CS31: Introduction to Computer Systems

Week 10, Class 2
Operating Systems
04/06/24

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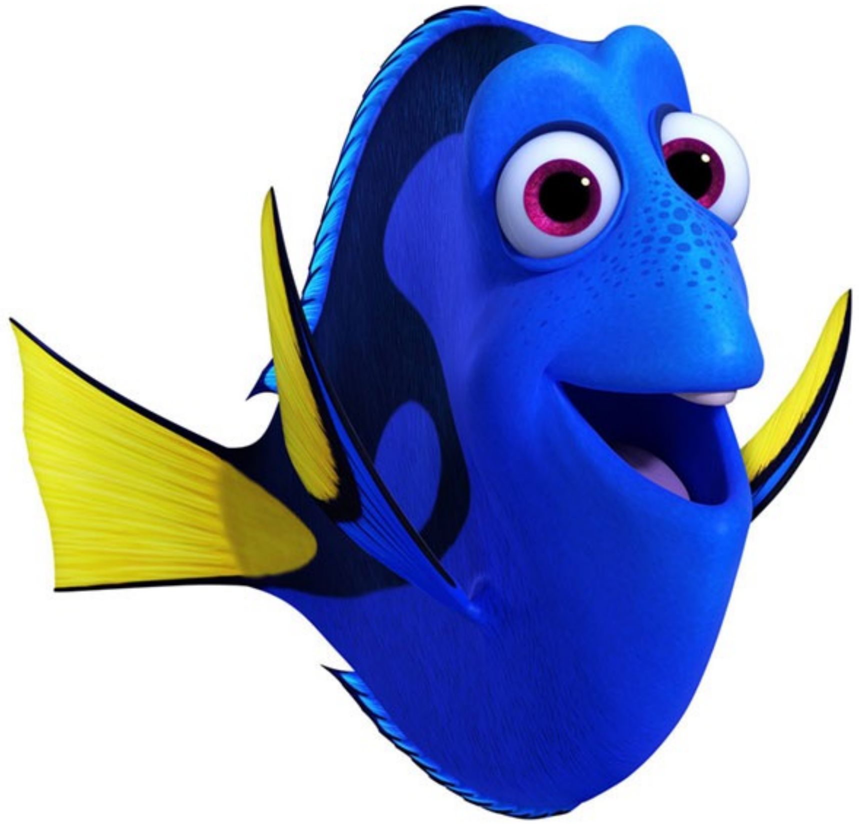
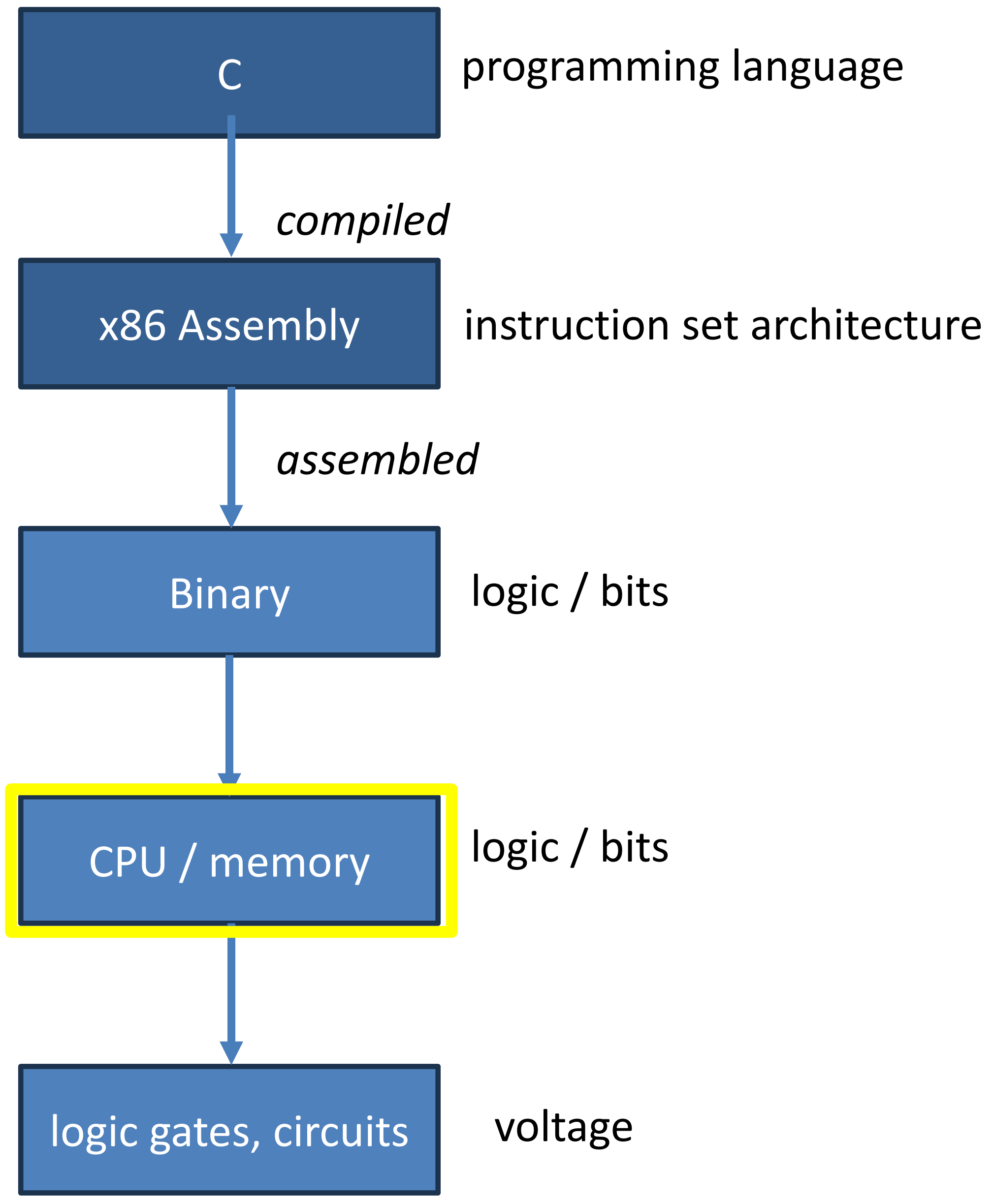
Welcome!



