK

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

SHARED KERNEL

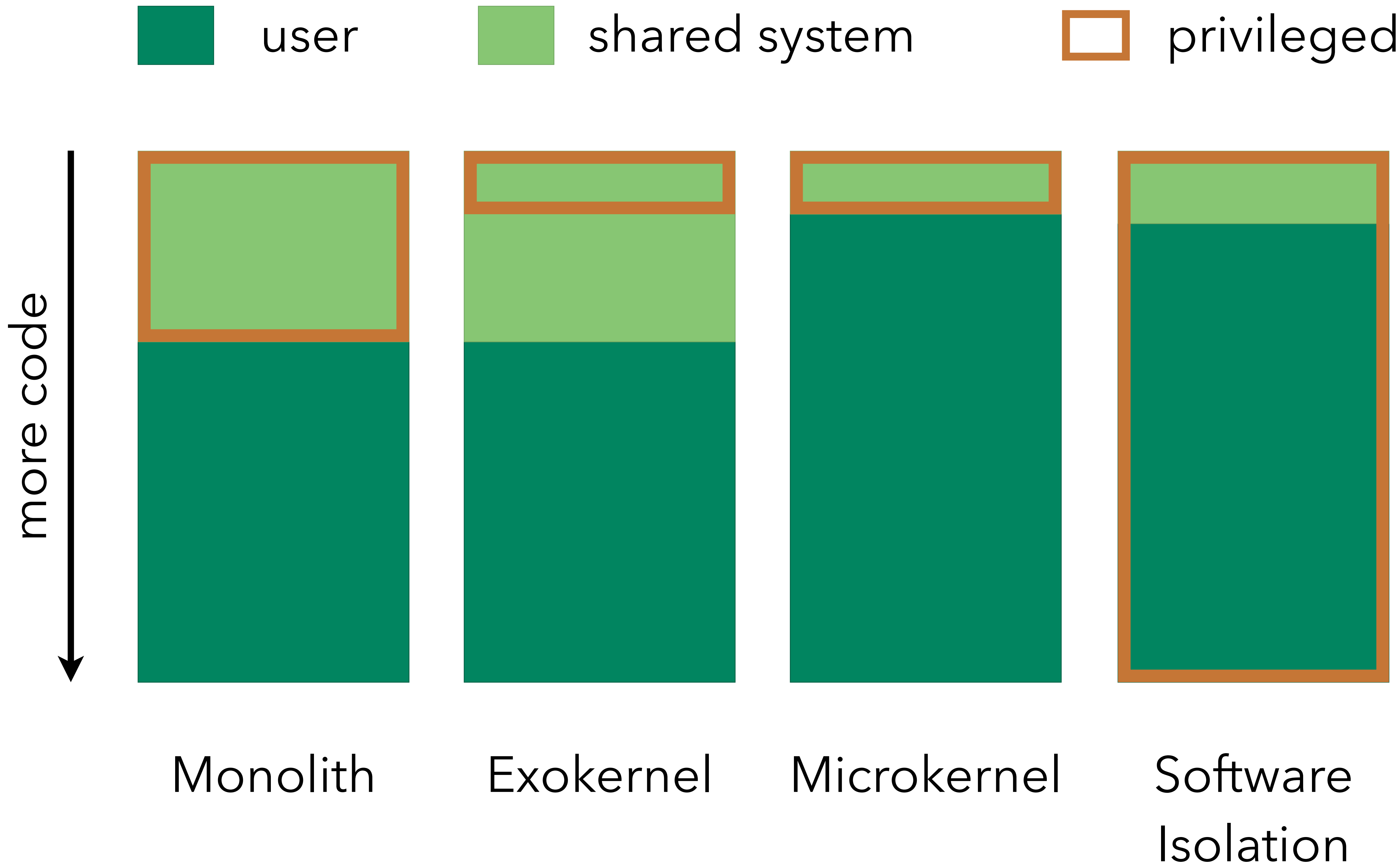


KERNEL AS

User Address Space

Kernel Address Space

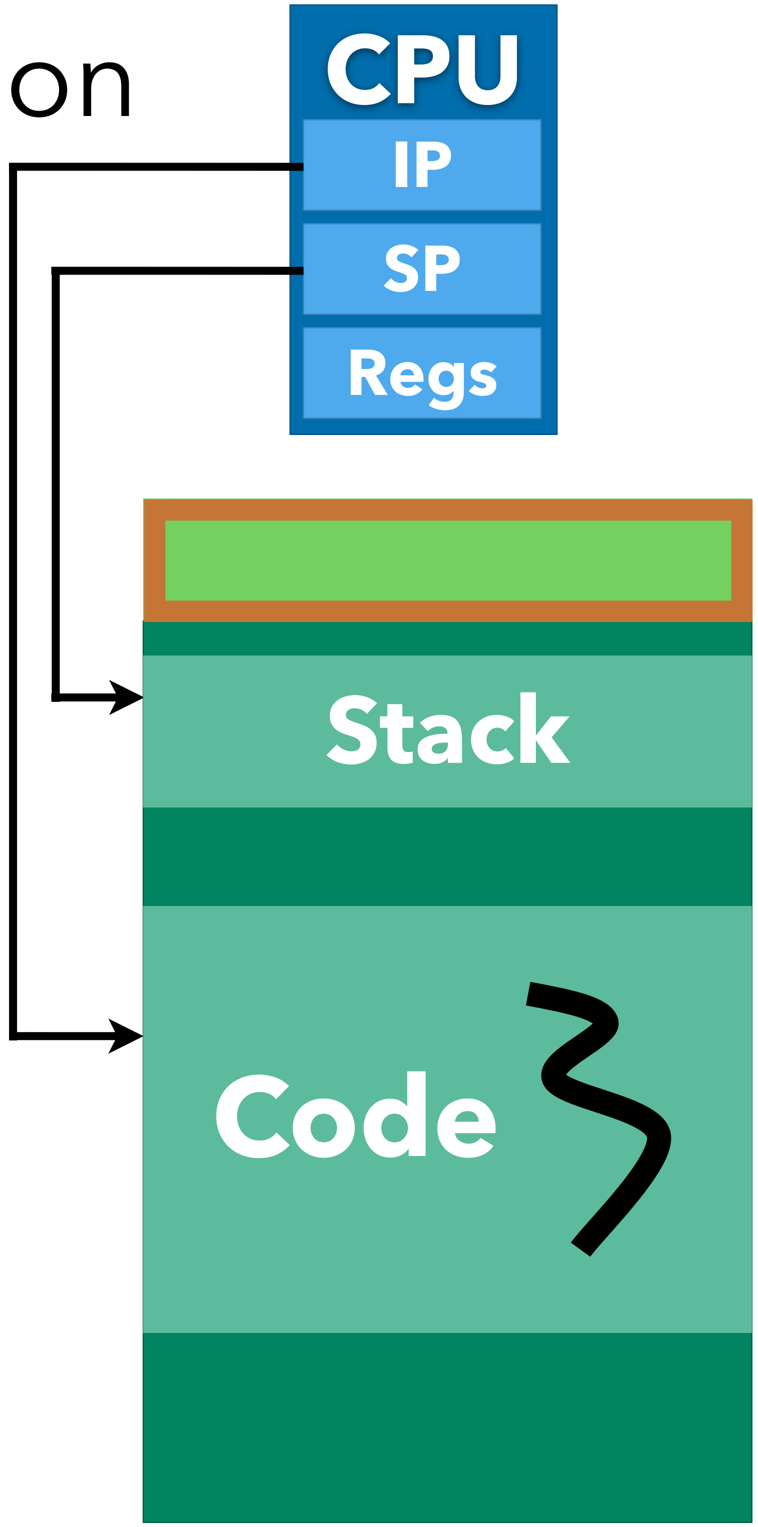
ALTERNATIVES



THREADS

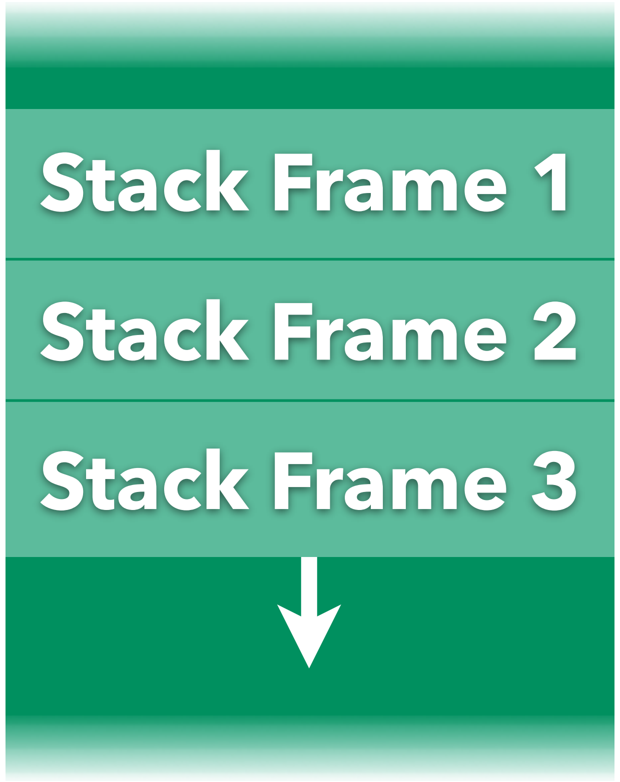
BASICS

