Department of Physics,
Computer Science & Engineering

CPSC 410 – Operating Systems I

Process Description & Control

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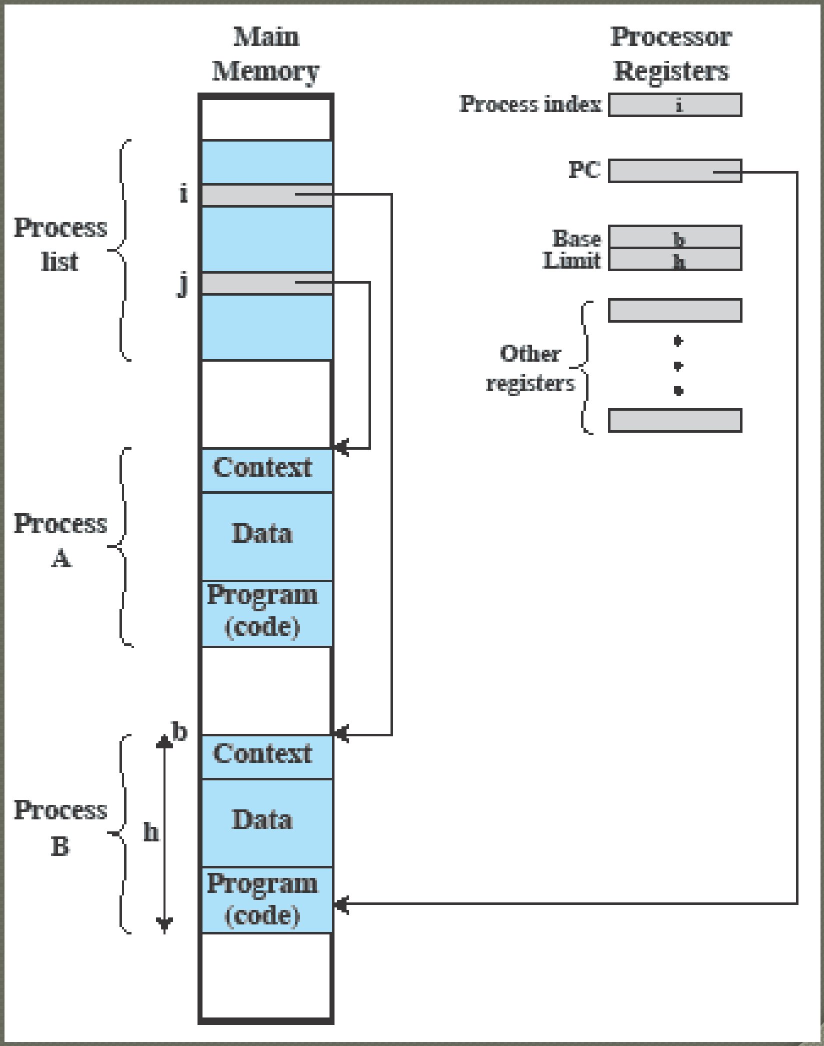
Adapted from original slides by Dr. Roberto A. Flores
Also from “CS 537 Introduction to Operating Systems” Arpaci-Dusseau

Chapter 3 Topics

- Everything about Processes
  - Control blocks
  - States
  - Description
  - Control
- OS Execution

Revisit - Process Management

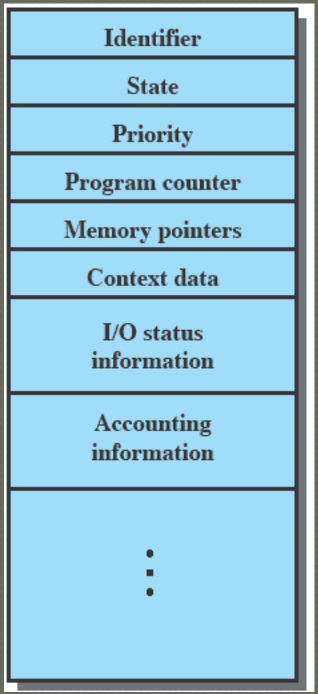
- Scheduler chooses a process to run (more later)
- Dispatcher runs it
- How? What's in the Process List?
- BTW this list is a simplification



Processes

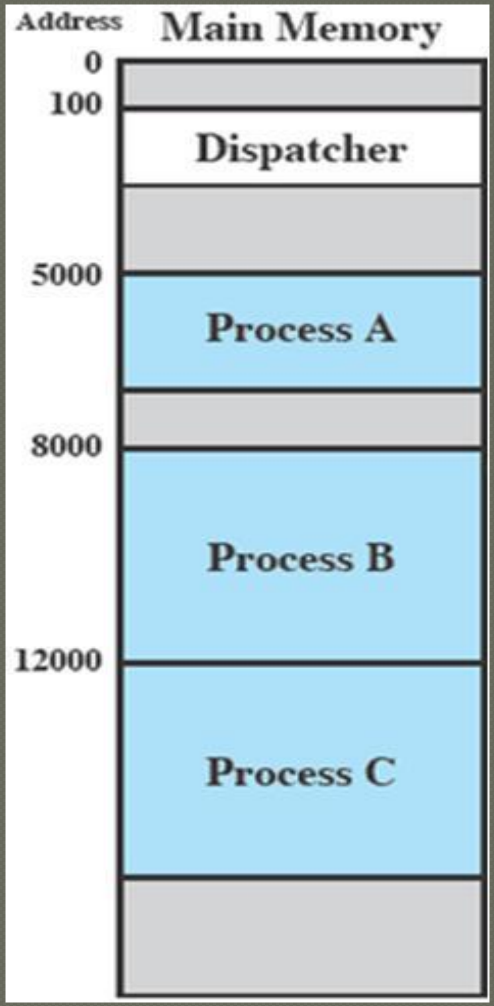
Control Blocks

- data structure created & managed by OS
  - Identifier: unique ID
  - State: (e.g., running, blocked)
  - Priority: relative to other processes
  - Program counter: address of next instruction
  - Memory pointers: to code & data
  - I/O status: I/O in use/pending
  - Accounting: CPU time used, IDs, …
- data to hold/restore process state on interrupt/resume
  - key to support multiprocessing



