Operating Systems

Processes and Threads - Part 1

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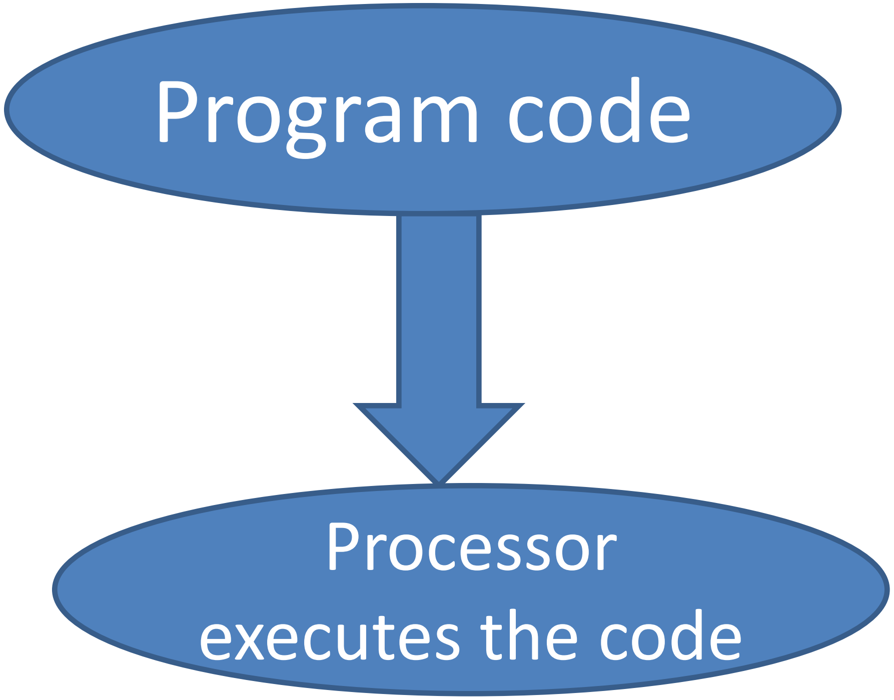
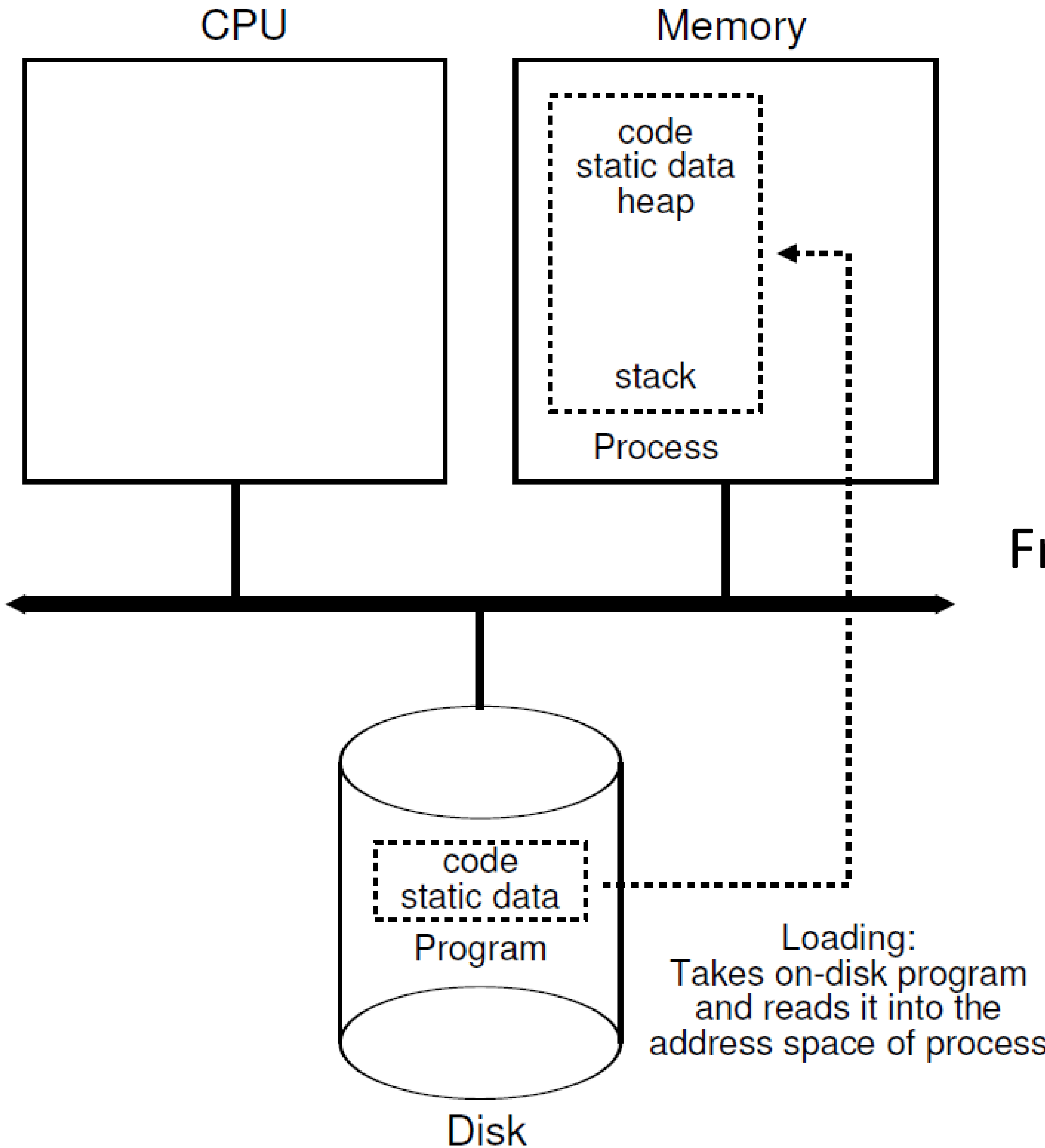
OS Management of Application Execution

- Resources are made available to multiple applications.
- The processor is switched among multiple applications so all will appear to be progressing.
- **Main Goal:** The processor, memory, and I/O devices can be used efficiently



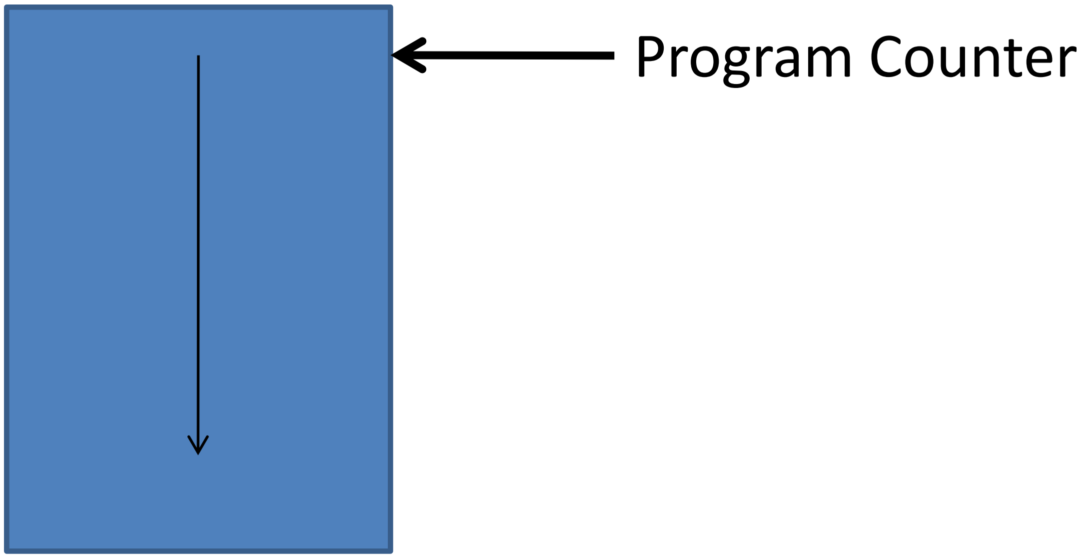
When the processor begins to execute the program code, we refer to this executing entity as a ***process***



From a program
to a process.

What Is a Process?