Where are we?

Wk	Lecture	Lab
1	Intro to C	C Arrays, Sorting
2	Binary Representation, Arithmetic	Data Rep. & Conversion
3	Digital Circuits	Circuit Design
4	ISAs & Assembly Language	”
5	Pointers and Memory	Pointers and Assembly
6	Functions and the Stack	Maze Lab
7	Arrays, Structures & Pointers	”
Spring Break		
8	Storage and Memory Hierarchy	Game of Life
9	Storage, Caching	”
10	Caching, Operating System, Processing	Strings
11	Virtual Memory	Unix Shell
12	Parallel Applications, Threading	”
13	Threading	pthreads Game of Life
14	Threading	”



Reading Quiz

The ___ is the abstraction an OS uses to manage the resources of a running program.

A. file

B. container

C. process

D. virtual memory

Essential OS functionality is built into the OS’s ___.

A. center

B. core

C. foundation

D. kernel

User processes interact with the OS by making…

A. request calls

B. system calls

C. utility calls

D. cries for help

OS Big Picture Goals

- OS is a layer of code between user programs and hardware.

- Goal: Make life easier for users and programmers.

- How can the OS do that?

If you were asked to design a layer between user programs and the hardware, what might your layer provide?

- What sort of services might the programs you’ve written need?
- (Discuss with your neighbors)

Key OS Responsibilities

1. Simplifying abstractions for programs

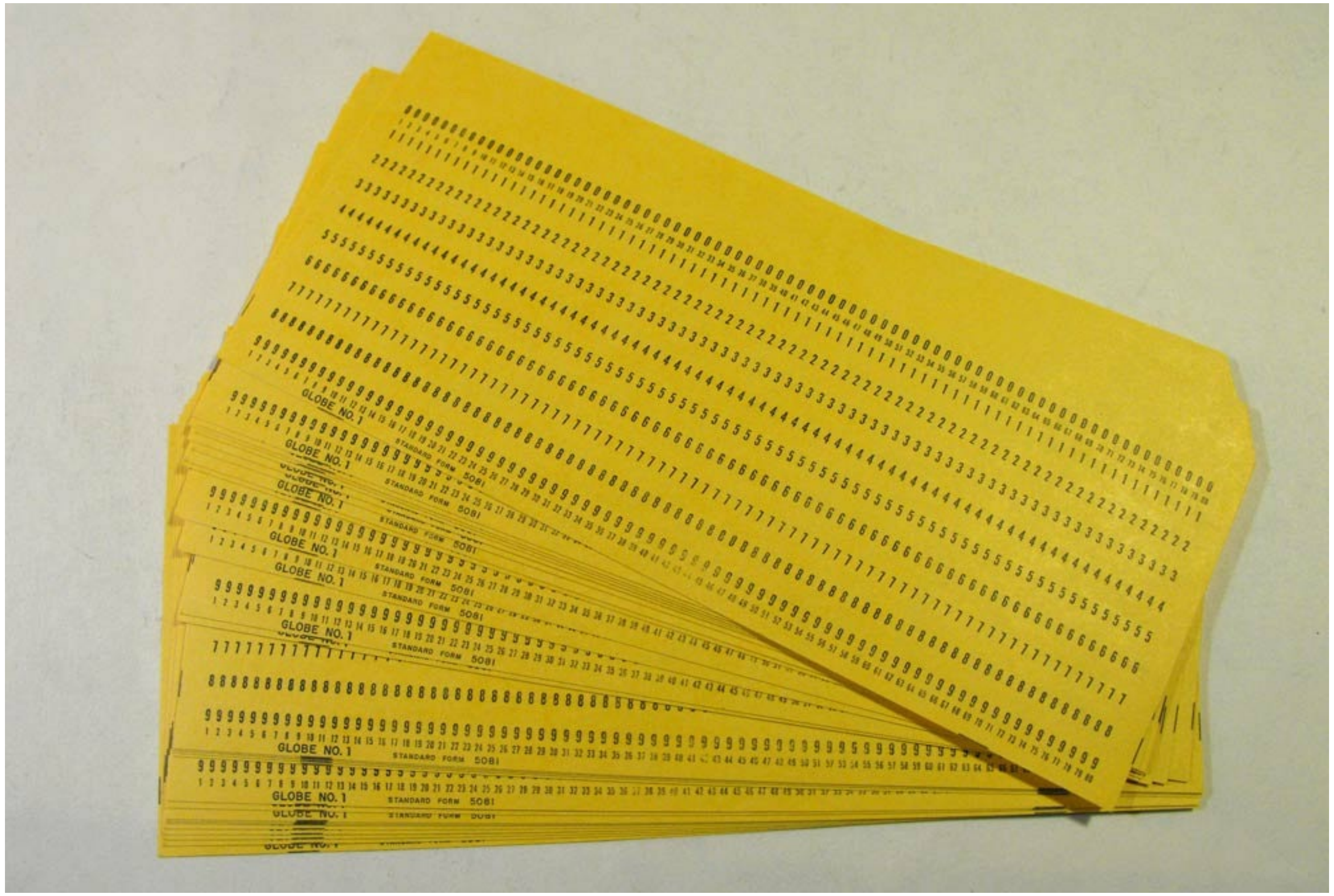
2. Resource allocation and/or sharing

3. Hardware gatekeeping and protection

OS: Manage complexity/limitations

- Turn undesirable inconveniences: reality
  - Complexity of hardware
  - Single processor
  - Limited memory

Before Operating Systems



- One program executed at a time…

Why is it not ideal to have only a single program available to the hardware?