Processes

- Dispatcher
  - Program that switches processes in/out of the CPU



Processes

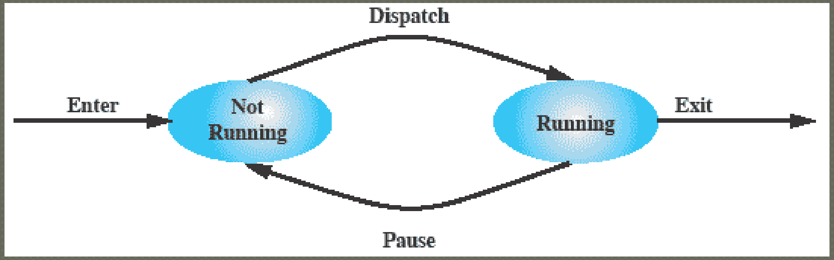
- **States**
  - Trace
    - Instructions executed by a process
    - In multiprogramming:
      - interleaving of instructions as processes alternate using the CPU
  - The pale blue lower right is dispatcher code
- Process switches because of Interrupts (timer, I/O)

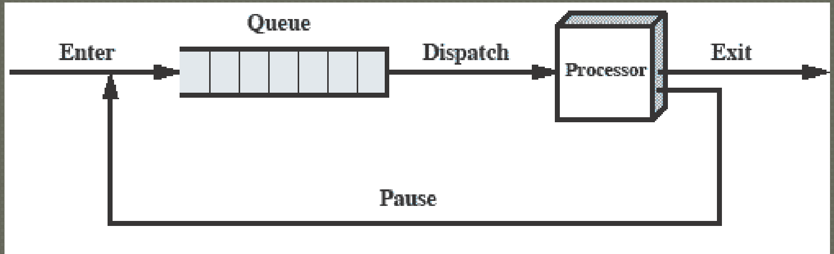
(a) Trace of Process A	(b) Trace of Process B	(c) Trace of Process C
5000	8000	12000
5001	8001	12001
5002	8002	12002
5003	8003	12003
5004		12004
5005		12005
5006		12006
5007		12007
5008		12008
5009		12009
5010		12010
5011		12011

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

Processes

- States (2 states)
  - One CPU
  - Round-robin (timeout)
  - Running: CPU time!
  - Not running: or not





(b) Queuing diagram

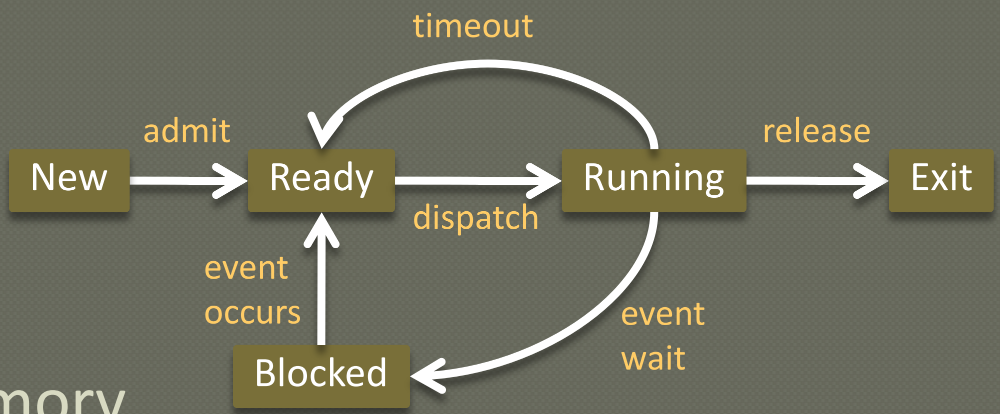
- Where do processes come from?
- When do they stop?

Processes

- Where do processes come from? (start)
  - New batch job: Next job in the incoming batch stream
  - Interactive logon: User in terminal logs in
  - OS service: OS-provided service (e.g., print spooler)
  - Spawned by process: uses parallelism (parent spawns child)
- When do they end? (termination)
  - Normal
    - Job finishes, user logs off, OS shutting down, etc.
  - Abnormal
    - Timeout: running too long
    - Resource error: out of memory, I/O device unresponsive, deadlock
    - Runtime error: arithmetic operation, uninitialized variable
    - Authorization error: memory out of bounds, resource/instruction privilege

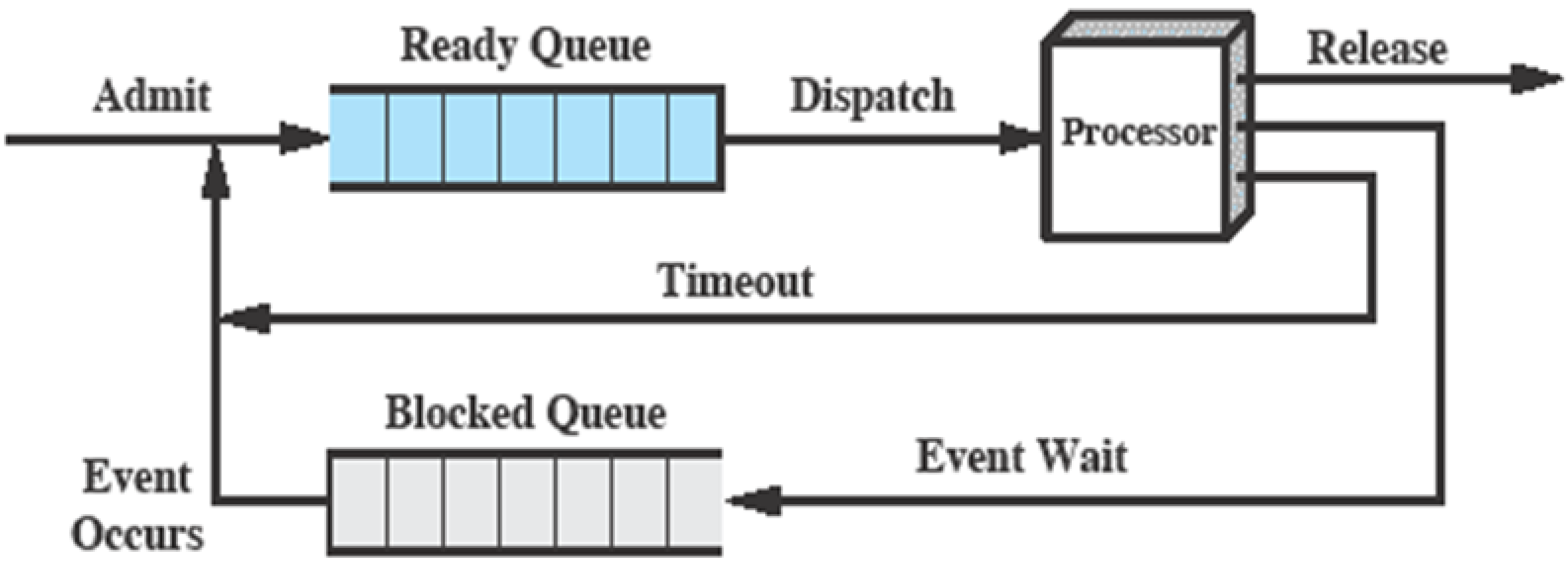
Processes

States (5 states)