An abstraction of a running program



The Process Model

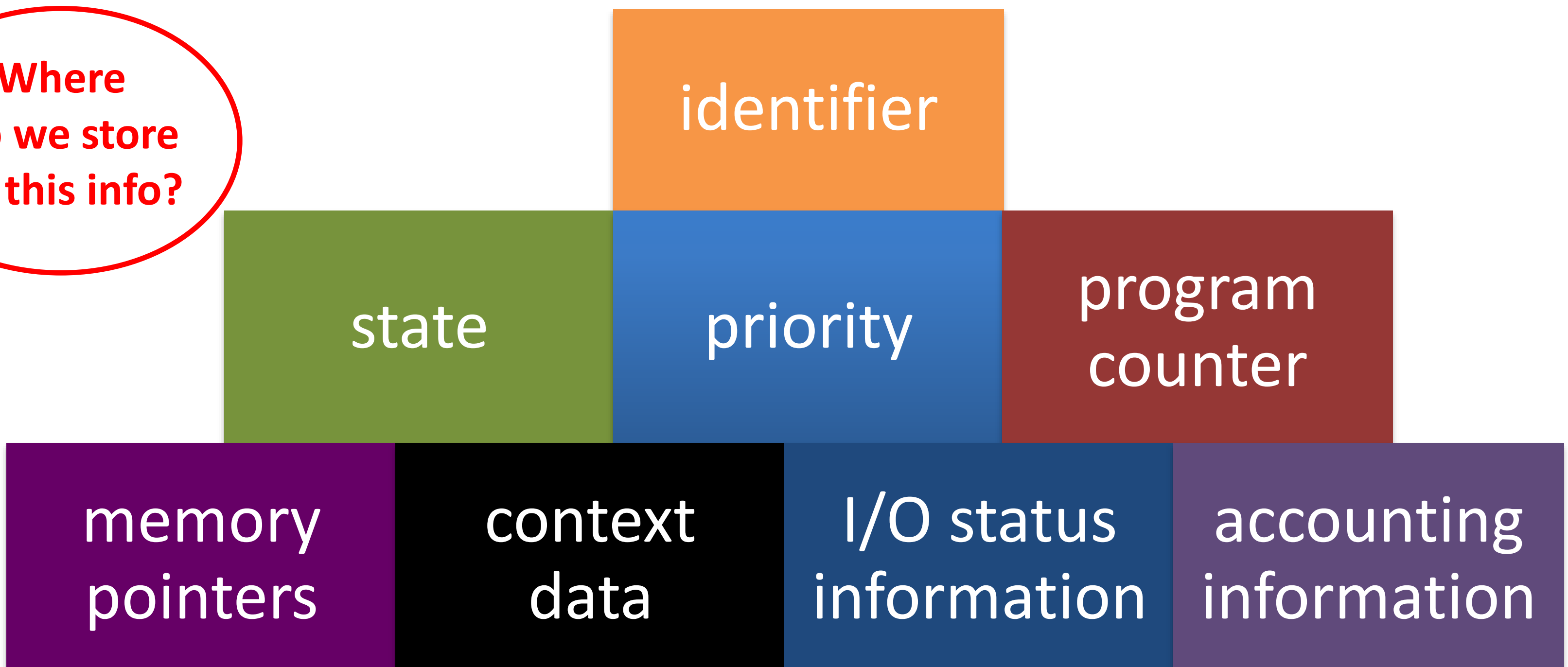
- A process is an instance of an executing program and includes
  - Program counter
  - Registers
  - Variables
  - …
- A process has a program, input, output, and state.

If a program is running twice, does it count as two processes? or one?

Process

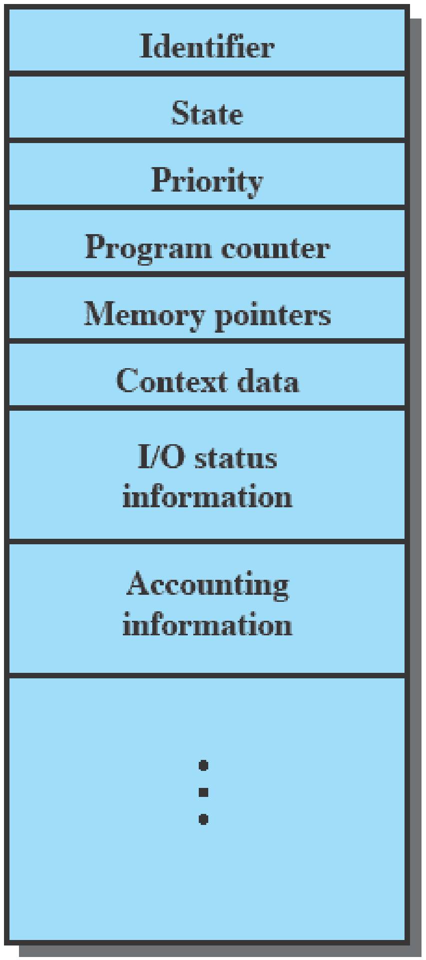
- While the program is executing, its process can be uniquely characterized by a number of elements, including:

Where do we store all this info?



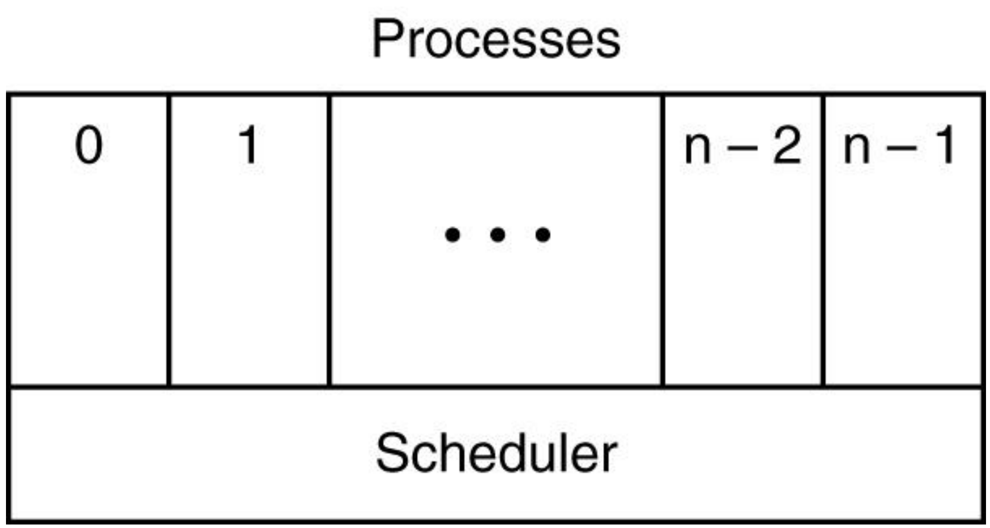
Process Control Block

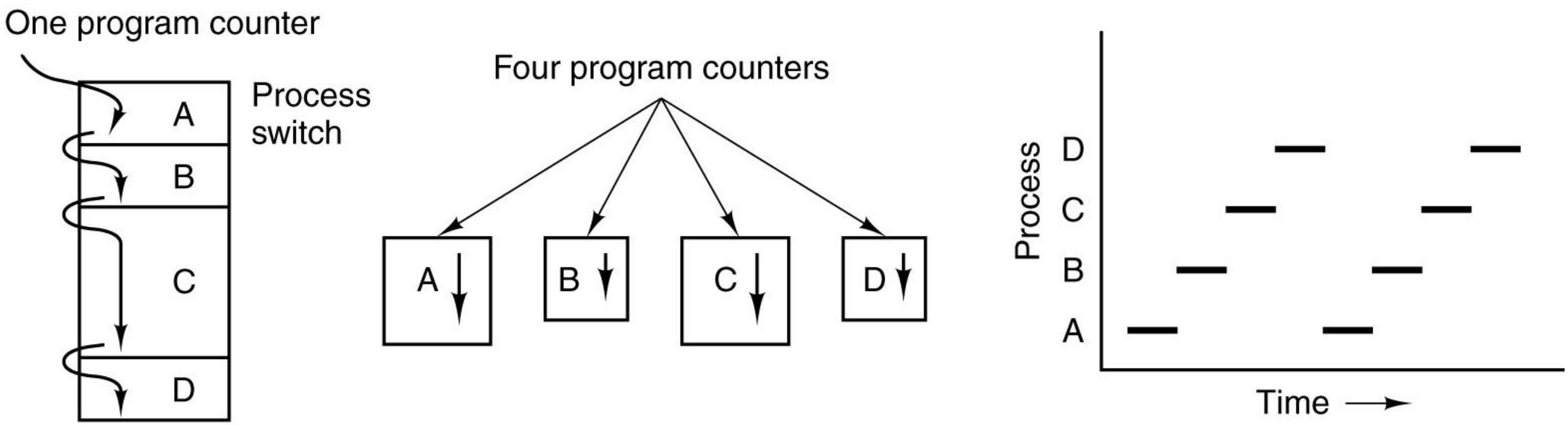
- Contains the process elements
- It is possible to interrupt a running process and later resume execution as if the interruption had not occurred
- Created and managed by the operating system
- Key tool that allows support for multiple processes



Multiprogramming

- One CPU and several processes
- CPU switches from process to process quickly

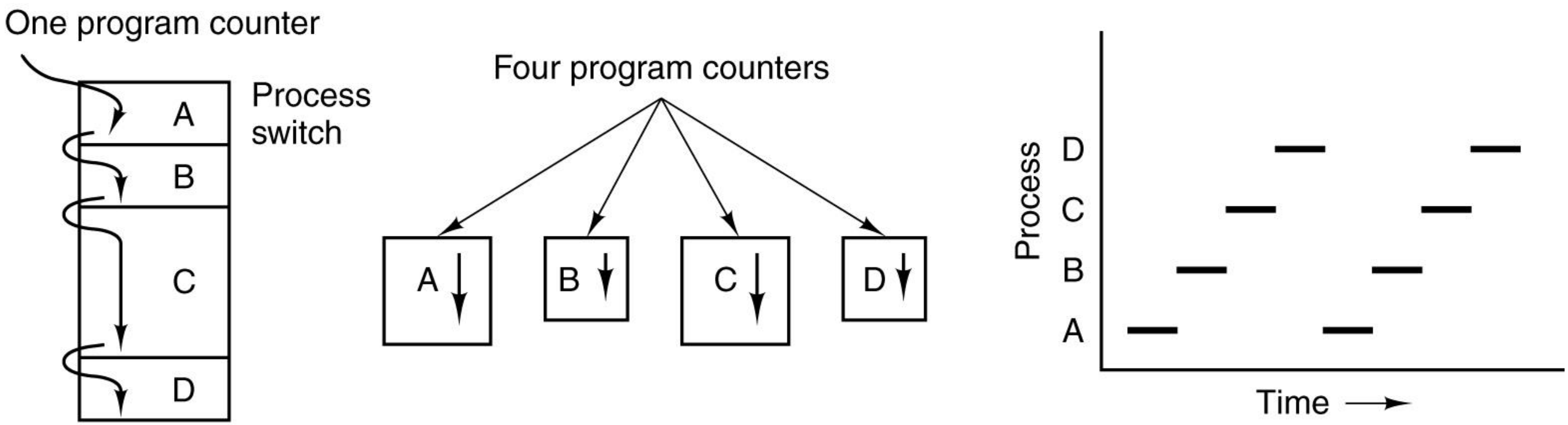




(a) (b)