A. The hardware might run out of work to do

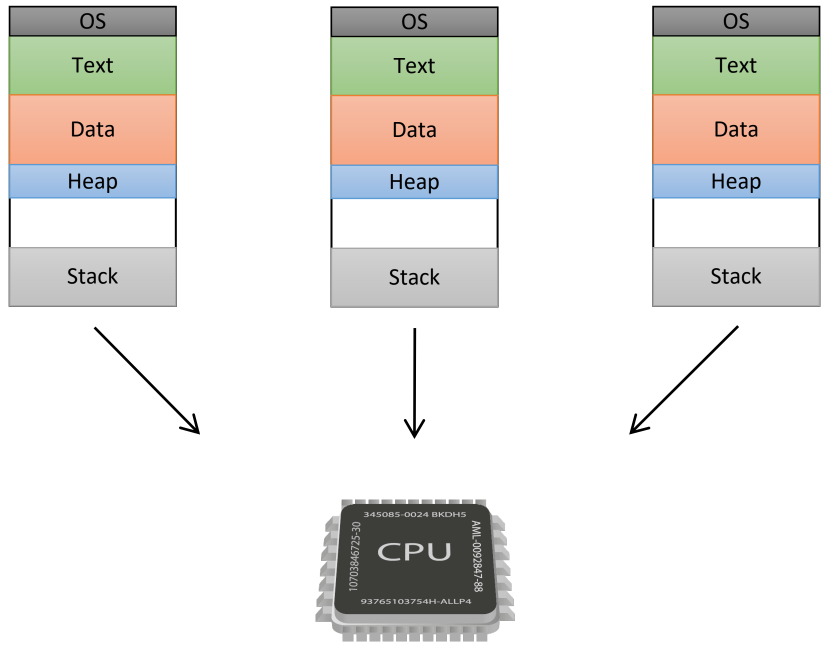
B. The hardware won’t execute as quickly

C. The hardware’s resources won’t be used as efficiently

D. Some other reason(s) (What?)

Today: Multiprogramming

- Multiprogramming: have multiple programs available to the machine, even if you only have one CPU core that can execute them.



How many programs do you think are running on a typical desktop computer?

A. 1-10

B. 20-40

C. 40-80

D. 80-160

E. 160+

Running multiple programs

- Benefits: when I/O issued, CPU not needed
  - Allow another program to run
  - <u>Requires yielding and sharing memory</u>

- Challenges: what if one running program…
  - Monopolizes CPU, memory?
  - Reads/writes another's memory?
  - Uses I/O device being used by another?

OS: Turn undesirable into desirable

- Turn undesirable inconveniences: reality
  - Complexity of hardware
  - Single processor
  - Limited memory
- Into desirable conveniences: illusions
  - Simple, easy-to-use resources
  - Multiple/unlimited number of processors
  - Large/unlimited amount of memory

Virtualization

- Rather than exposing real hardware, introduce a “virtual”, abstract notion of the resource

- Multiple virtual processors
  - By rapidly switching CPU use
- Multiple virtual memories
  - By memory partitioning and re-addressing
- Virtualized devices
  - By simplifying interfaces, and using other resources to enhance function

We’ll focus on the OS ‘kernel’

- “Operating system” has many interpretations
  - E.g., all software on machine minus applications (user or even limited to 3rd party)

- Our focus is the *kernel*
  - What’s necessary for everything else to work
  - Low-level resource control
  - Originally called the nucleus in the 60’s

The Kernel

- All programs depend on it
  - Loads and runs them
  - Exports system calls to programs
- Works closely with hardware
  - Accesses devices
  - Responds to interrupts (hardware events)
- Allocates basic resources
  - CPU time, memory space
  - Controls I/O devices: display, keyboard, disk, network

Tron, 1982

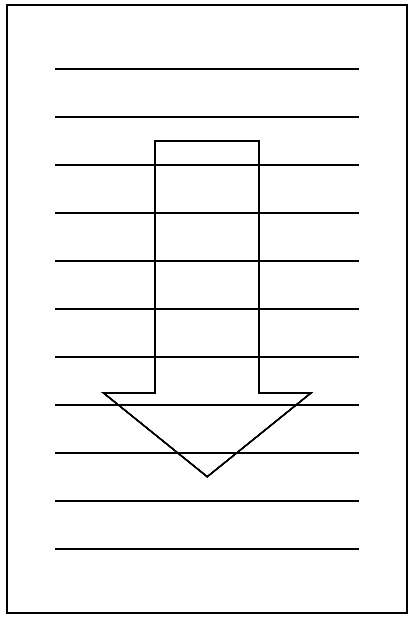
The Kernel: Takes Over Hardware

Kernel provides common functions

- Some functions useful to many programs
  - I/O device control
  - Memory allocation
- Place these functions in central place (kernel)
  - Called by programs ("system calls")
  - Or accessed in response to hardware events
- What should functions be?
  - How many programs should benefit?
  - Might kernel get too big?

Main Abstraction: The Process

- Abstraction of a running program
  - “a program in execution”
- Dynamic
  - Has state, changes over time
  - Whereas a program is static
- Basic operations
  - Start/end
  - Suspend/resume



Basic Resources for Processes

- To run, process needs some basic resources:
  - CPU
    - Processing cycles (time)
    - To execute instructions
  - Memory
    - Bytes or words (space)
    - To maintain state
  - Other resources (e.g., I/O)
    - Network, disk, terminal, printer, etc.

What sort of information might the OS need to store to keep track of a running process?

- That is, what MUST an OS know about a process?
- (Discuss with your neighbors.)