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



STACK

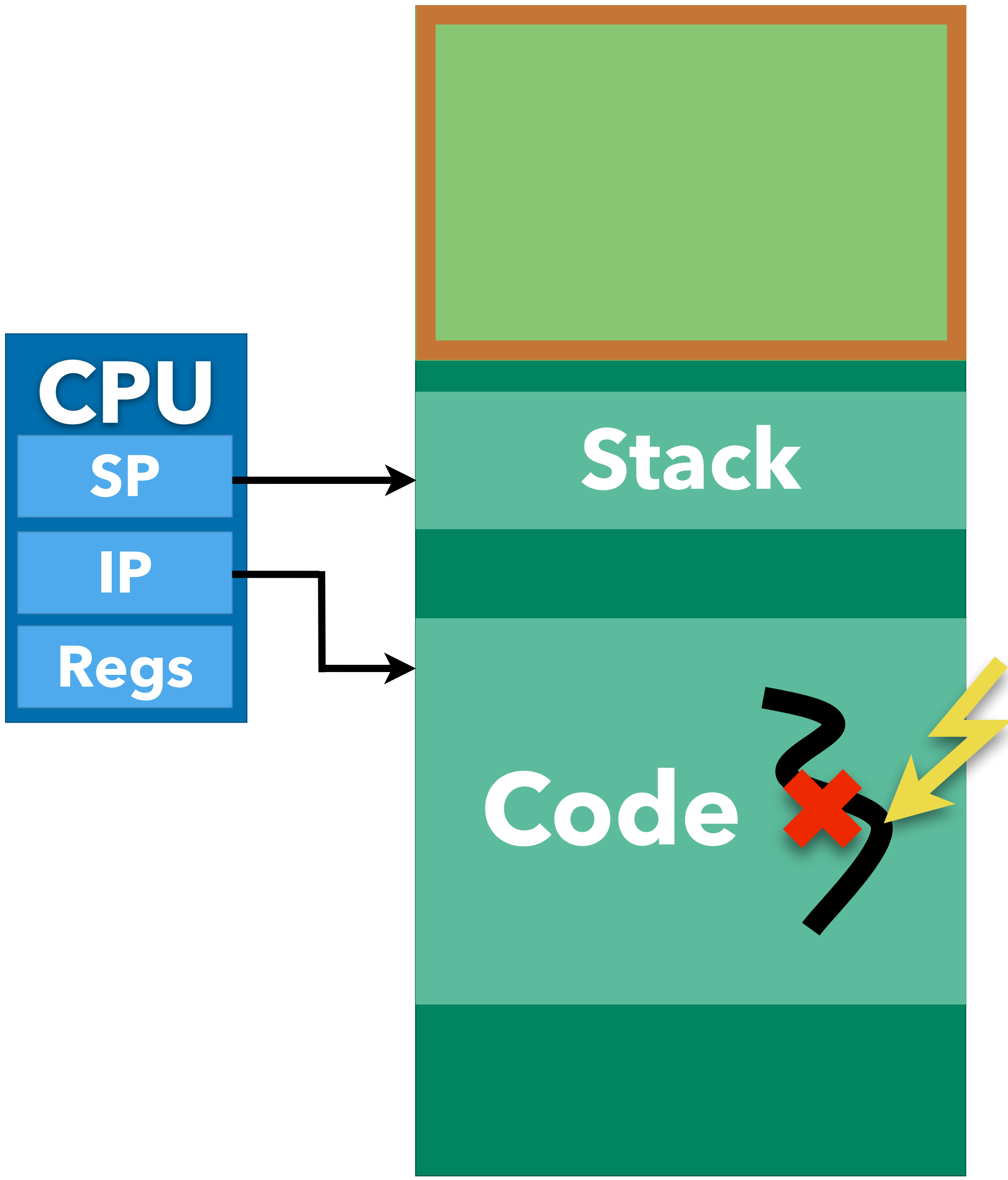
- storage for function-local data
  - local variables
  - return address
- one stack frame per function
- grows and shrinks dynamically
- grows from high to low addresses