What Really Happens **What We Think It Happens**

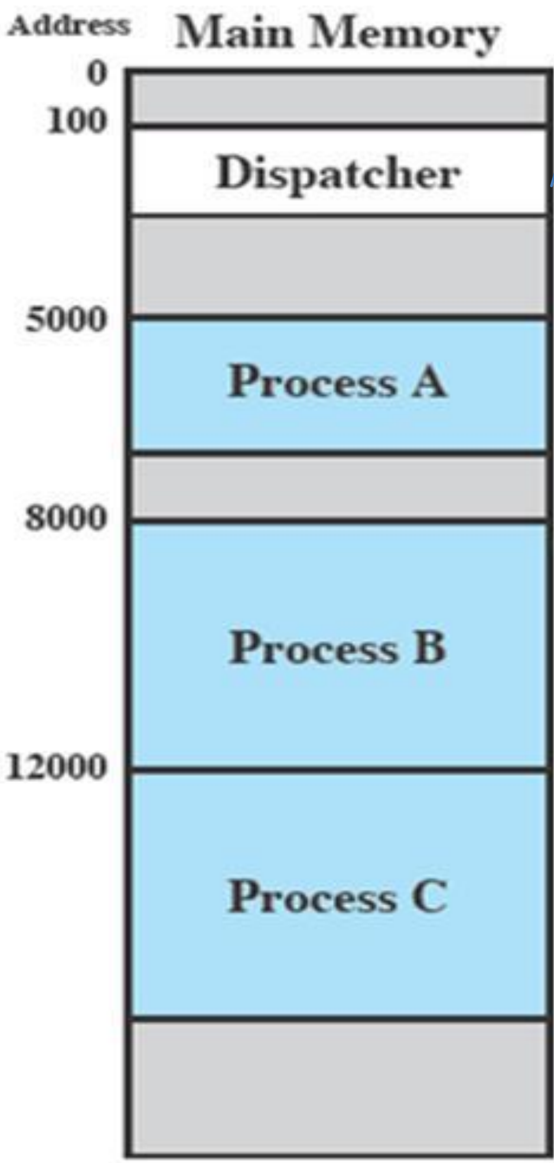
If we run the same program several times, will we get the same execution time?



(a) (b)

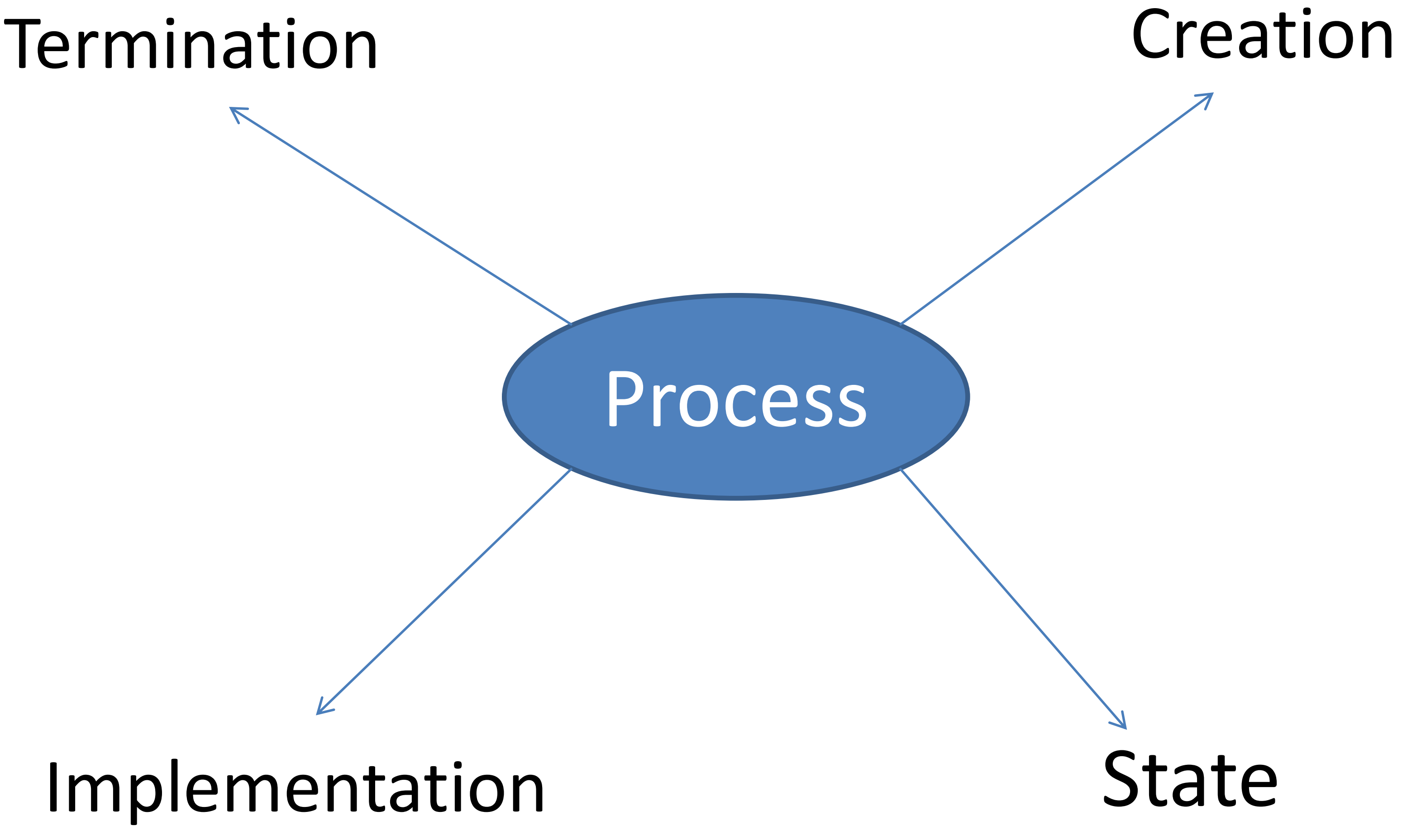
What Really Happens **What We Think It Happens**

Example



1 5000
2 5001
3 5002
4 5003
5 5004
6 5005
------------------ Timeout
7 100
8 101
9 102
10 103
11 104
12 105
13 8000
14 8001
15 8002
16 8003
-------------- I/O Request
17 100
18 101
19 102
20 103
21 104
22 105
23 12000
24 12001
25 12002
26 12003
27 12004
28 12005
------------------ Timeout
29 100
30 101
31 102
32 103
33 104
34 105
35 5006
36 5007
37 5008
38 5009
39 5010
40 5011
------------------ Timeout
41 100
42 101
43 102
44 103
45 104
46 105
47 12006
48 12007
49 12008
50 12009
51 12010
52 12011
------------------ Timeout

Small program that switches the processor from one process to another (also called Scheduler)



Termination
Creation
Process
Implementation
State

Process Creation: When Does it Happen?

- System initialization
  - At boot time
  - Foreground
  - Background (daemons)
- Execution of a process creation system call by a running process
- A user request
- A batch job
- Created by OS to provide a service
- Interactive logon

Process Termination: When Does it Happen?

- Normal exit (voluntary)
- Error exit (voluntary)
- Fatal error (involuntary)
- Killed by another process (involuntary)

Process Termination: More Scenarios

Normal completion	The process executes an OS service call to indicate that it has completed running.
Time limit exceeded	The process has run longer than the specified total time limit. There are a number of possibilities for the type of time that is measured. These include total elapsed time ("wall clock time"), amount of time spent executing, and, in the case of an interactive process, the amount of time since the user last provided any input.
Memory unavailable	The process requires more memory than the system can provide.
Bounds violation	The process tries to access a memory location that it is not allowed to access.
Protection error	The process attempts to use a resource such as a file that it is not allowed to use, or it tries to use it in an improper fashion, such as writing to a read-only file.
Arithmetic error	The process tries a prohibited computation, such as division by zero, or tries to store numbers larger than the hardware can accommodate.
Time overrun	The process has waited longer than a specified maximum for a certain event to occur.
I/O failure	An error occurs during input or output, such as inability to find a file, failure to read or write after a specified maximum number of tries (when, for example, a defective area is encountered on a tape), or invalid operation (such as reading from the line printer).
Invalid instruction	The process attempts to execute a nonexistent instruction (often a result of branching into a data area and attempting to execute the data).
Privileged instruction	The process attempts to use an instruction reserved for the operating system.
Data misuse	A piece of data is of the wrong type or is not initialized.
Operator or OS intervention	For some reason, the operator or the operating system has terminated the process (e.g., if a deadlock exists).
Parent termination	When a parent terminates, the operating system may automatically terminate all of the offspring of that parent.
Parent request	A parent process typically has the authority to terminate any of its offspring.