- New: not yet in memory
- Ready: awaiting its turn
- Running: CPU time!
- Blocked: waiting for I/O
- Exit: done & gone

Using Two Queues

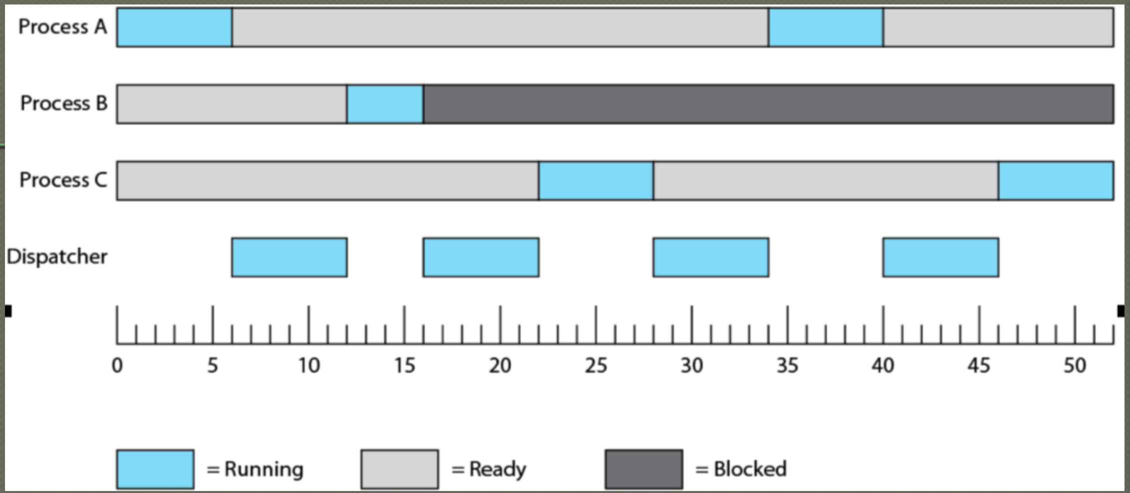


(a) Single blocked queue

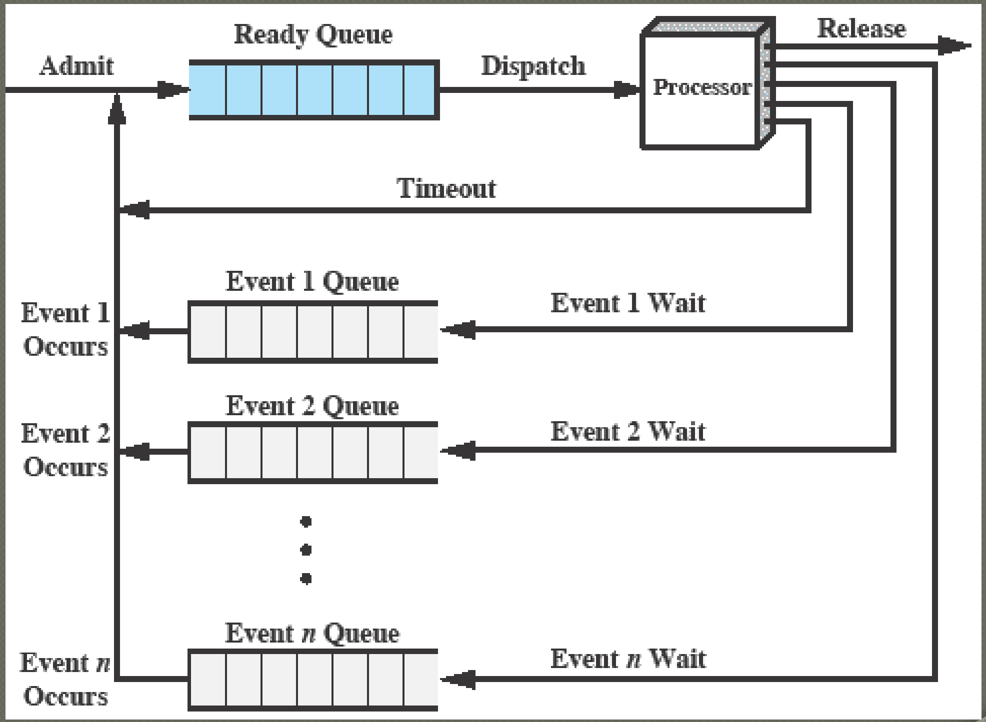
Control blocks
States
Description
Control

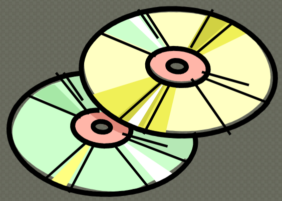
States (5 states)

- e.g., Processes A, B & C



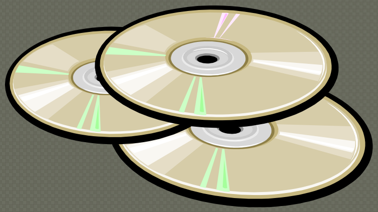
- Multiple block queues (1 per I/O device)