KERNEL'S VIEW

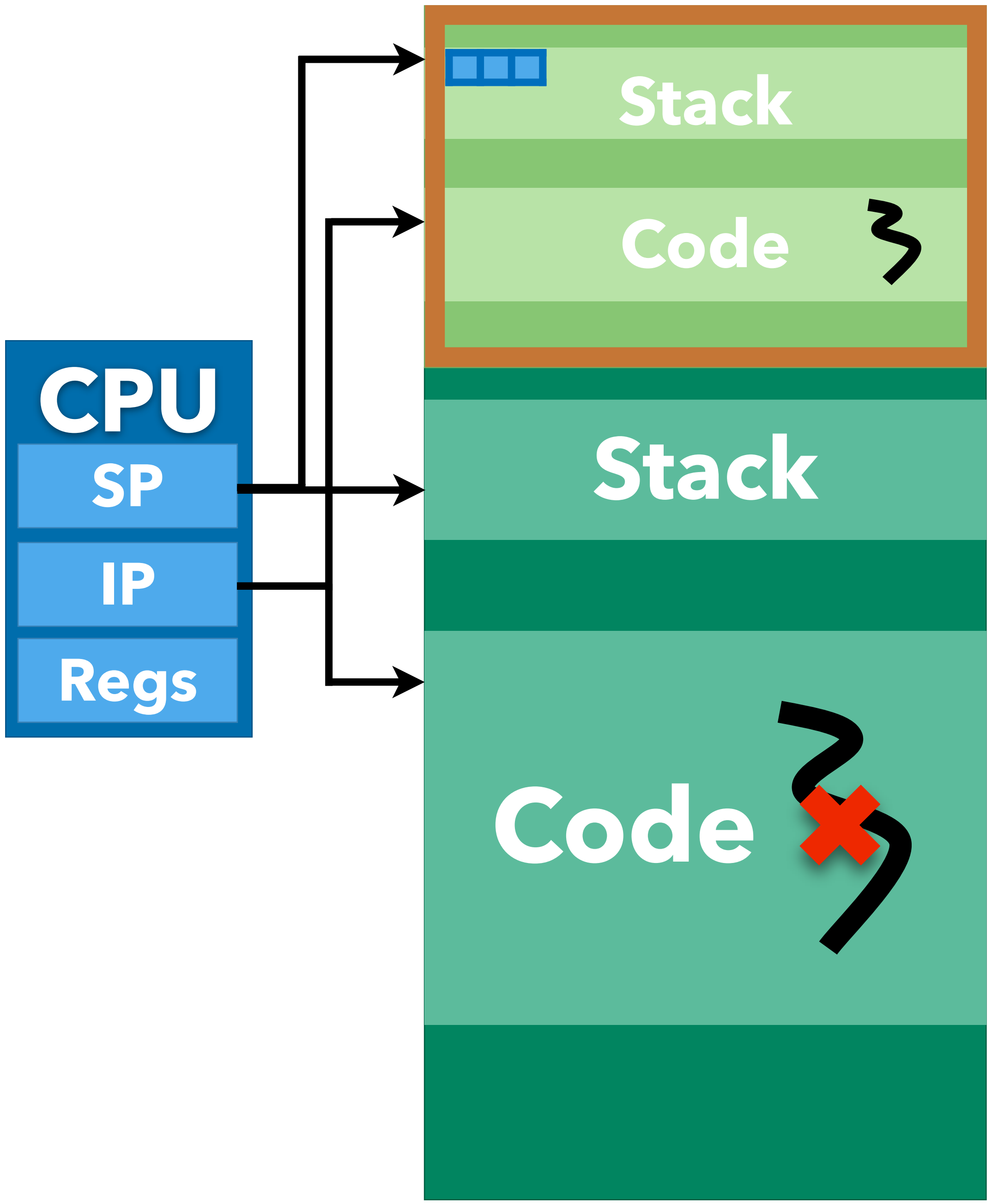
- maps user-level threads to kernel-level threads
  - often a 1:1 mapping
  - threads can be implemented in userland
- assigns threads to hardware
- one kernel-level thread per logical CPU
- with hyper-threading and multicore, we have more than one hardware context