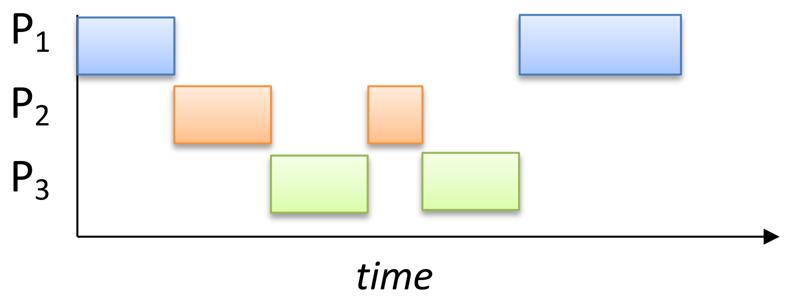
Machine State of a Process

- CPU or <u>processor context</u>
  - PC (program counter)
  - SP (stack pointer)
  - General purpose registers
- Memory
  - Code
  - Global Variables
  - Stack of activation records / frames
  - Other (registers, memory, kernel-related state)

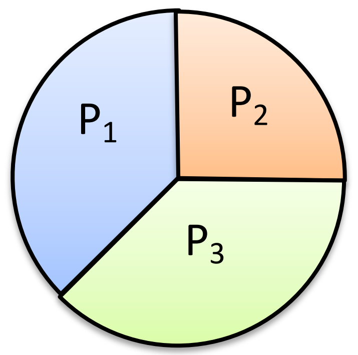
Must keep track of these for every running process !

Resource Sharing

CPU: Time



Memory: Space



Reality

- Multiple processes
- Small number of CPUs
- Finite memory

Abstraction

- Process is all alone
- Process is always running
- Process has all the memory

Resource: CPU

- Many processes, limited number of CPUs.
- Each process needs to make progress over time. Insight: processes don’t know how quickly they *should* be making progress.
- Illusion: every process is making progress in parallel.

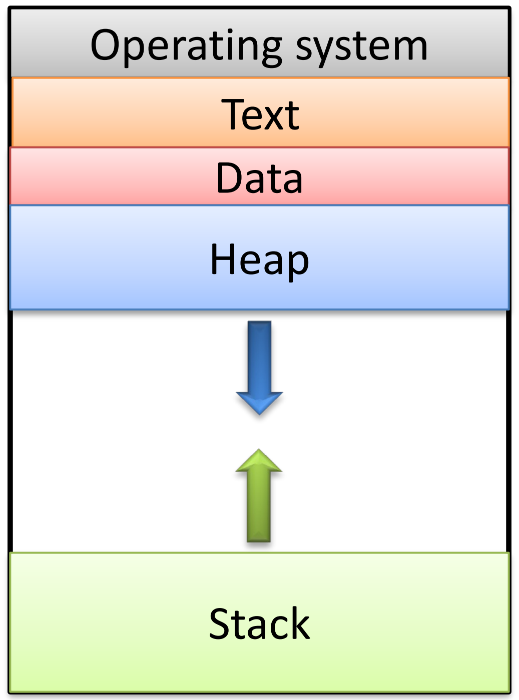
Timesharing: Sharing the CPUs

- Abstraction goal: make every process think it’s running on the CPU all the time.
  - Alternatively: If a process was removed from the CPU and then given it back, it shouldn’t be able to tell

- Reality: put a process on CPU, let it run for a short time (~10 ms), switch to another, … ("context switching")

Resource: Memory

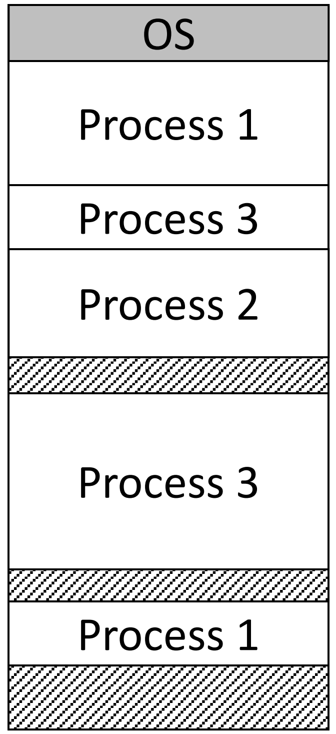
- Abstraction goal: make every process think it has the same memory layout.
  - MUCH simpler for compiler if the stack always starts at 0xFFFFFFFF, etc.



Memory

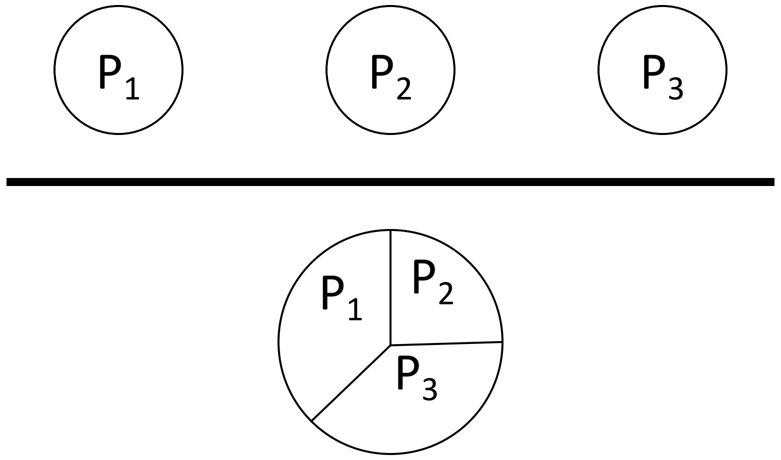
- Abstraction goal: make every process think it has the same memory layout.
  - MUCH simpler for compiler if the stack always starts at 0xFFFFFFFF, etc.

- Reality: there's only so much memory to go around, and no two processes should use the same (physical) memory addresses (unless they're sharing).



OS (with help from hardware) will keep track of who's using each memory region.

Virtual Memory: Sharing Storage



- Like CPU cache, memory is a cache for disk.

- Processes never need to know where their memory truly is, OS translates virtual addresses into physical addresses for them.

Kernel Execution

- Great, the OS is going to somehow give us these nice abstractions.

- So…how / when should the kernel execute to make all this stuff happen?