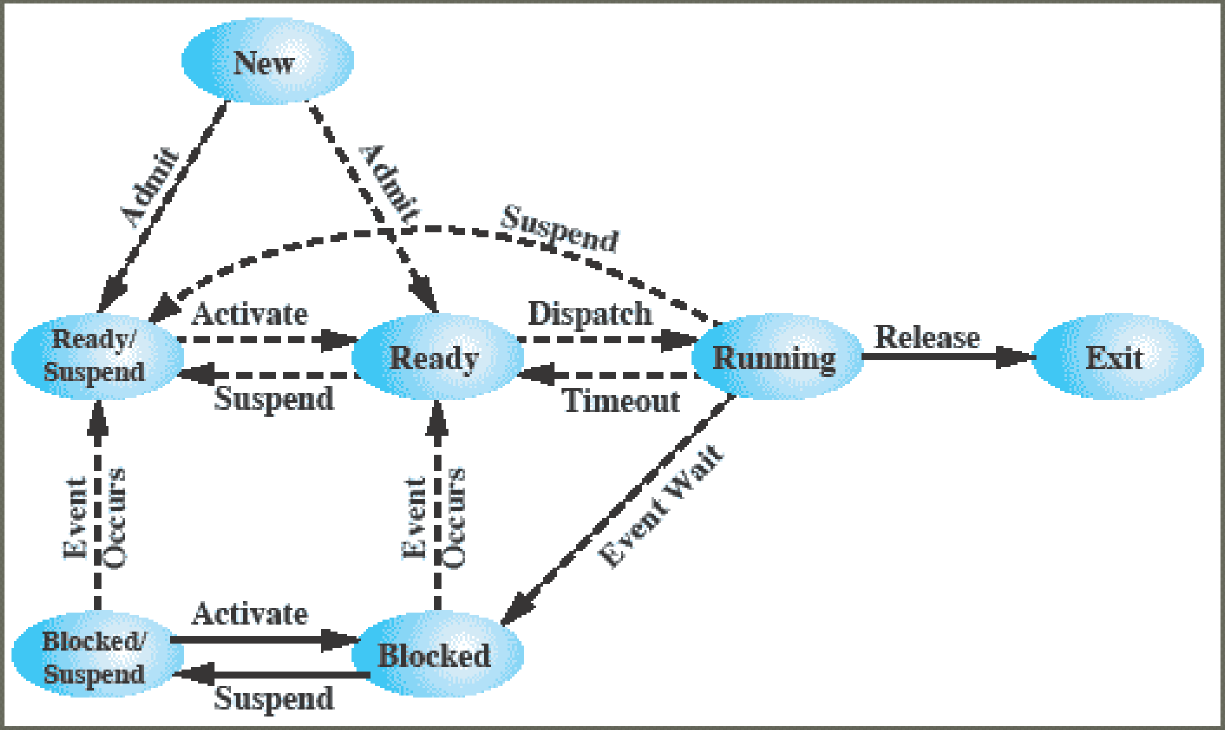
Suspended Processes

- Swapping
  - involves moving part of all of a process from main memory to disk
  - when none of the processes in main memory is in the Ready state, the OS swaps one of the blocked processes out on to disk into a suspend queue



Processes

- States (7 states)
  - What if not all processes fit in memory at once?
    - Suspended: when a process has been swapped to disk