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

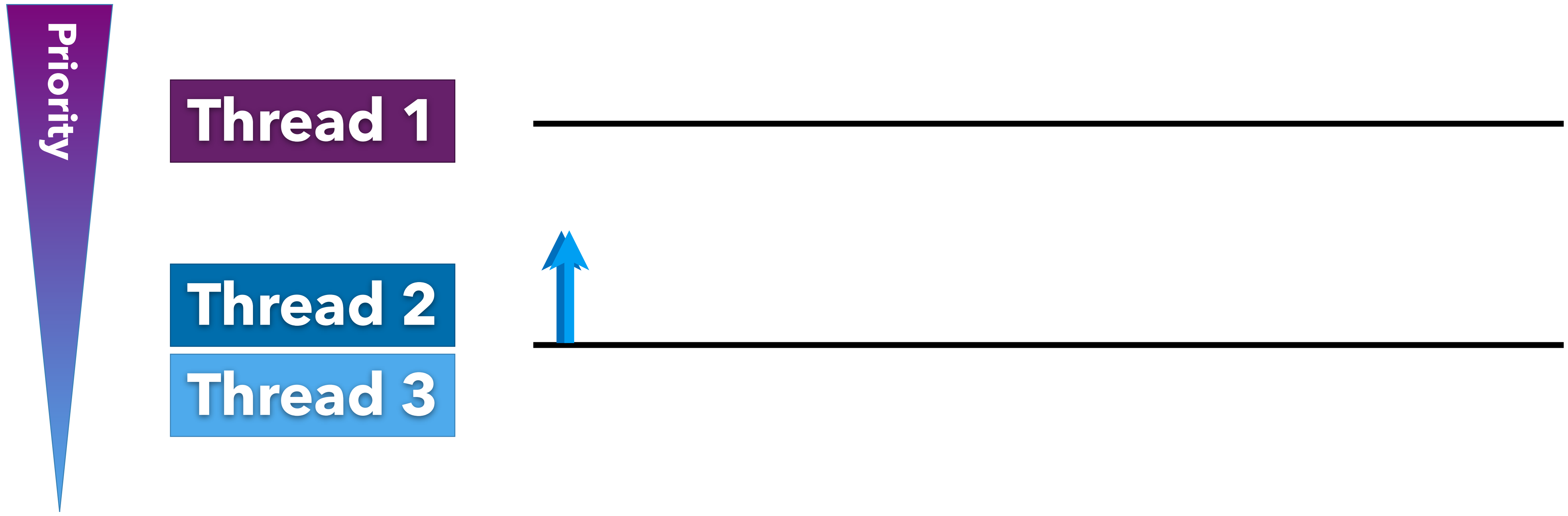
POLICY

- 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

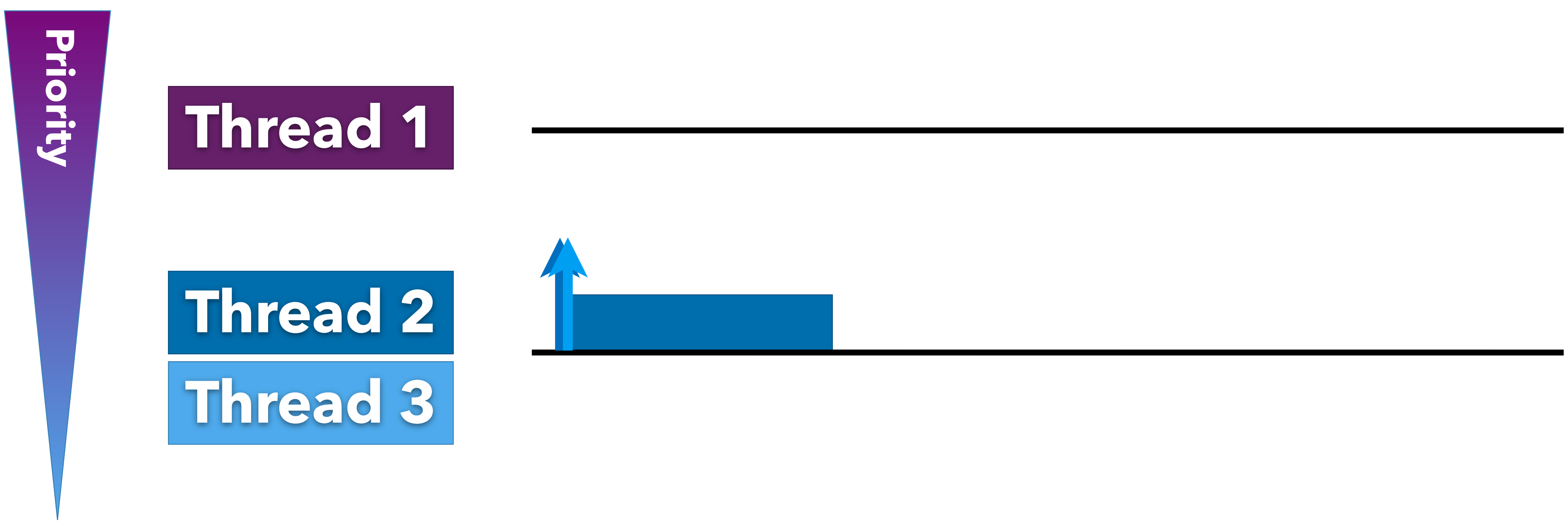
EXAMPLE