The operating system kernel…

A. Executes as a process.

B. Is always executing, in support of other processes.

C. Should execute as little as possible.

D. More than one of the above. (Which ones?)

E. None of the above.

Process vs. Kernel

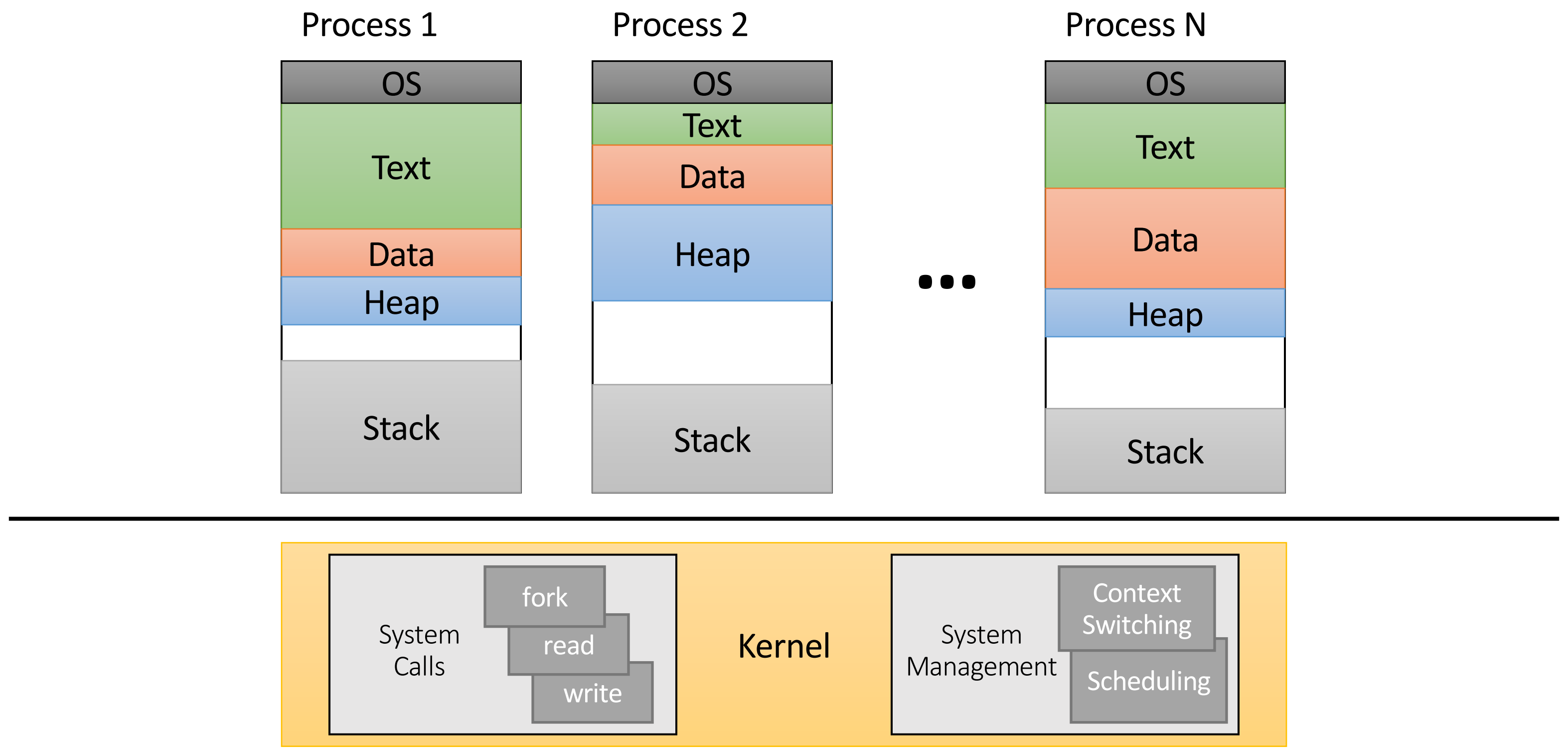
- Is the kernel itself a process?
  - No, it supports processes and devices

- OS only runs when necessary…
  - as an extension of a process making system call
  - in response to a device issuing an interrupt