Structure of Process

Images in Virtual Memory

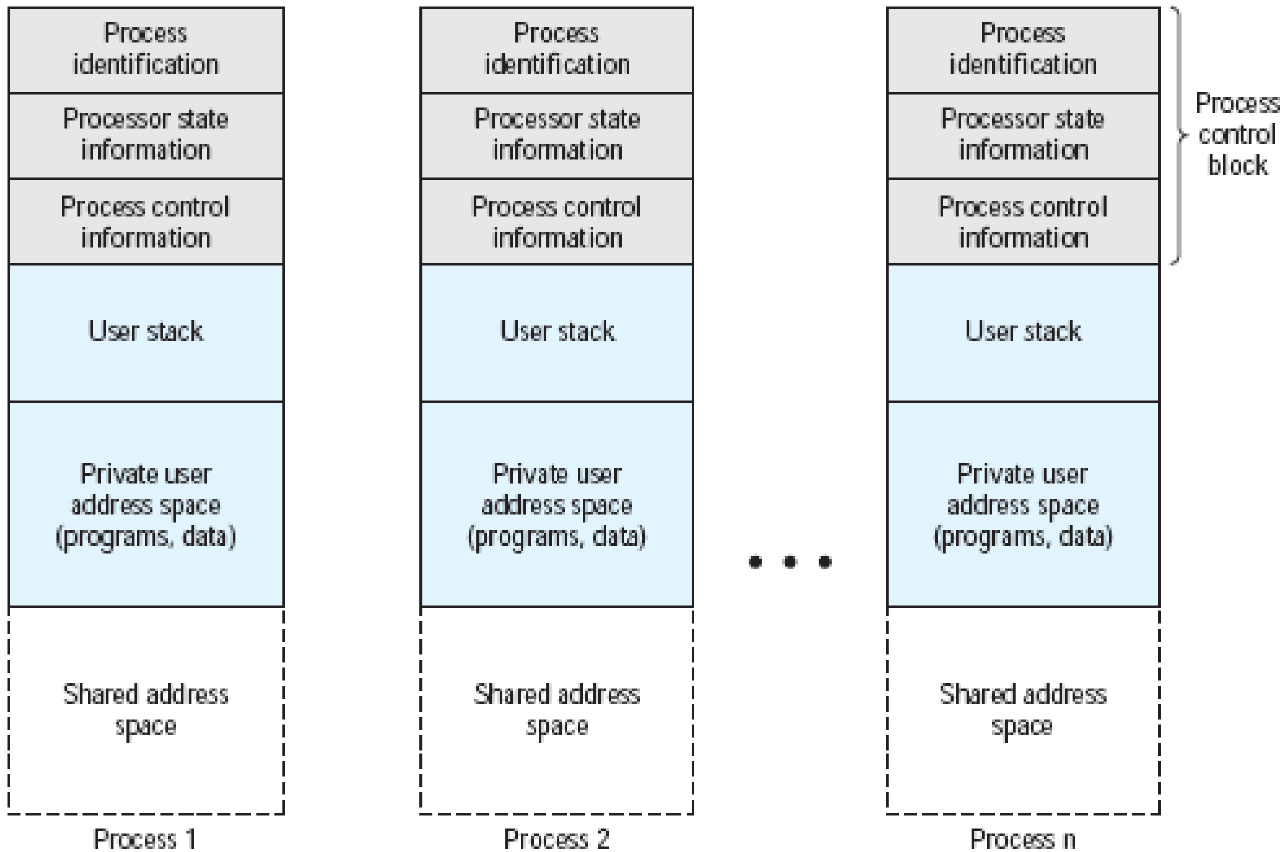


Figure 3.13 User Processes in Virtual Memory

Process List Structures

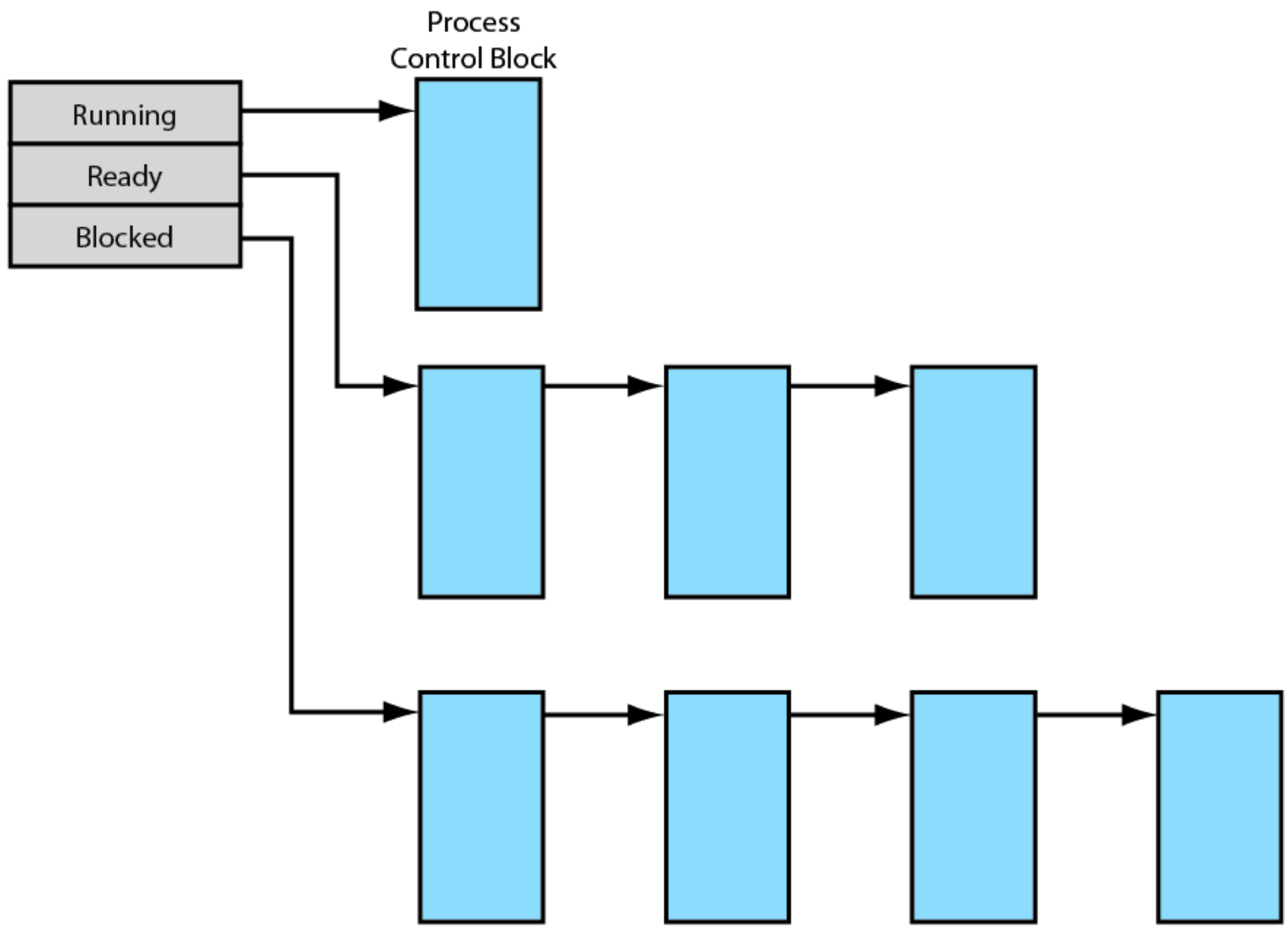


Figure 3.14 Process List Structures

Processes

- Process tables
  - keep data about each process (process image)
    - user data: modifiable part of program, e.g., variables
    - user program: program to execute
    - stack: stores method calls & parameters
    - process control block (PCB): data OS uses to control process
      - process identification: process/parent/user ID
      - processor state information: user/control registers, stack pointers
      - process control information: scheduling, inter-process comms, …
  - reference (directly/indirectly) memory, I/O & file tables

Processes

Process tables

Process identification

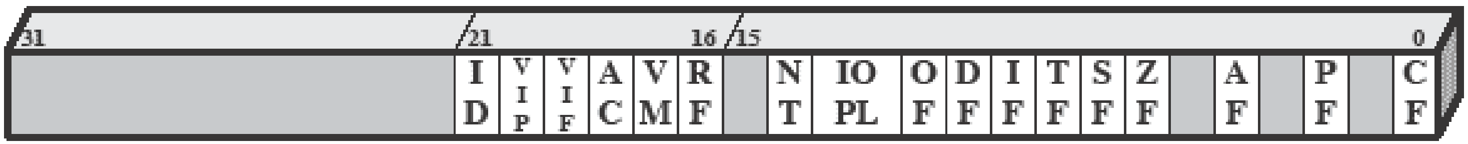
- Each process has a unique ID
- IDs are used for reference:
  - in other tables
  - in inter-process communication
  - when a parent spawns a child process

- process identification: process/parent/user ID
- processor state information: user/control registers, stack pointers
- process control information: scheduling, inter-process comms, …

- reference (directly/indirectly) memory, I/O & file tables

Process state information

- stack pointers
- user-visible registers
- control & status registers
  - program status word (PSW), e.g., EFLAGS in x86 processors



ID	=	Identification flag	DF	=	Direction flag
VIP	=	Virtual interrupt pending	IF	=	Interrupt enable flag
VIF	=	Virtual interrupt flag	TF	=	Trap flag
AC	=	Alignment check	SF	=	Sign flag
VM	=	Virtual 8086 mode	ZF	=	Zero flag
RF	=	Resume flag	AF	=	Auxiliary carry flag
NT	=	Nested task flag	PF	=	Parity flag
IOPL	=	I/O privilege level	CF	=	Carry flag
OF	=	Overflow flag			

- processor state information: user/control registers, stack pointers
- process control information: scheduling, inter-process comms, …