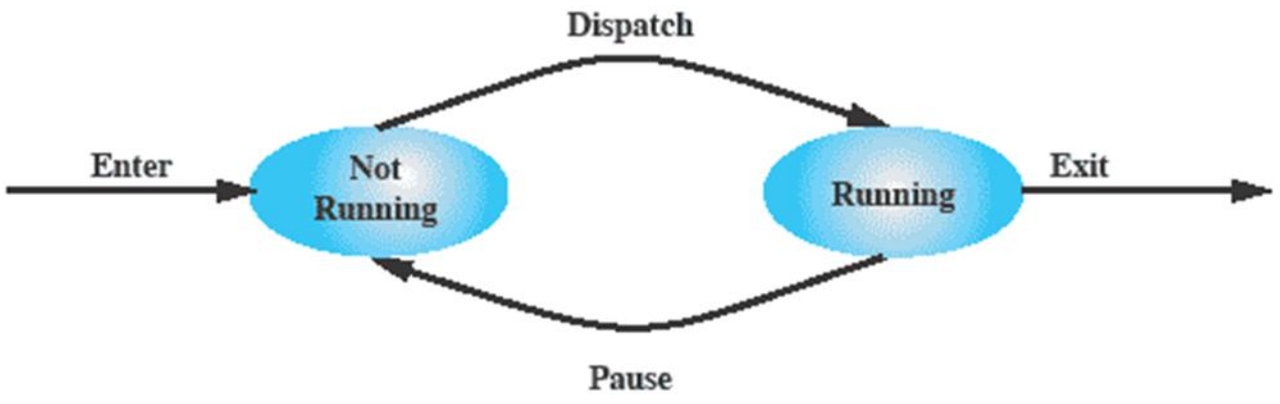
Process State

- Depending on the implementation, there can be several possible state models.

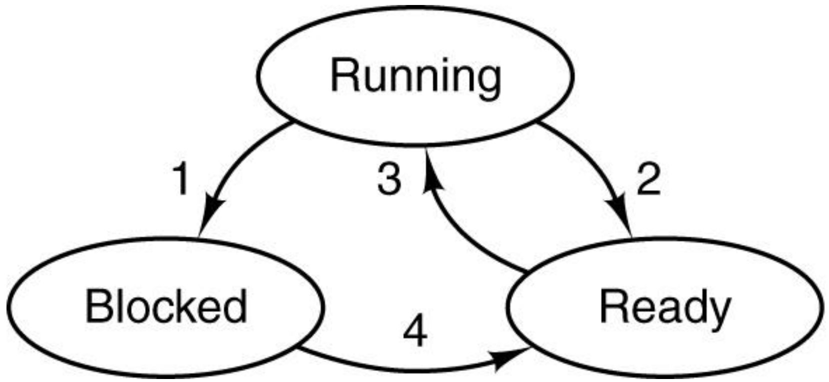
- Each state model shows:
  - number of states
  - type of each state
  - when to move from a state to another

Process State: Two-State Model

The simplest model

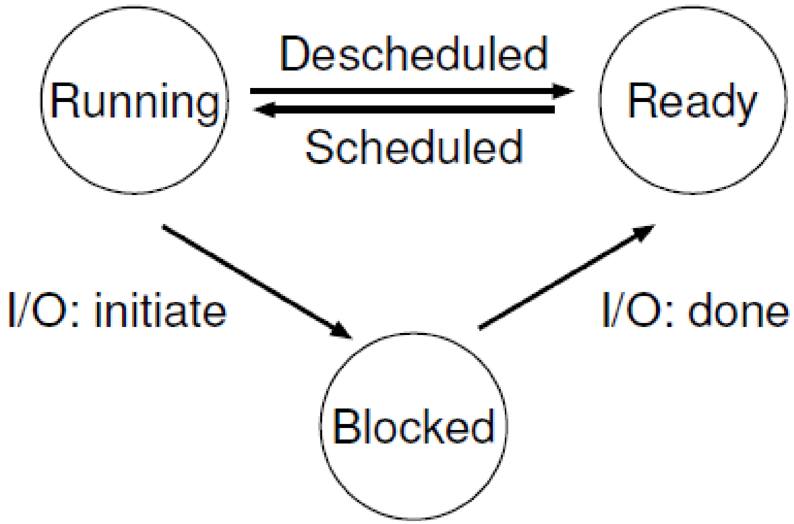


Process State: Three-State Model



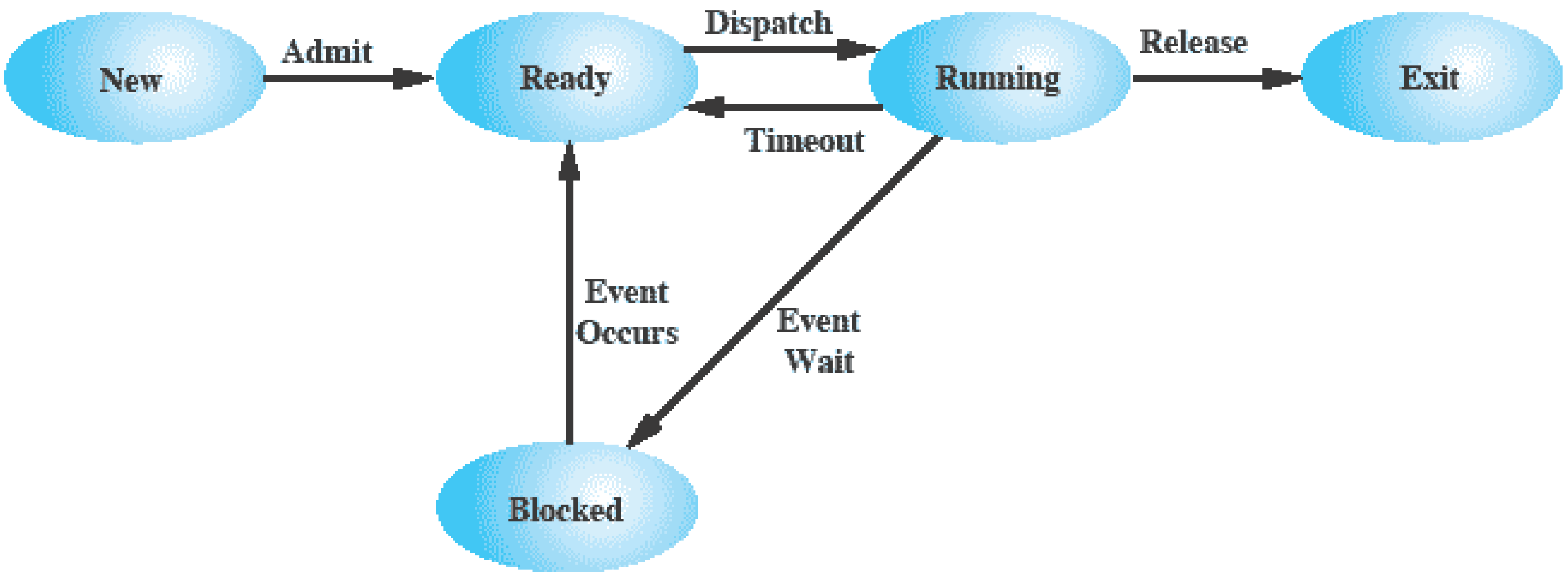
1. Process blocks for input
2. Scheduler picks another process
3. Scheduler picks this process
4. Input becomes available