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



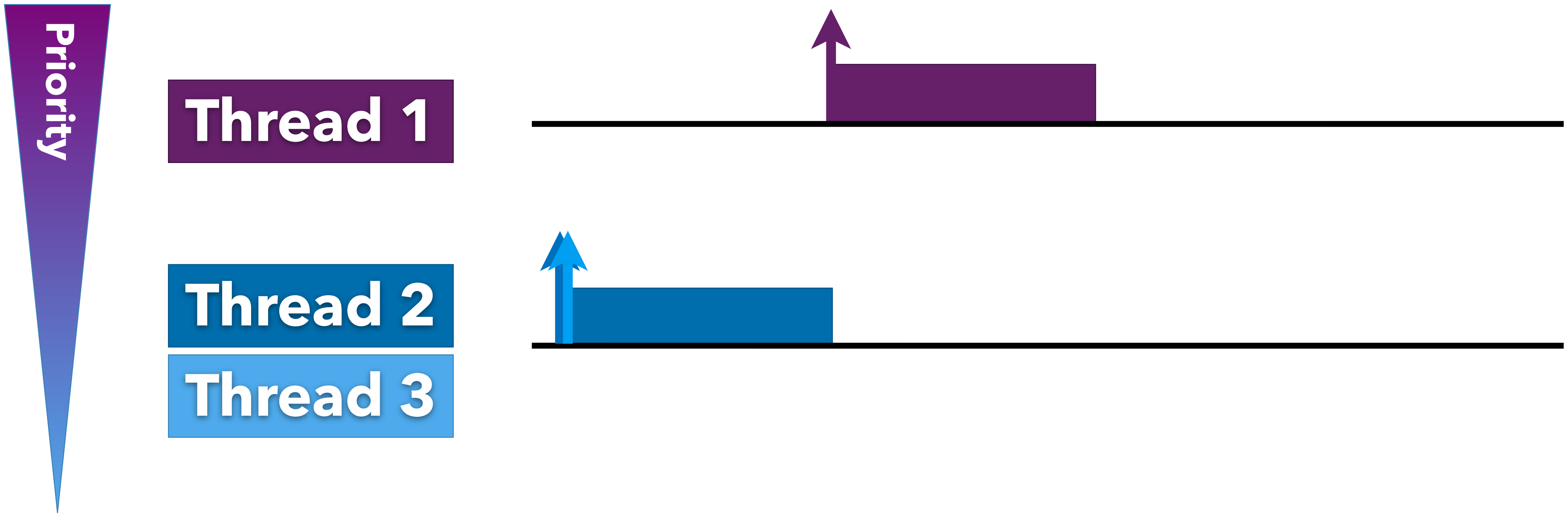
EXAMPLE

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



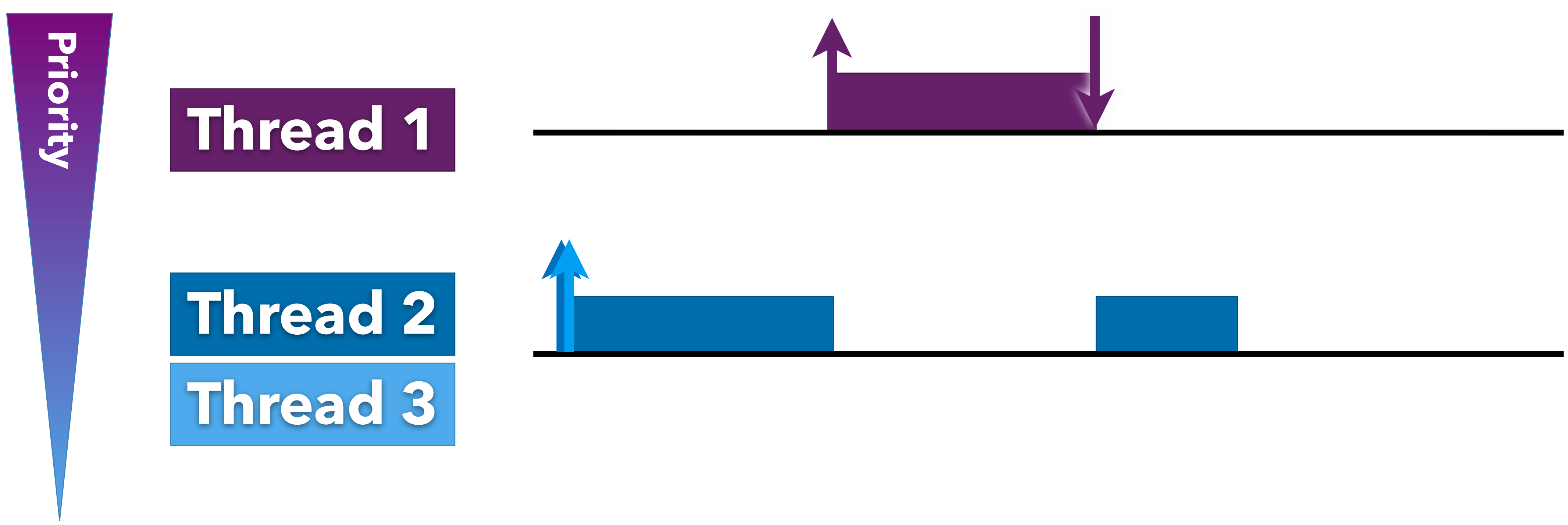
EXAMPLE

- 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