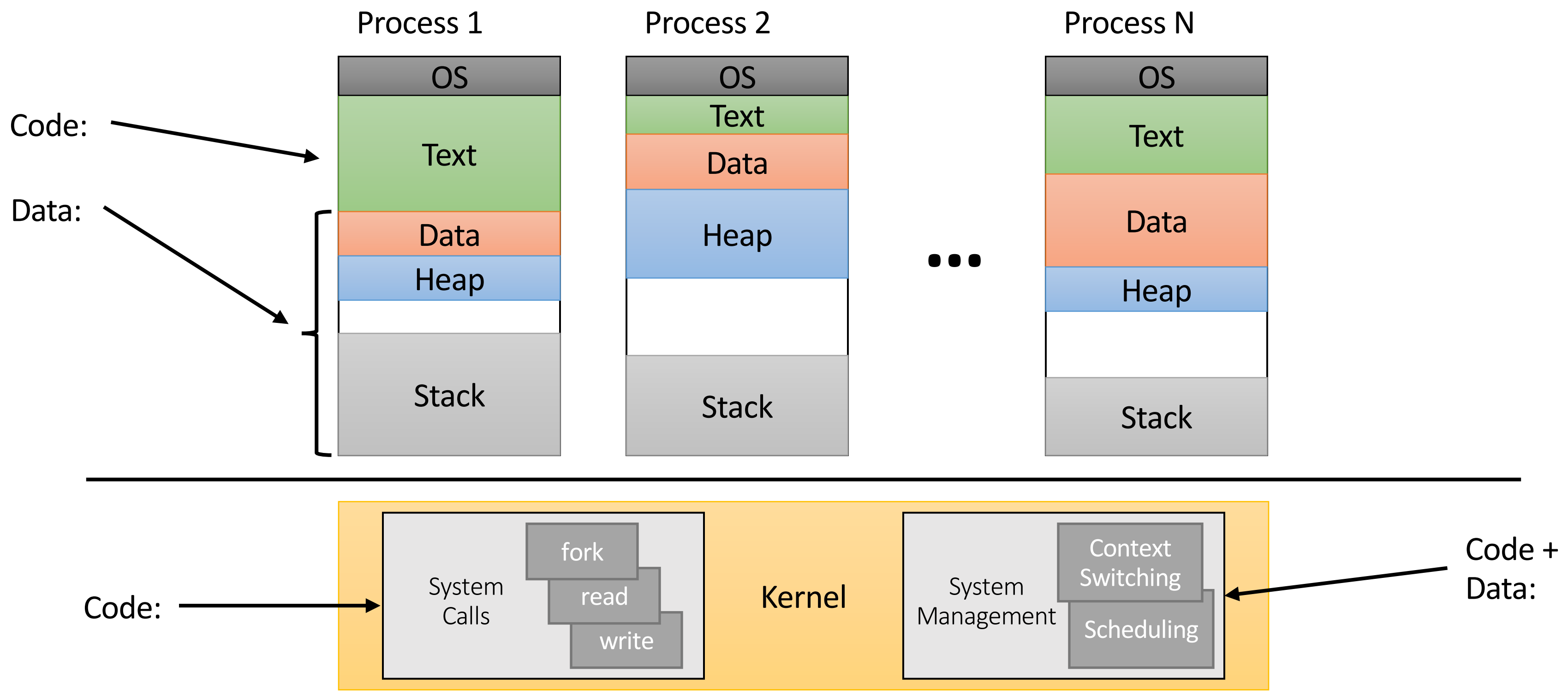
Process vs. Kernel

- The kernel is the code that supports processes
  - System calls: fork ( ), exit ( ), read ( ), write ( ), …
  - System management: context switching, scheduling, memory management