Process State: Three-State Model

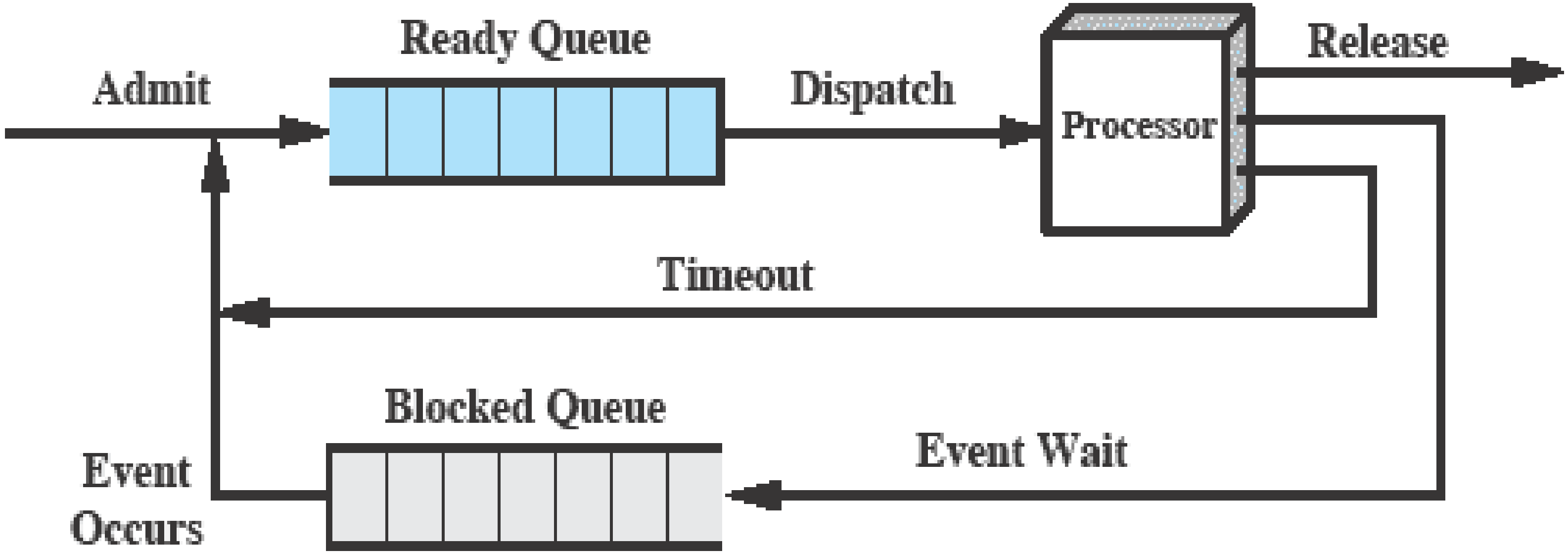


Summarizing the previous slide

Process State
Five-State Model



Using Queues to Manage Processes



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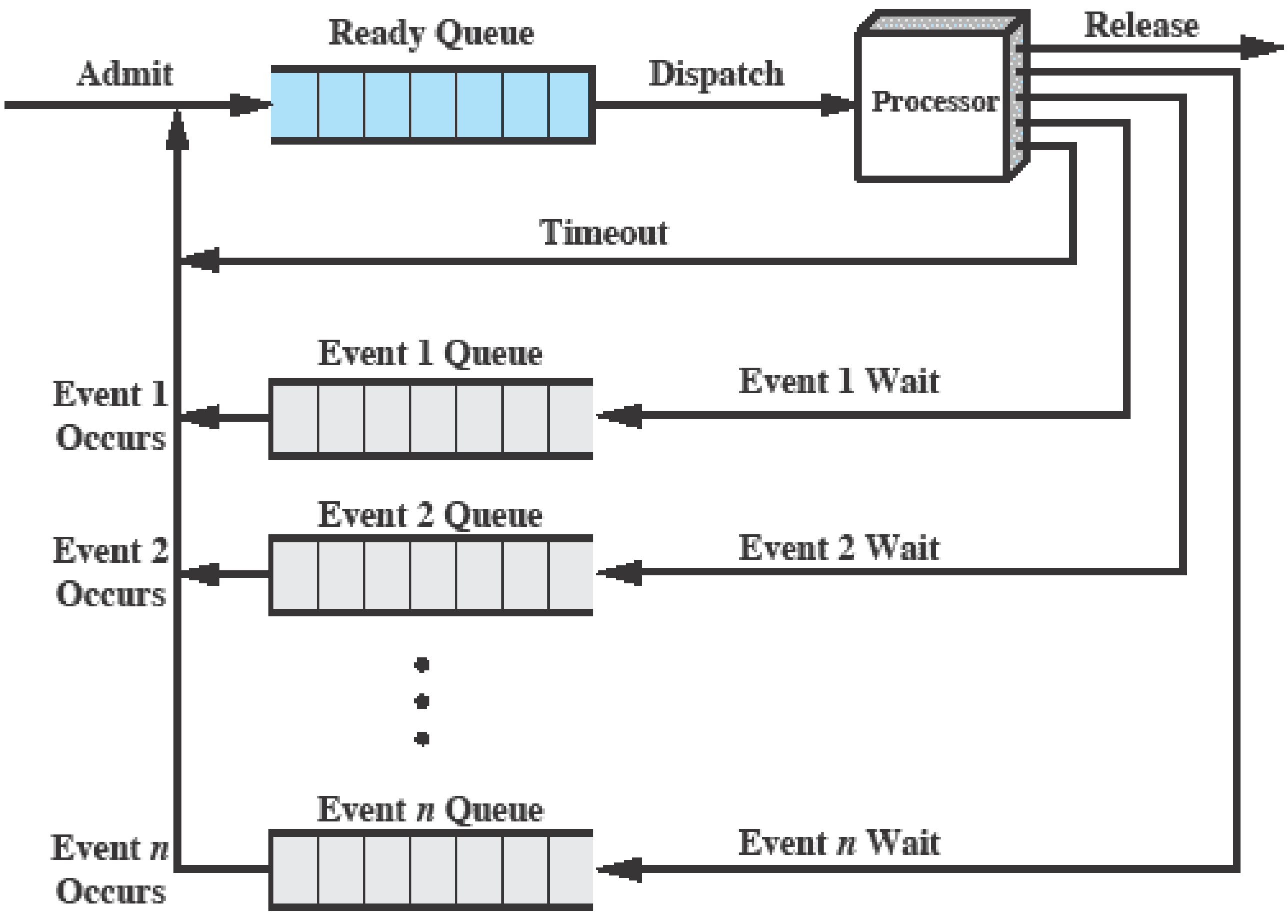
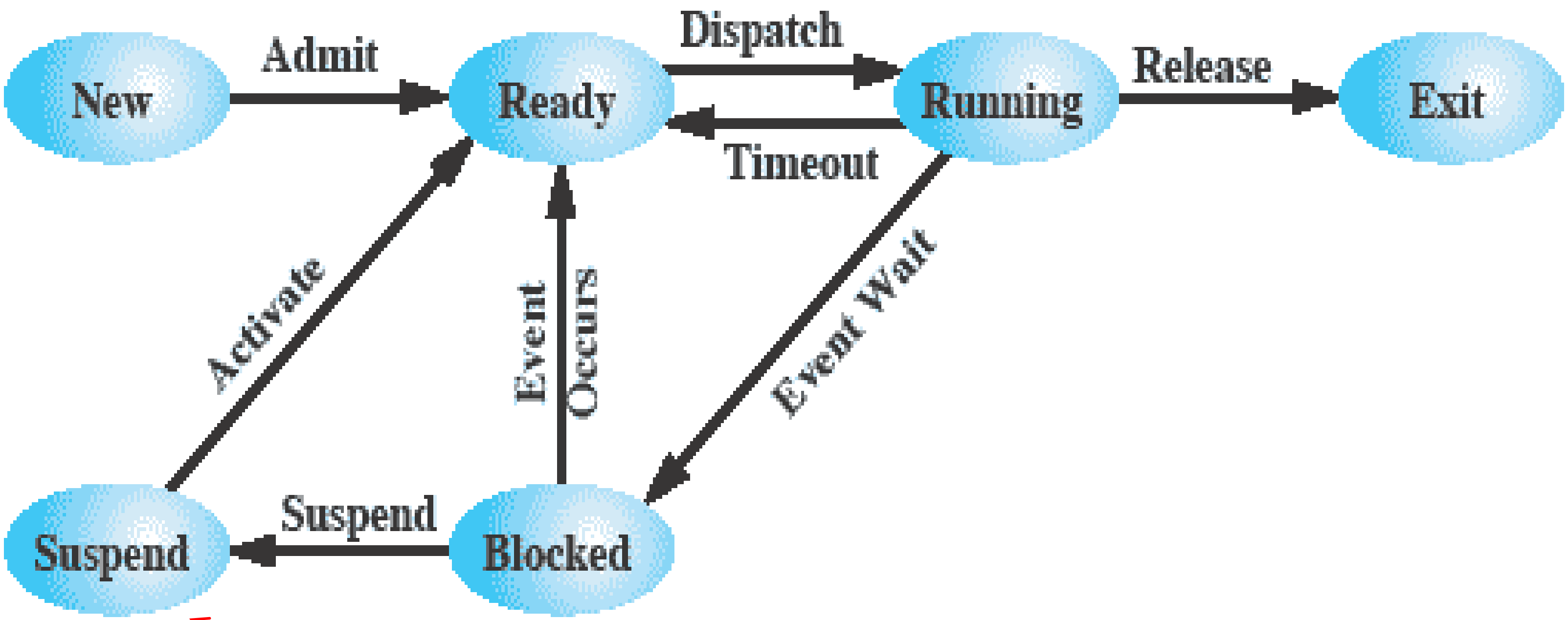


One Extra State!