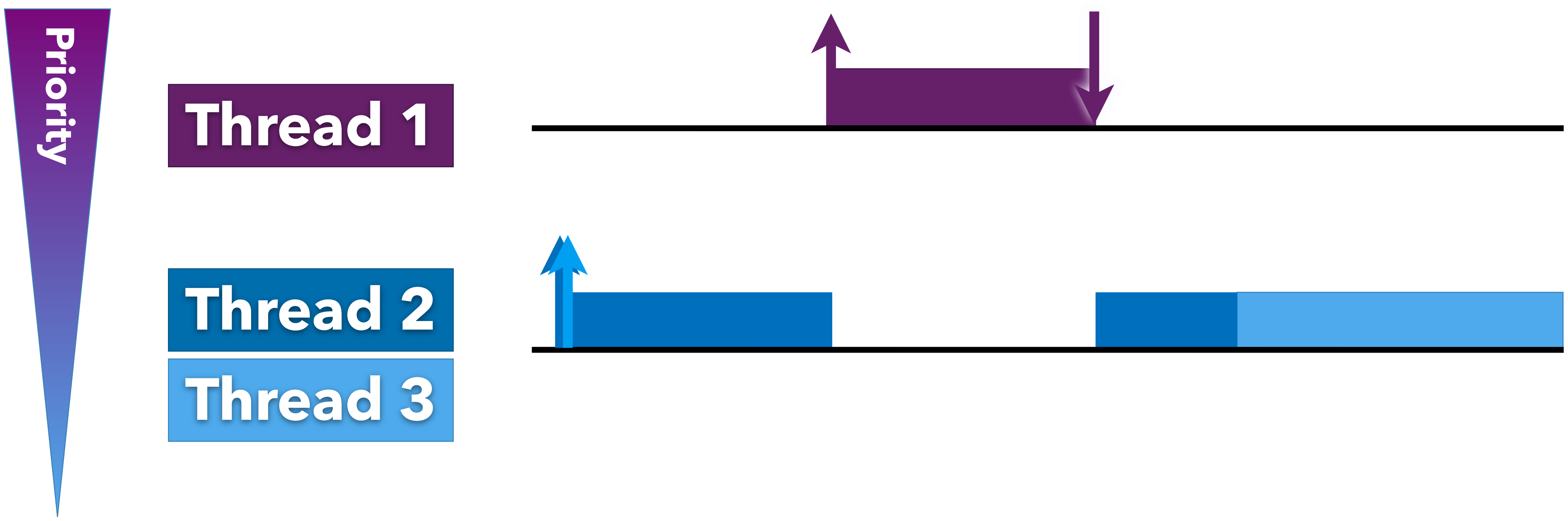
EXAMPLE

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



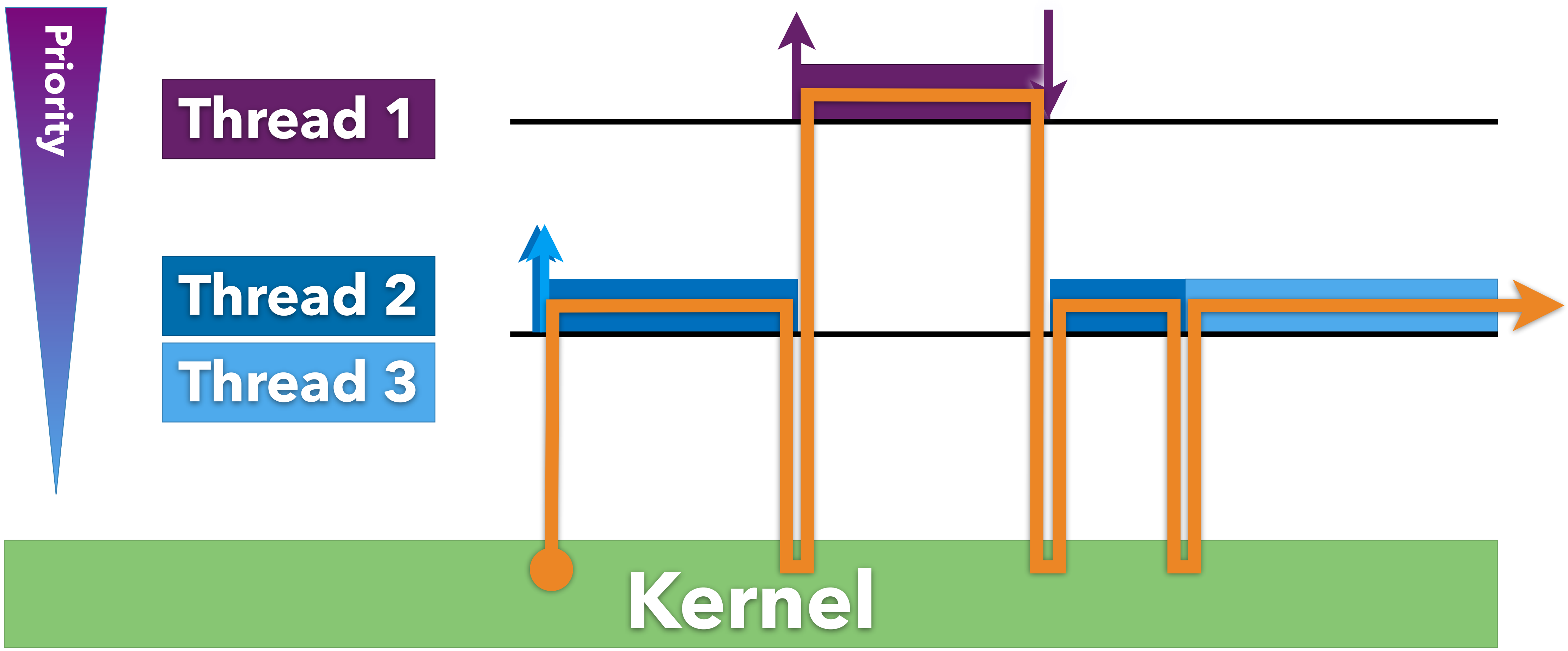
EXAMPLE

- 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)