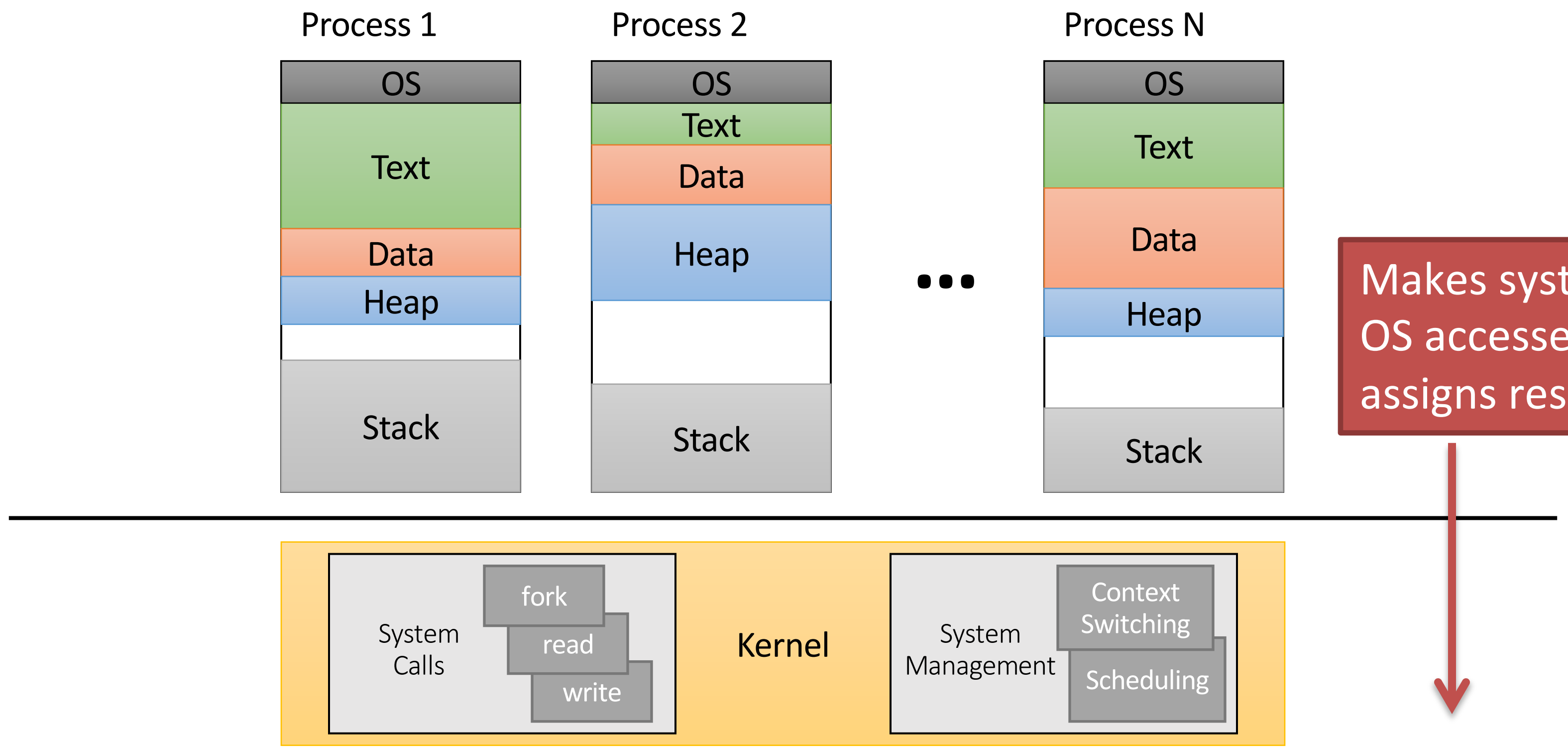
Kernel vs. Userspace: Model



Kernel vs. Userspace: Model

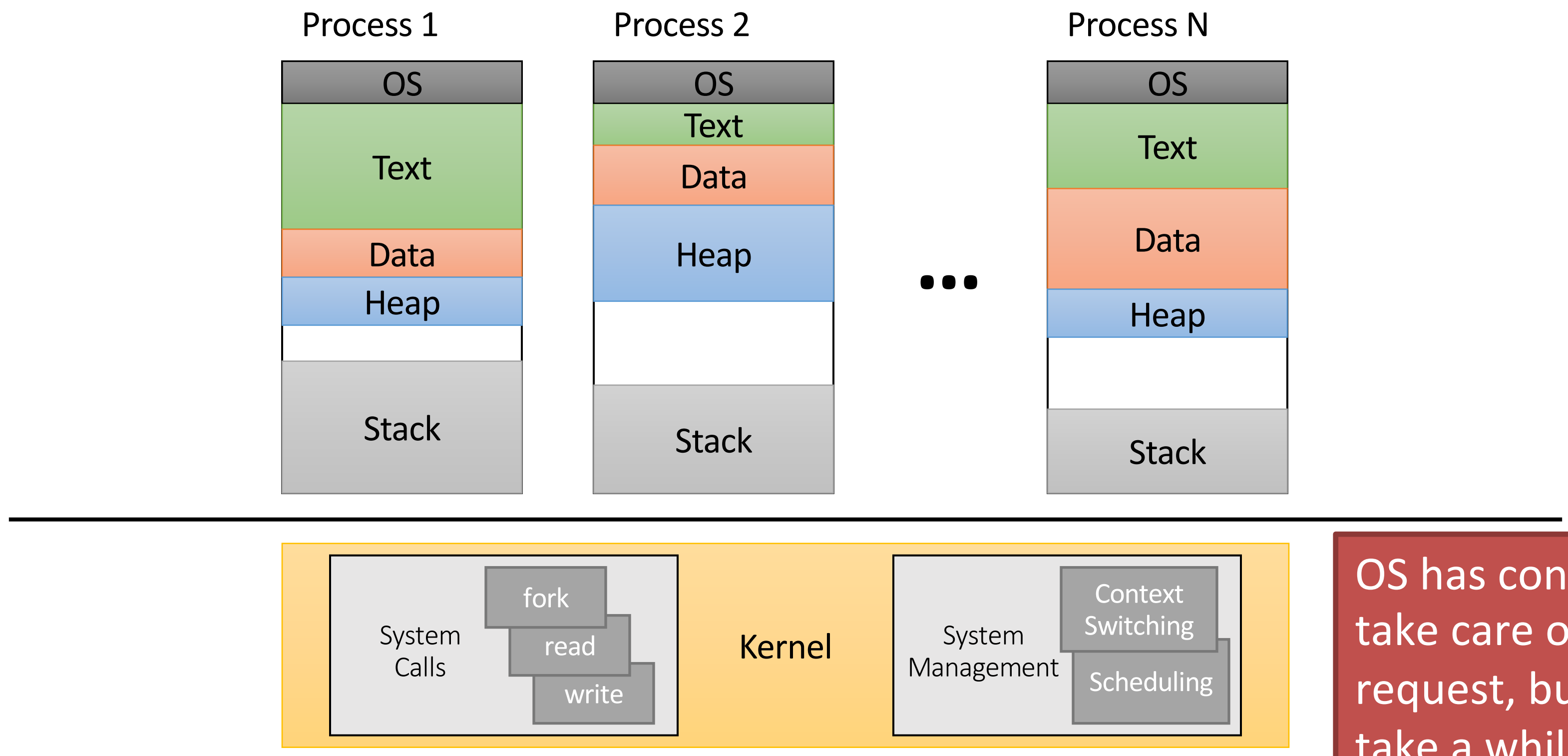


Kernel vs. Userspace: Model



Makes system call. OS accesses device, assigns resource, etc.