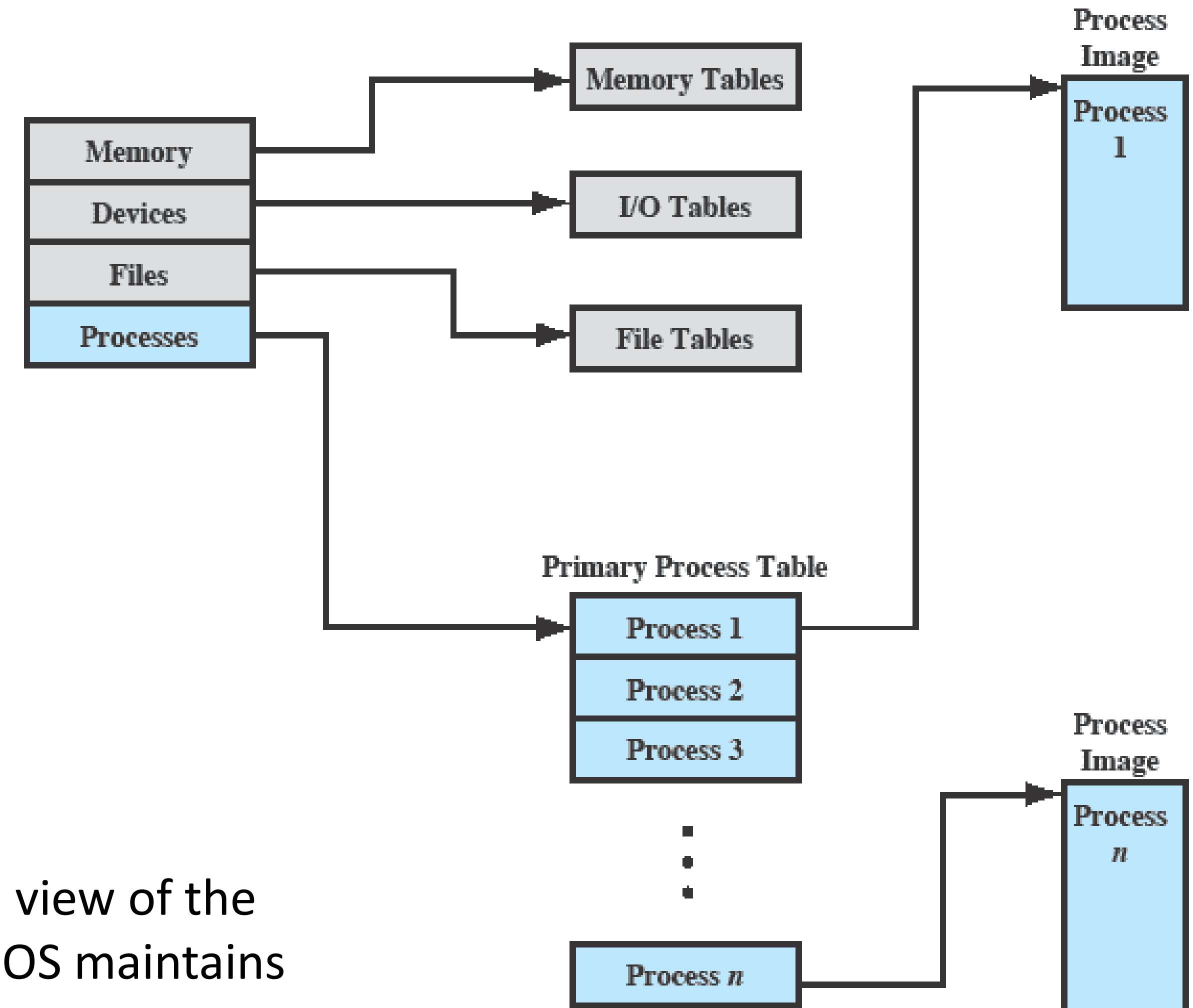


Swapped to disk

Implementation of Processes

- OS maintains a Control table (also called process table)
- An array of structures
- One entry per process

Process management	Memory management	File management
Registers	Pointer to text segment info	Root directory
Program counter	Pointer to data segment info	Working directory
Program status word	Pointer to stack segment info	File descriptors
Stack pointer		User ID
Process state		Group ID
Priority		
Scheduling parameters		
Process ID		
Parent process		
Process group		
Signals		
Time when process started		
CPU time used		
Children's CPU time		
Time of next alarm		



Conceptual view of the
tables that OS maintains
in order to manage execution
of processes on resources.

A Bit About Interrupts

- **Interrupt means**:
  - Current running process is suspended
  - OS takes control (i.e. the machine moves form user mode to kernel mode)
- **Interrupt occurs** due to many scenarios, for example:
  - Time out of current running process
  - Hardware interrupt from an I/O device
  - Page fault

A Bit About Interrupts

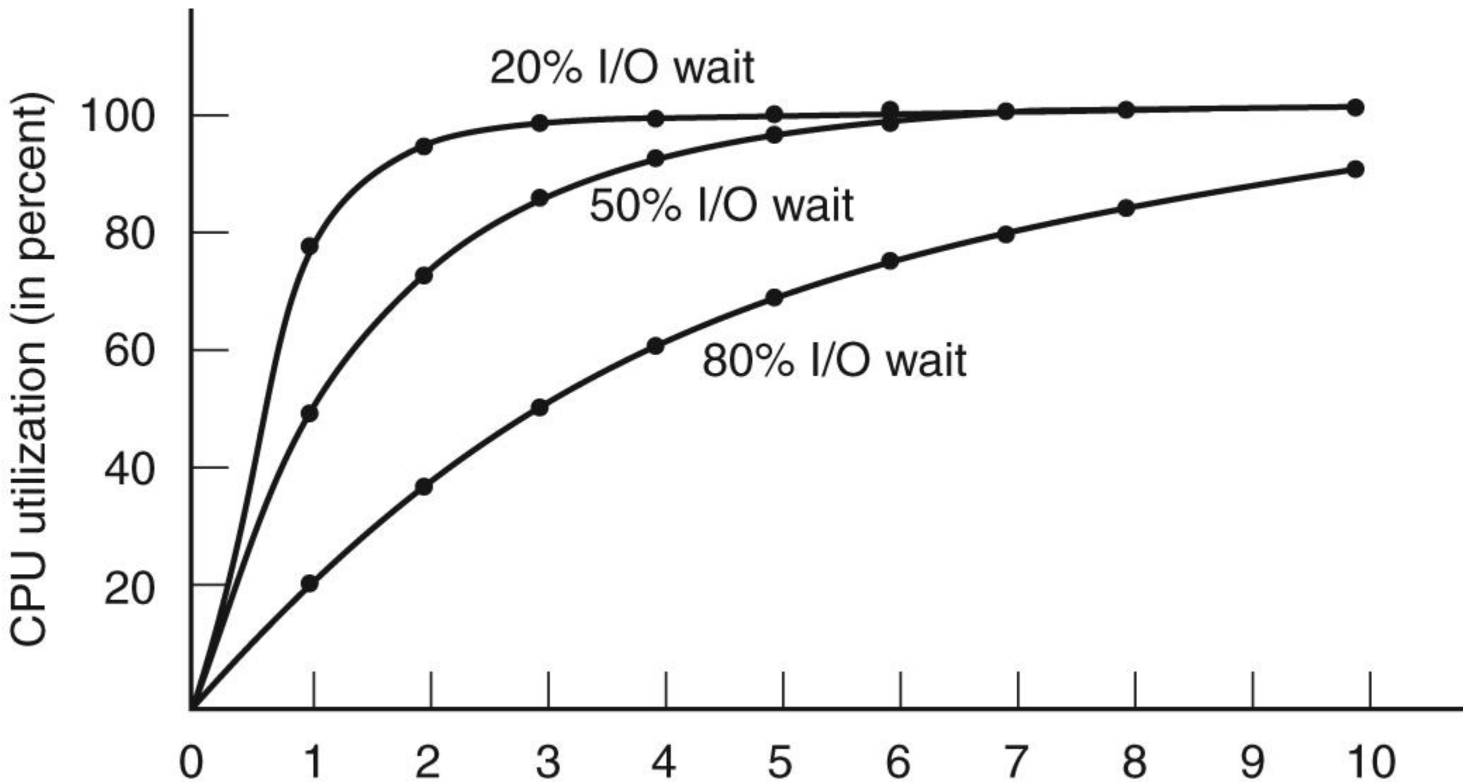
1. Hardware saves program counter, registers, etc of the current process.
2. Hardware loads program counter of the interrupt service routine (ISR).
3. ISR runs.
4. When done, the next process to run is picked.
5. Program counter, registers, etc of the picked process are loaded.
6. The picked process starts running,

Moving from User Mode to Kernel Mode

- We saw one possibility: interrupts.
- Another possibility: system call
  - voluntary

Simple Modeling of Multiprogramming

- A process spends fraction p waiting for I/O
- Assume n processes in memory at once
- The probability that all processes are waiting for I/O at once is p^n
- So -> CPU Utilization = $1 - p^n$

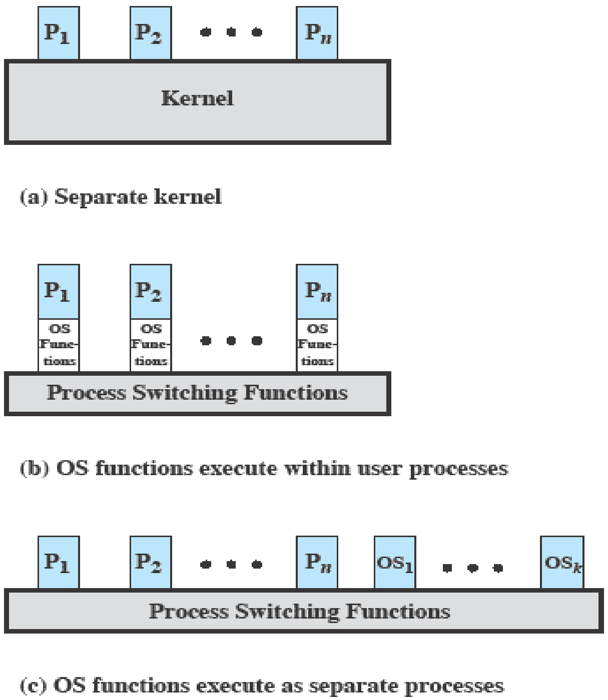


Degree of Multiprogramming

(i.e. number of processes currently in the system)

Multiprogramming lets processes use the CPU when it would otherwise become idle.