EXAMPLE

it's really only one hardware thread being multiplexed



SYNCHRONIZATION

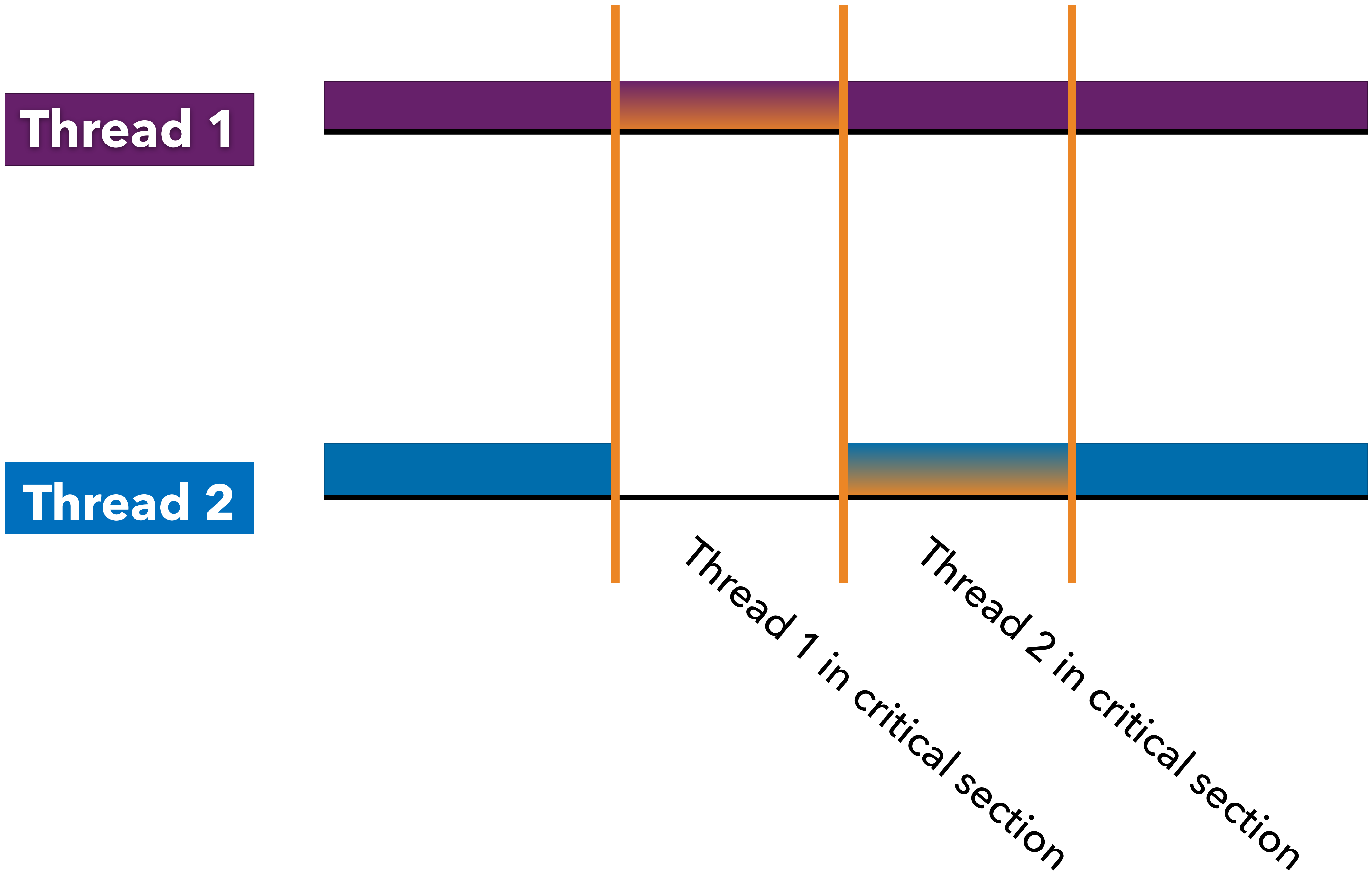
BASICS

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

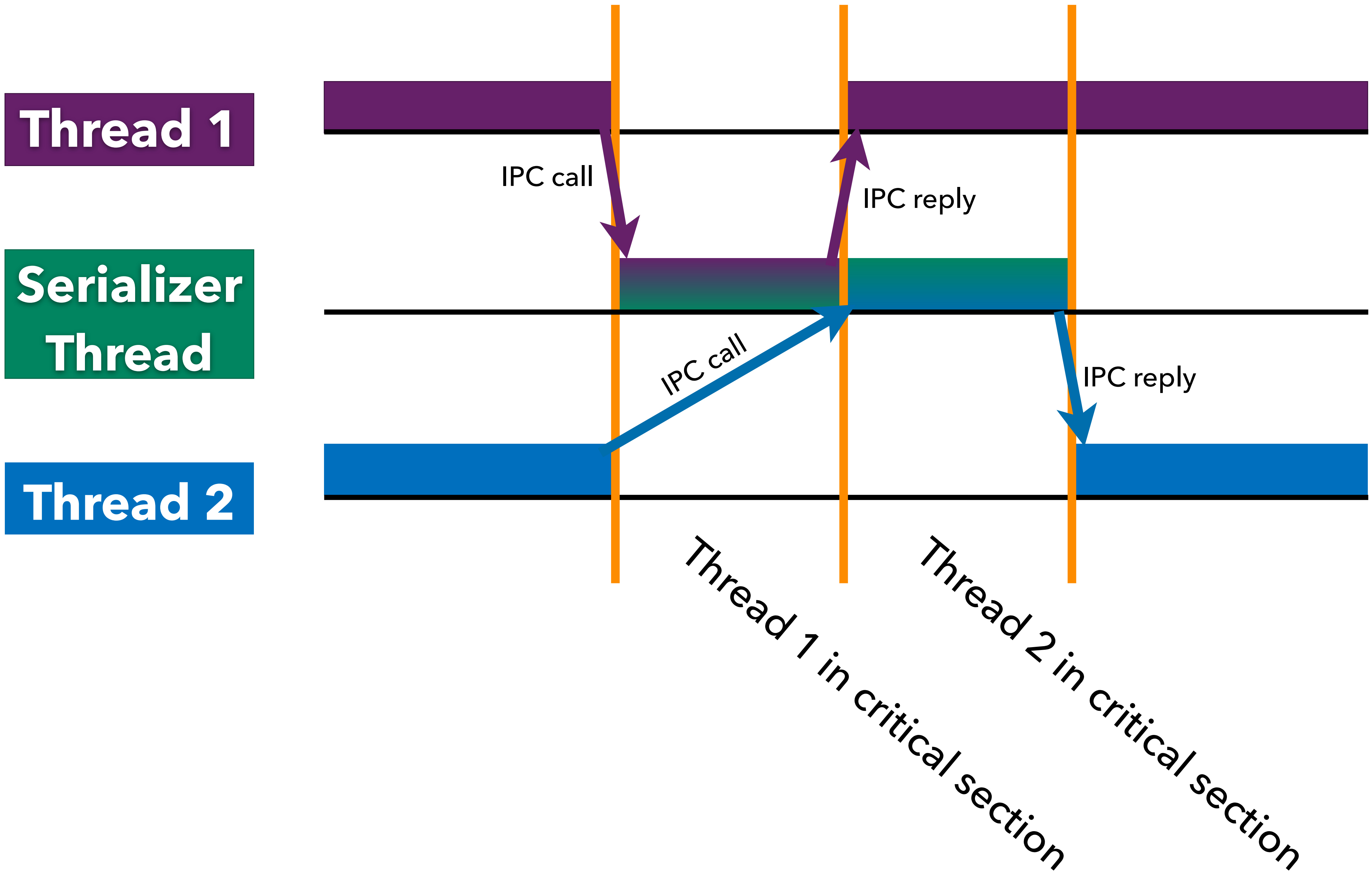
ATOMIC OPS

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

EXPECTATION



SOLUTION