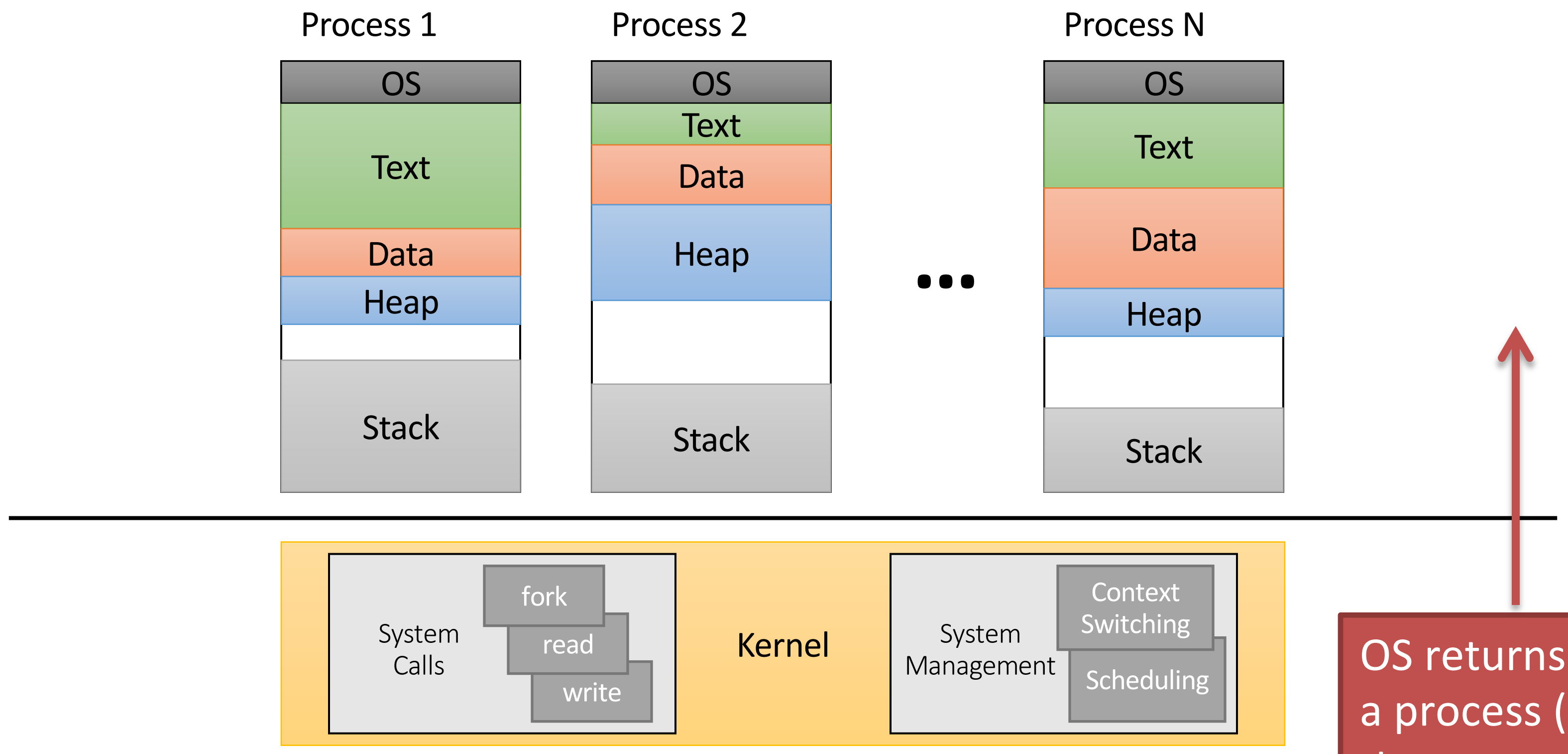
Kernel vs. Userspace: Model



OS has control. It will take care of process's request, but it might take a while.

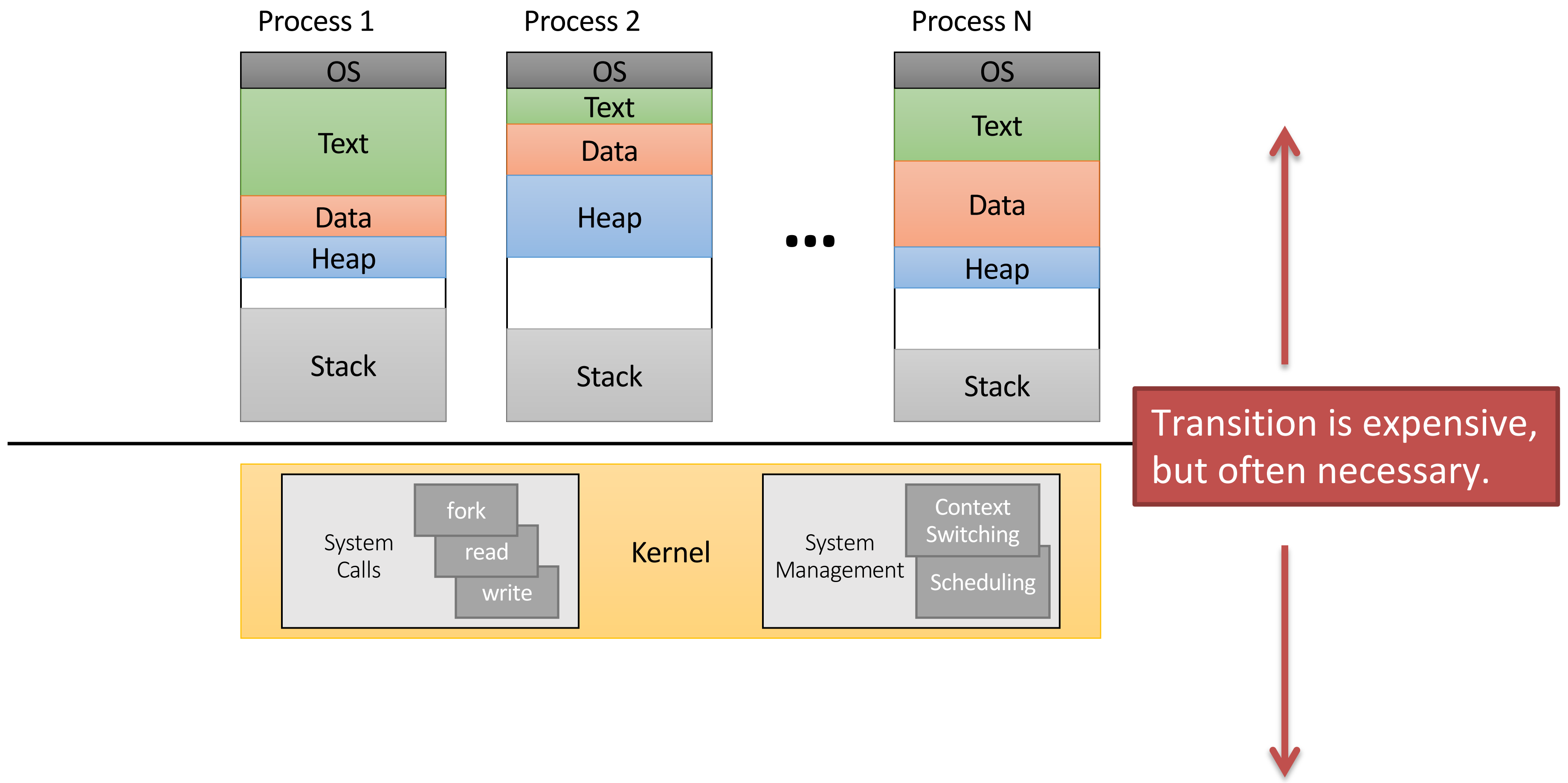
It can context switch (and usually does at this point).

Kernel vs. Userspace: Model



OS returns control to a process (usually not the same one).

Kernel vs. Userspace: Model



Control over the CPU

- To context switch processes, kernel must get control:

1. Running process can give up control voluntarily
   - To block, call yield () to give up CPU
   - Process makes a blocking system call, e.g., read ()
   - Control goes to kernel, which dispatches new process

2. CPU is forcibly taken away: preemption

How might the OS forcibly take control of a CPU?

A. Ask the user to give it the CPU.

B. Require a program to make a system call.

C. Enlist the help of a hardware device.

D. Some other means of seizing control (how?).

CPU Preemption

1. While kernel is running, set a hardware timer.
2. When timer expires, a hardware interrupt is generated. (device asking for attention)
3. Interrupt pauses process on CPU, forces control to go to OS kernel.
4. OS is free to perform a context switch.

Up next…

- How we create/manage processes.
- How we provide the illusion of the same enormous memory space for all processes.