Executing the OS Itself



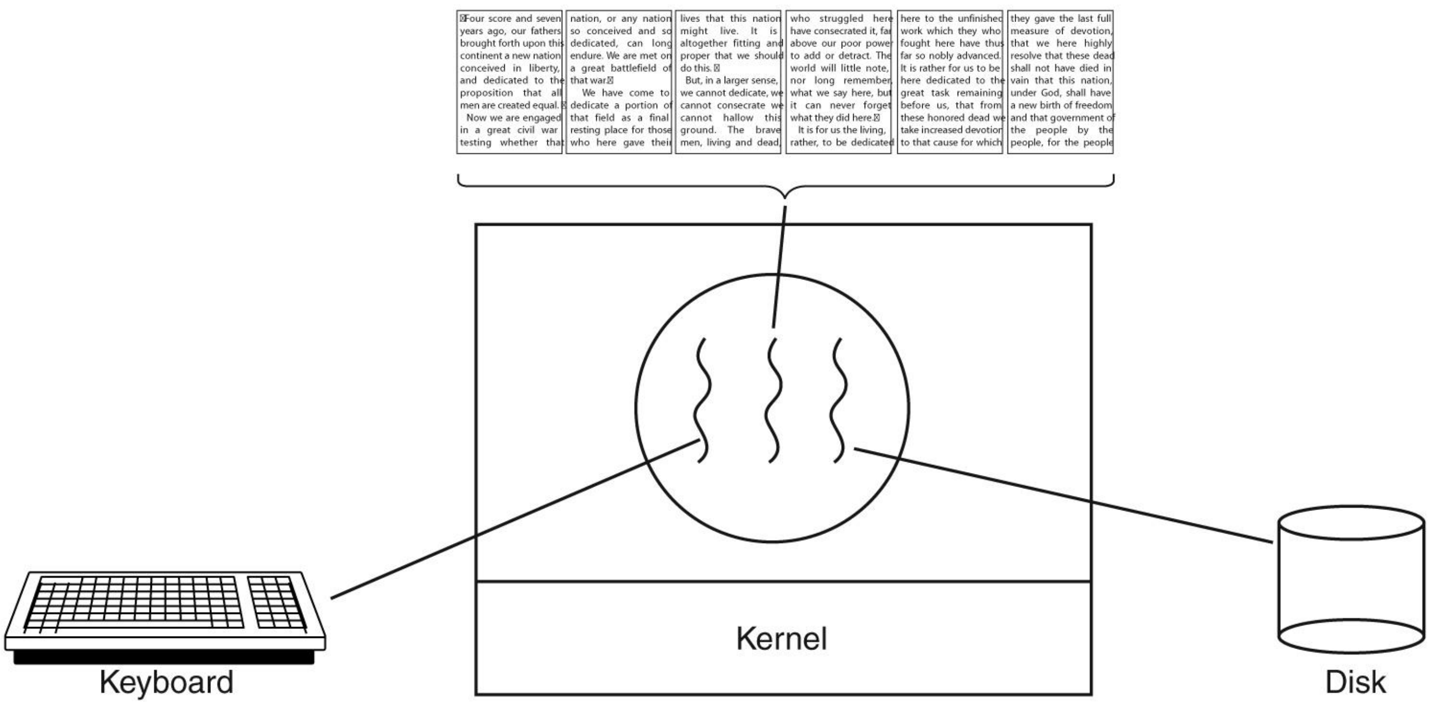
Threads

- Multiple threads of control within a process
- All threads of a process share the same address space.

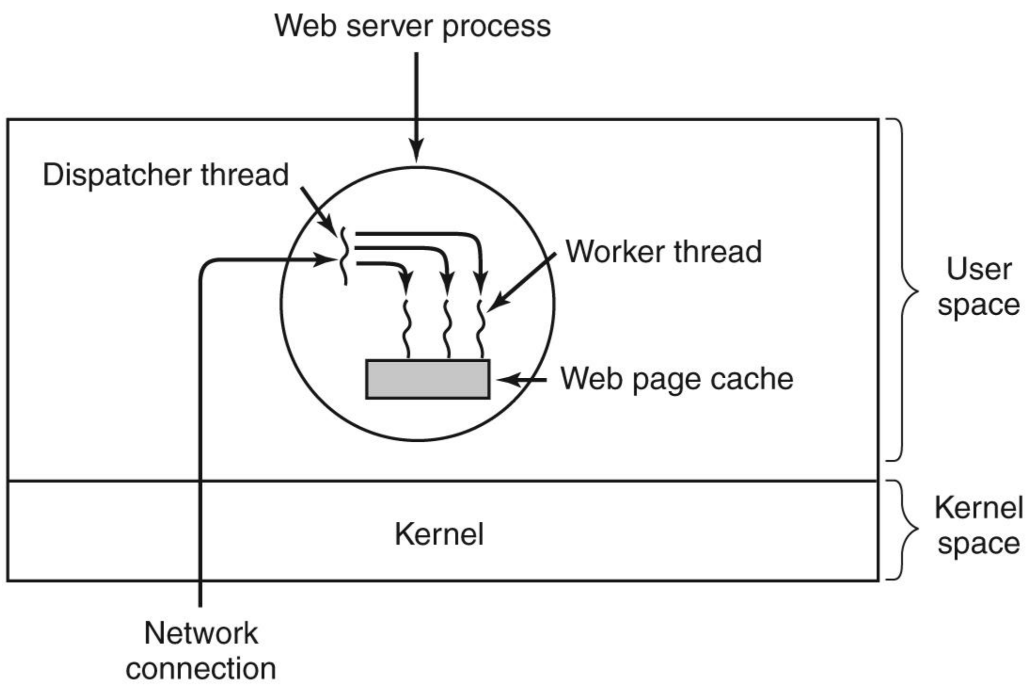
Why Threads?

- For some applications many activities can happen at once (i.e. concurrency)
  - With threads, programming becomes easier
  - Benefit applications with I/O and processing that can overlap
- Lighter weight than processes
  - Faster to create and restore

Example 1:
A Word Processor



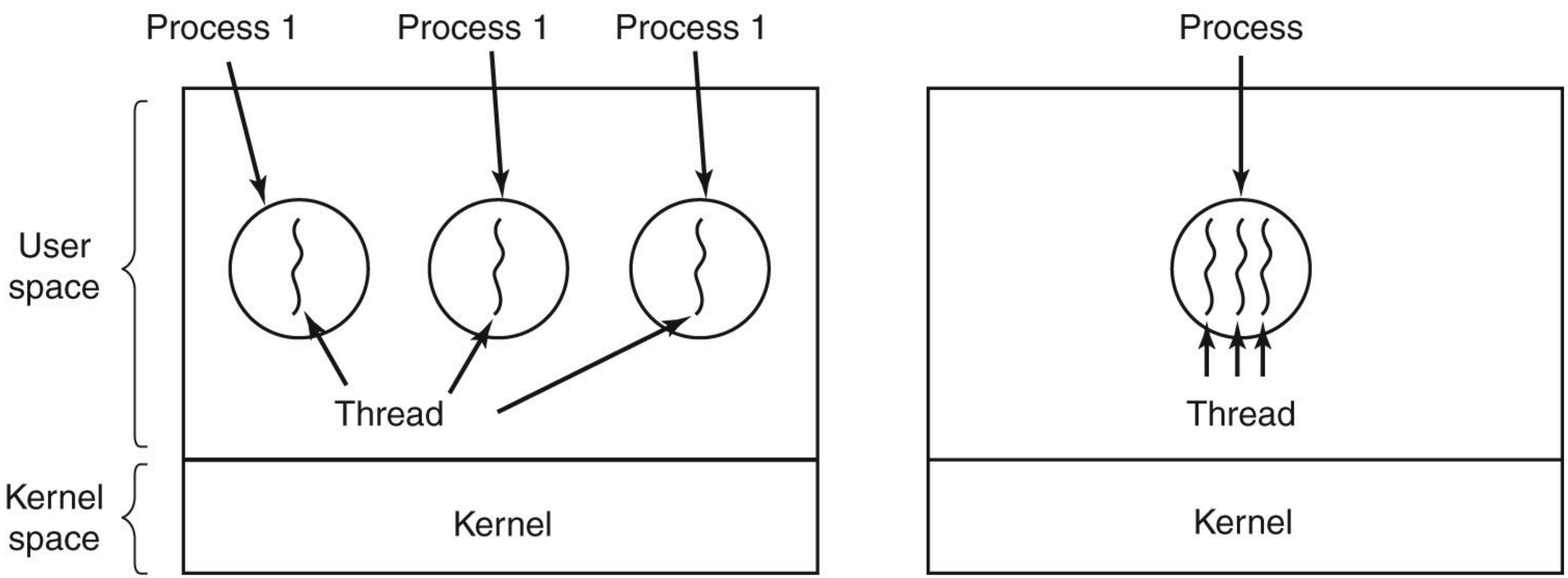
Example 2: Multithreaded Web Server



Processes vs Threads

- Process groups resources
- Threads are entities scheduled for execution on CPU
- No protections among threads (unlike processes) [Why?]
- Thread can be in any of several states: running, blocked, ready, and terminated