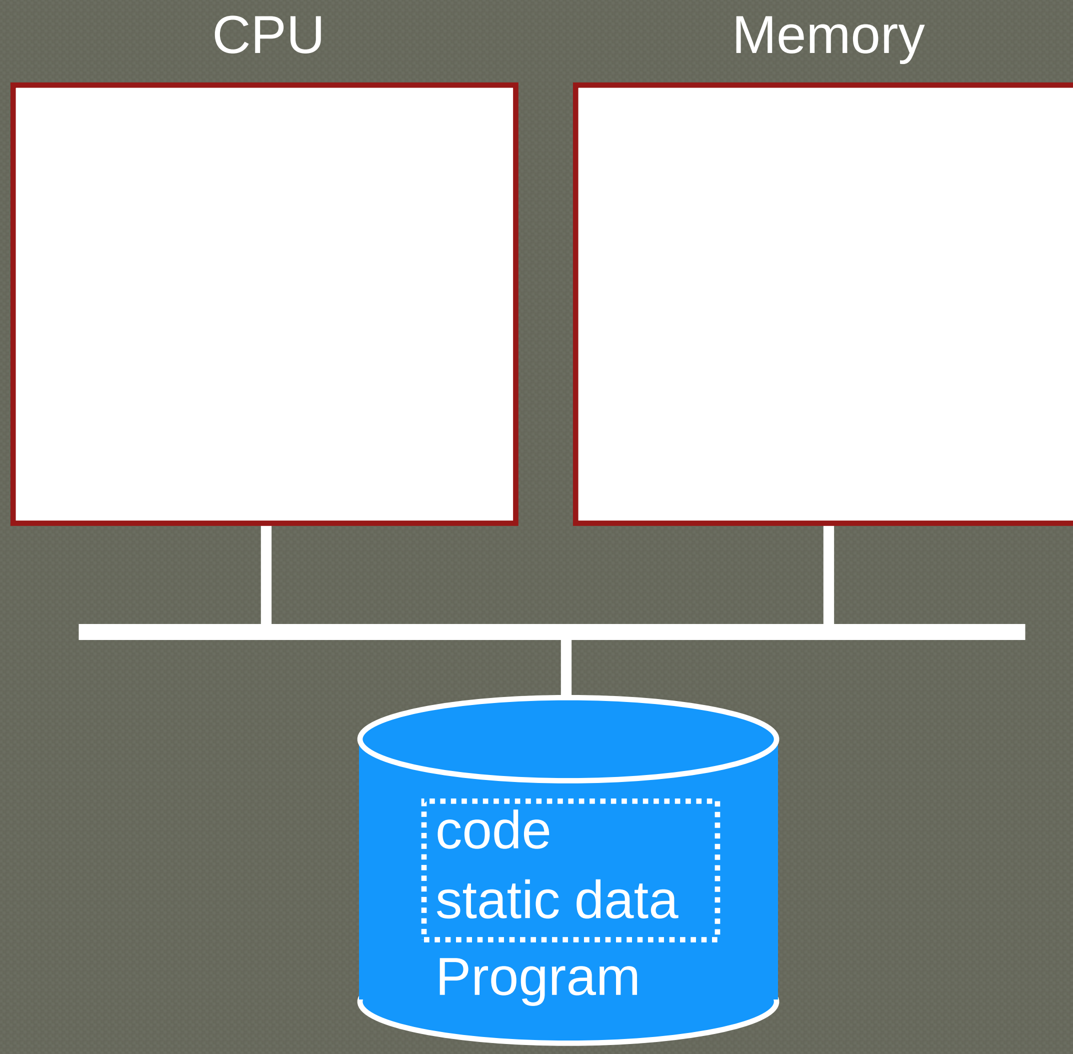
- reference (directly/indirectly) memory, I/O & file tables

Processes

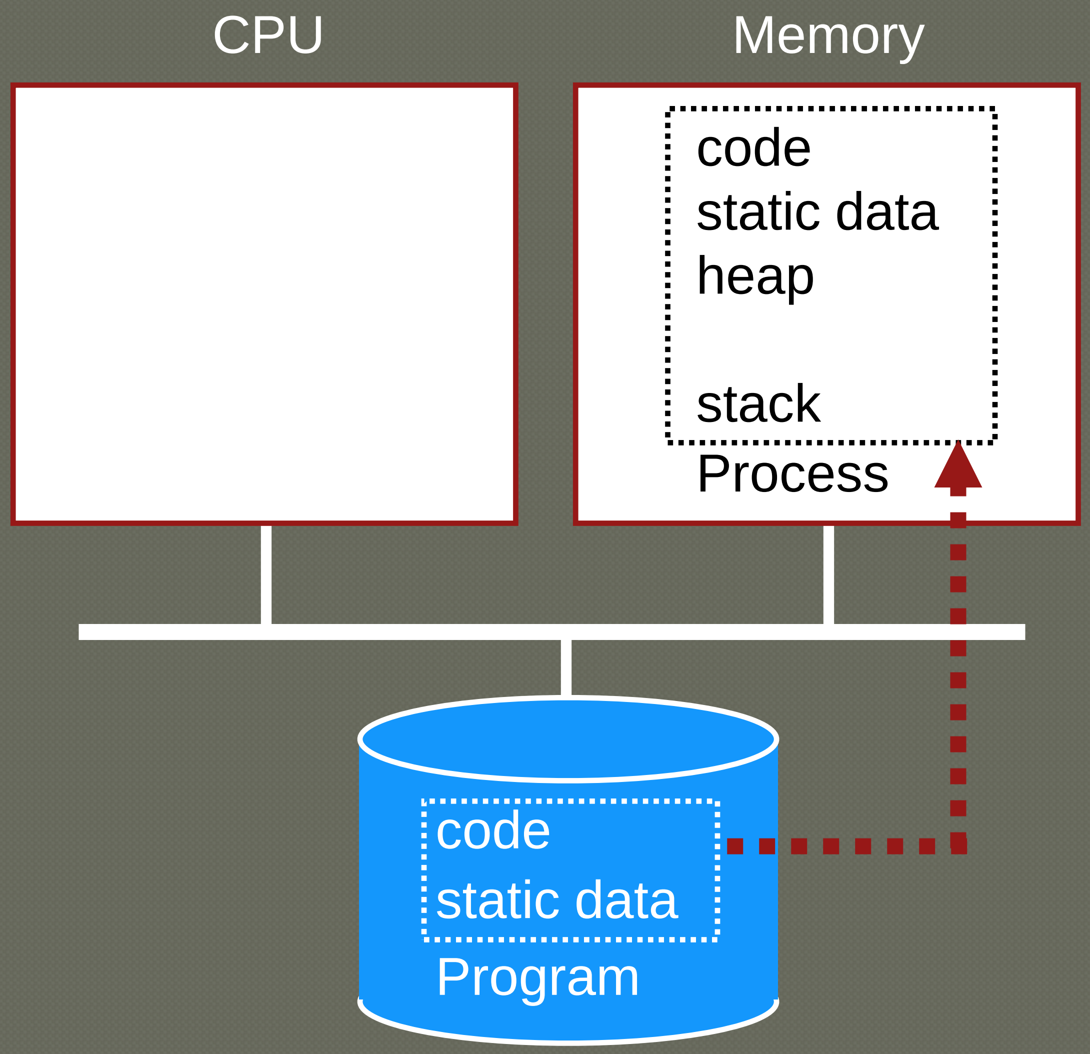
Control

- Process creation
  - What does OS do when a process is created?
    - assigns a new unique ID
    - allocates space for the process in memory
    - initializes its process control block & sets it in place (e.g. in process list)