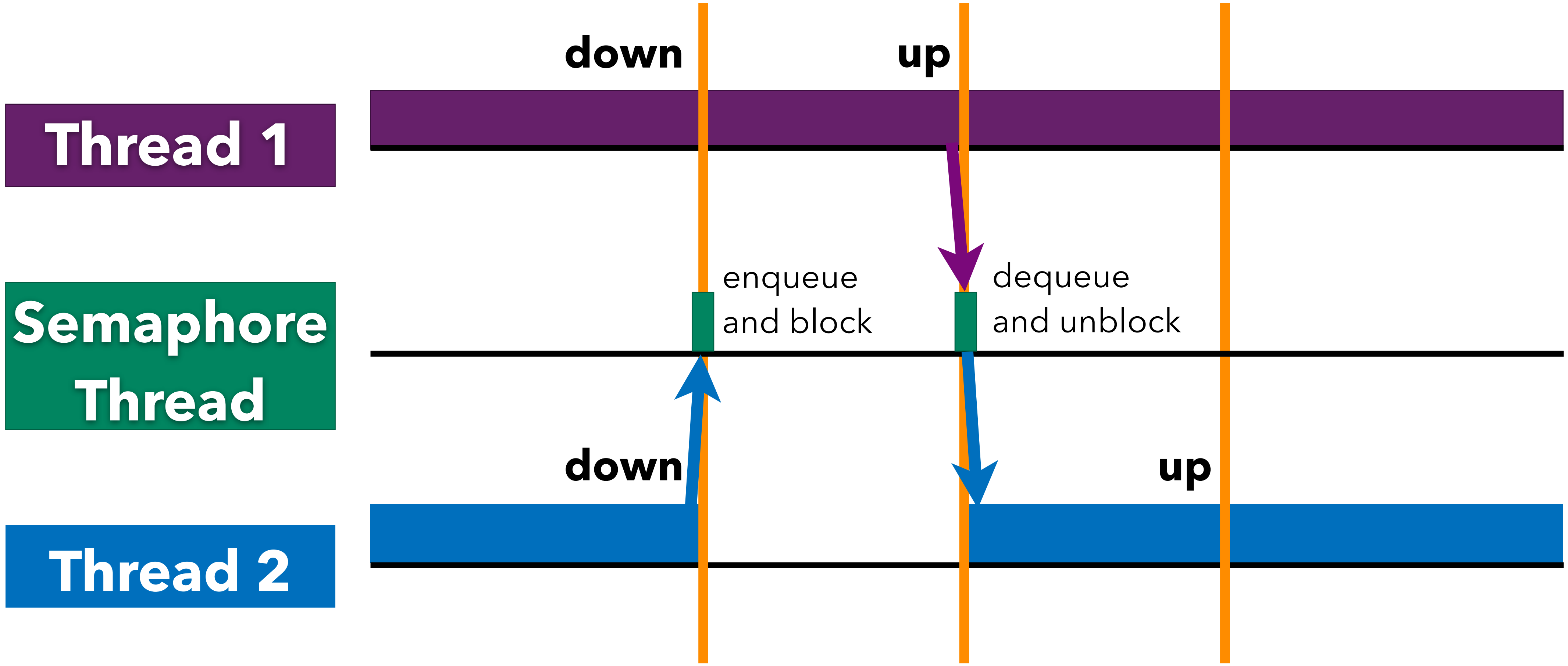

Thread 1
Serializer Thread
Thread 2
IPC call
IPC reply
IPC call
IPC reply
Thread 1 in critical section
Thread 2 in critical section

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
- optimisation for small critical sections in scheduling lecture

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: IPC