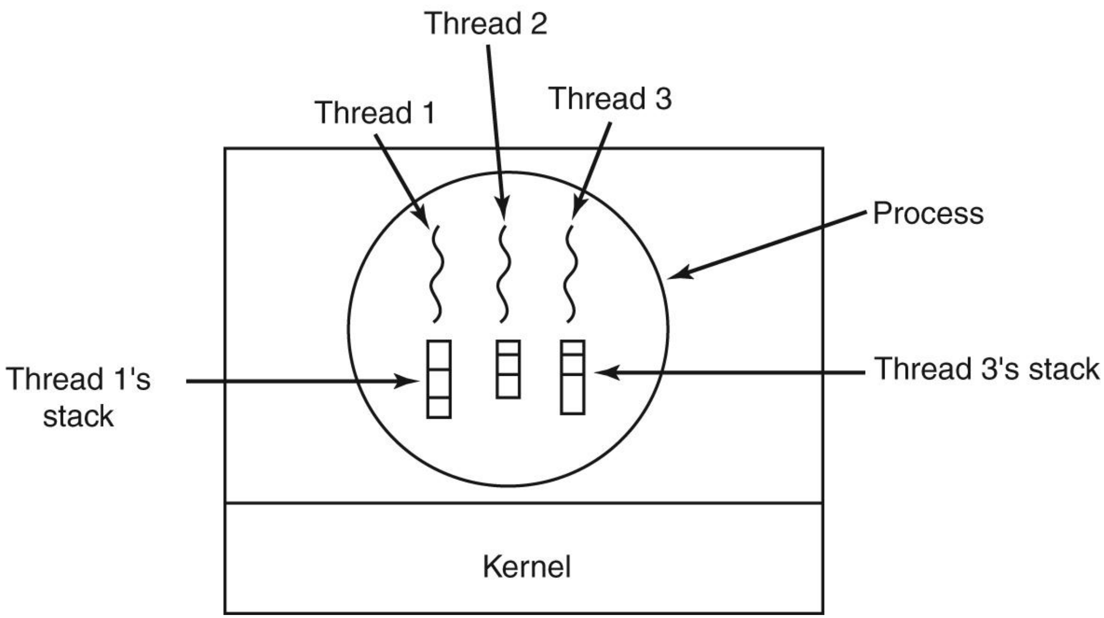
Per process items	**Per thread items**
Address space Global variables Open files Child processes Pending alarms Signals and signal handlers Accounting information	Program counter Registers Stack State



Process 1
Process 1
Process 1
User space
Thread
Kernel space
Kernel
Process
Thread
Kernel

(a)

(b)

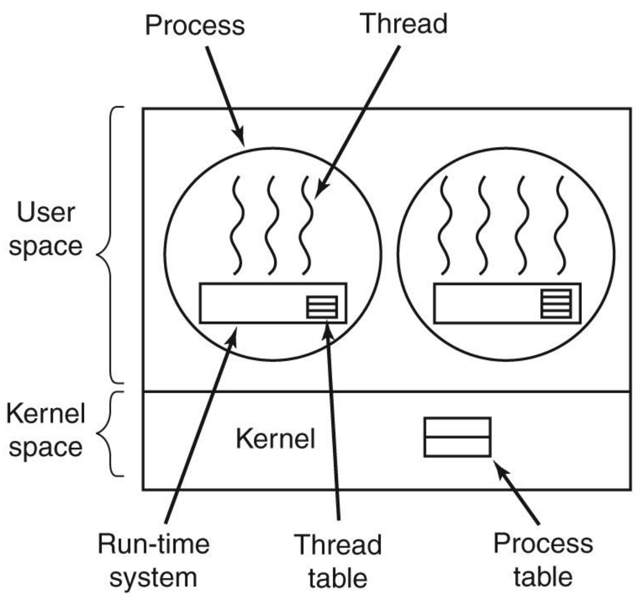


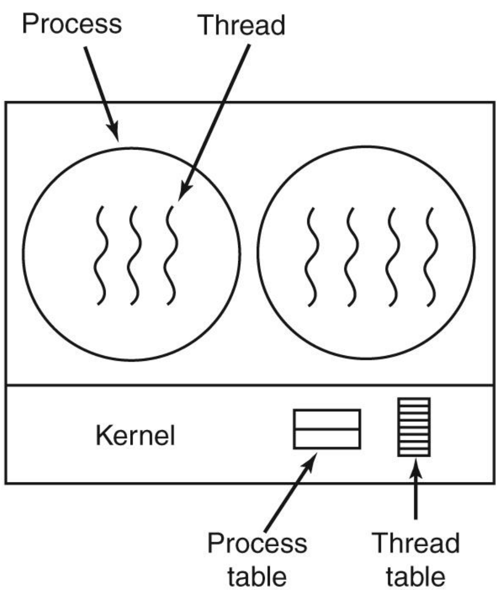
Each thread has its own stack.

Where to Put The Thread Package?

User space

Kernel space





Implementing Threads in User Space

- Threads are implemented by a library.
- Kernel knows nothing about threads.
- Each process needs its own private thread table.
- Thread table is managed by the runtime system.

Implementing Threads in User Space

Advantages

- Very fast thread scheduling
- Each process can have its own thread scheduling algorithm
- Scale better

Disadvantages

- Blocking system calls can block the whole process
- Page fault blocks the whole process
- No other thread of the process will ever run unless the running thread voluntarily gives up the CPU

Implementing Threads in Kernel Space

- Kernel knows about and manages the threads
- No thread management is needed by the runtime.
- Creating/destroying/(other thread related operations) a thread involves a system call

Implementing Threads in Kernel Space

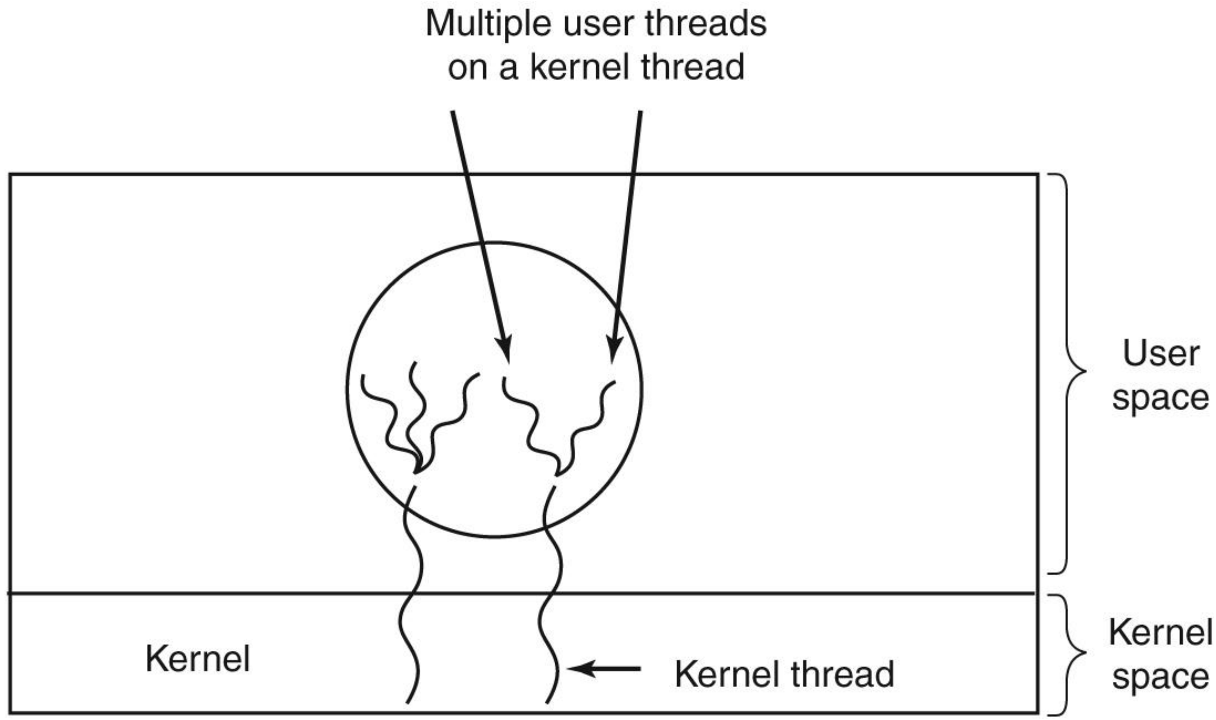
Advantages

- When a thread blocks (due to page fault or blocking system calls) the OS can execute another thread from the same process

Disadvantages

- Cost of system call is very high

Hybrid Implementation



Conclusions

- Processes is the most central concept in OS
- Process vs Thread
- Multiprogramming vs multithreading