Process Creation



Process Creation



Processes

Dispatch Mechanism

Process is running- how to switch to other process?

Processes

Dispatch Mechanism

Process is running- how to switch to other process?

OS runs dispatch loop

```
while (1) {
        run process A for some time-slice
        stop process A and save its context
        load context of another process B
}
```

Context-switch

Question 1: How does dispatcher gain control?

Question 2: What execution context must be saved and restored?

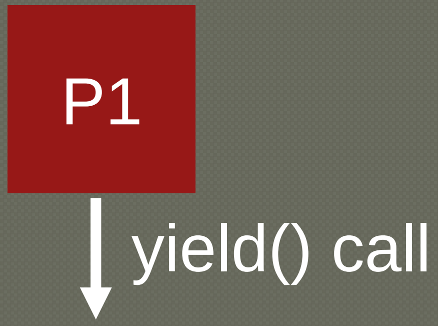
Processes

Q1: How does Dispatcher get CONTROL?

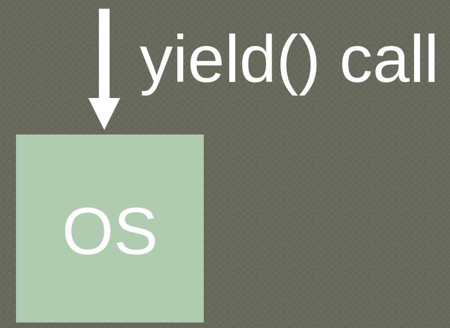
Option 1: Cooperative Multi-tasking

- Trust process to relinquish CPU to OS through traps
  - Examples: System call, page fault (access page not in main memory), or error (illegal instruction or divide by zero)
  - Provide special yield() system call

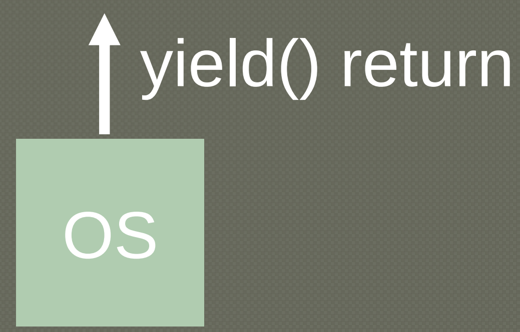
Cooperative Approach



Cooperative Approach

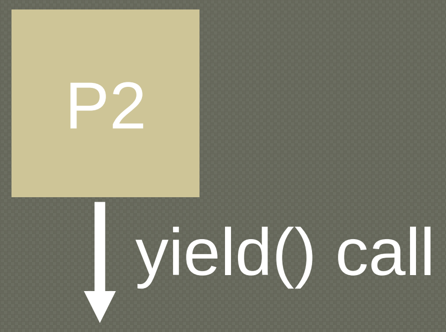


Cooperative Approach



Cooperative Approach

Cooperative Approach



Processes

Q1: How does Dispatcher get CONTROL?

- Problem with cooperative approach? YES
- Disadvantages: Processes can misbehave
  - By avoiding all traps and performing no I/O, can take over entire machine
  - Only solution: Reboot (windows 95)!
- Not performed in modern operating systems

Control blocks
States
Description
Control

Processes

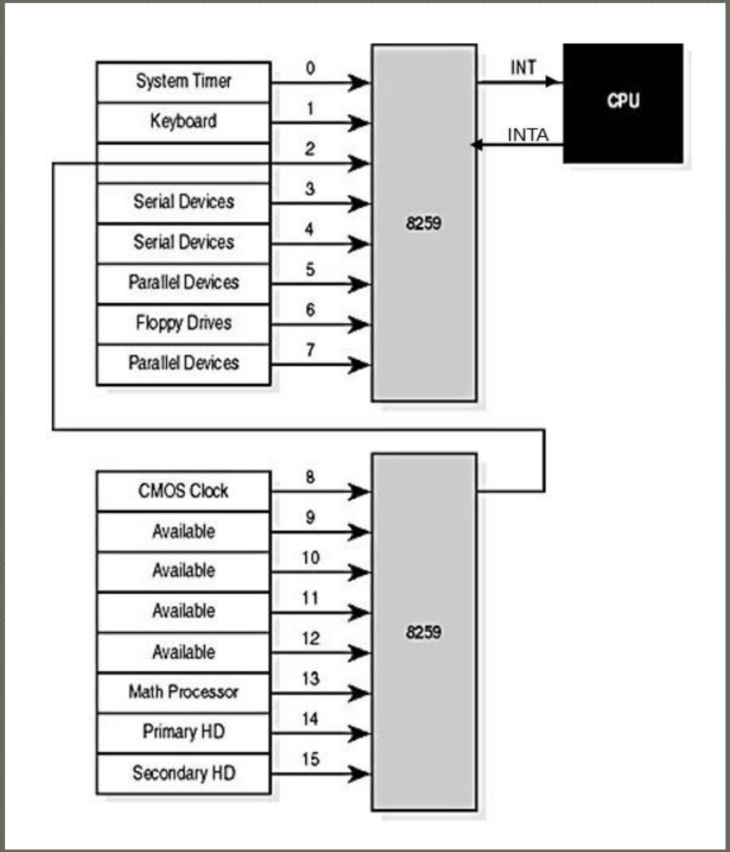
Q1: How does Dispatcher get CONTROL?

Option 2: True Multi-tasking

- Guarantee OS can obtain control periodically
- Enter OS by enabling periodic alarm clock
  - Hardware generates timer interrupt (CPU or separate chip)
  - Example: Every 10ms
- User must not be able to mask timer interrupt
- Dispatcher counts interrupts between context switches
  - Example: Waiting 20 timer ticks gives 200 ms time slice
  - Common time slices range from 10 ms to 200 ms

Interrupts-HW- timer example

- 8259 (Programmable interrupt controller or PIC) relays up to 8 interrupt to CPU
- Devices raise interrupts by an ‘interrupt request’ (IRQ)
- CPU acknowledges and queries the 8259 to determine which device interrupted (int#)
- Priorities can be assigned to each IRQ line
- 8259s can be cascaded to support more interrupts



Processes

What context to save?

Dispatcher must track context of process when not running

- Save context in process control block (PCB)

What information is stored in PCB?

- PID
- Process state (I.e., running, ready, or blocked)
- Execution state (all registers, PC, stack ptr)
- Scheduling priority
- Accounting information (parent and child processes)
- Credentials (which resources can be accessed, owner)
- Pointers to other allocated resources (e.g., open files)

Requires special hardware support

- Hardware saves process PC and PSR on interrupts

Operating System	Hardware	Program
		Process A …

Operating System	Hardware	Program
		Process A …
	timer interrupt save regs(A) to k-stack(A) move to kernel mode jump to trap handler	

Operating System	Hardware	Program
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Handle the trap Call **switch()** routine save regs(A) to proc-struct(A) restore regs(B) from proc-struct(B) switch to k-stack(B) return-from-trap (into B)		

Operating System	Hardware	Program
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	restore regs(B) from k-stack(B) move to user mode jump to B’s IP	

Operating System	Hardware	Program
		Process A …
	timer interrupt save regs(A) to k-stack(A) move to kernel mode jump to trap handler	
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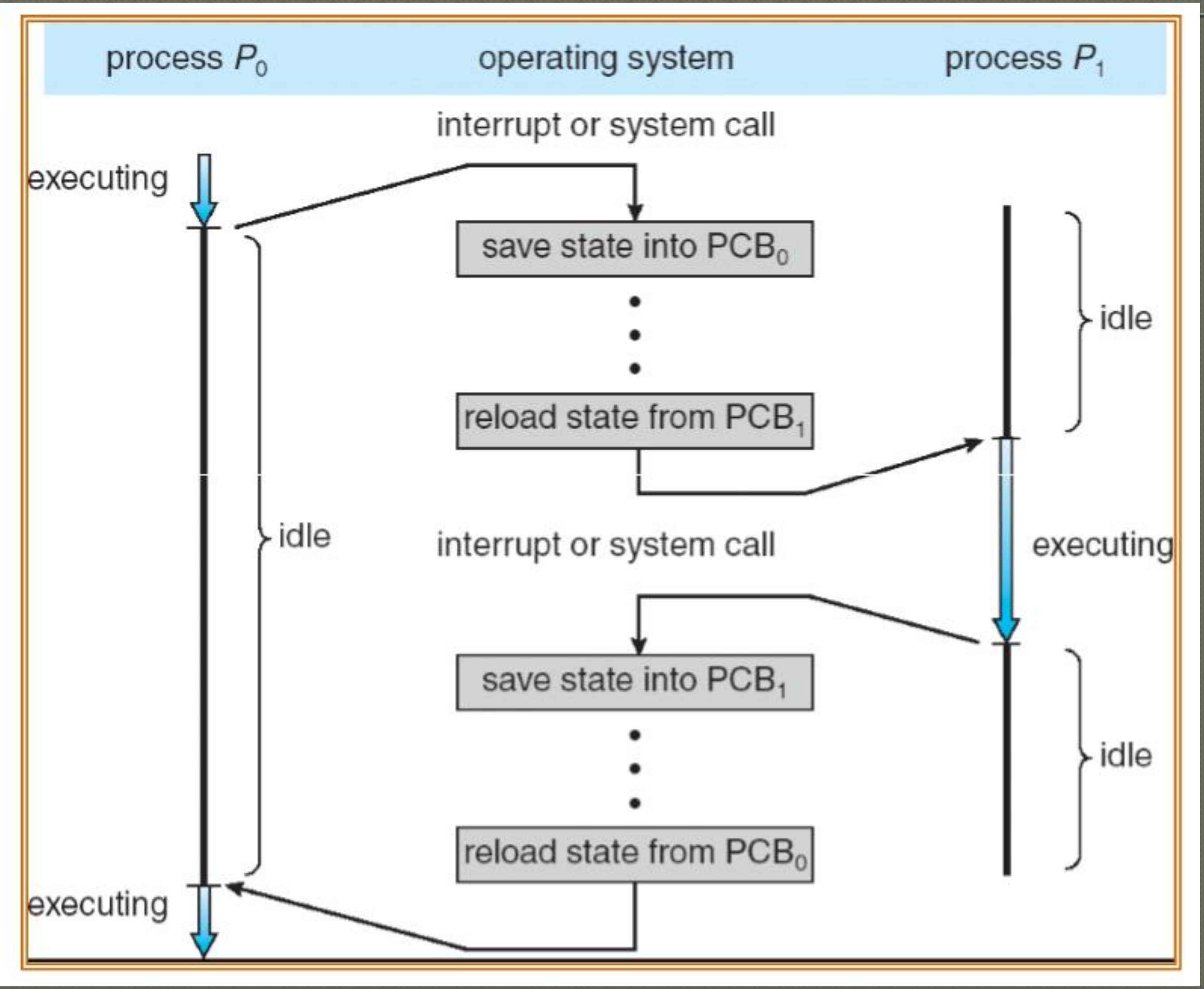
	restore regs(B) from k-stack(B) move to user mode jump to B's IP	
		Process B …

Interrupts



process P_0
operating system
process P_1
interrupt or system call
executing
save state into PCB_0
idle
reload state from PCB_1
idle
interrupt or system call
executing
save state into PCB_1
idle
reload state from PCB_0
executing

Change of Process State

- The steps in a full process switch are:

save the context of the processor

update the process control block of the process currently in the Running state

move the process control block of this process to the appropriate queue

select another process for execution

update the process control block of the process selected

update memory management data structures

restore the context of the processor to that which existed at the time the selected process was last switched out

If the currently running process is to be moved to another state (Ready, Blocked, etc.), then the OS must make substantial changes in its environment

Chapter 3 Topics

- Everything about Processes
  - Elements
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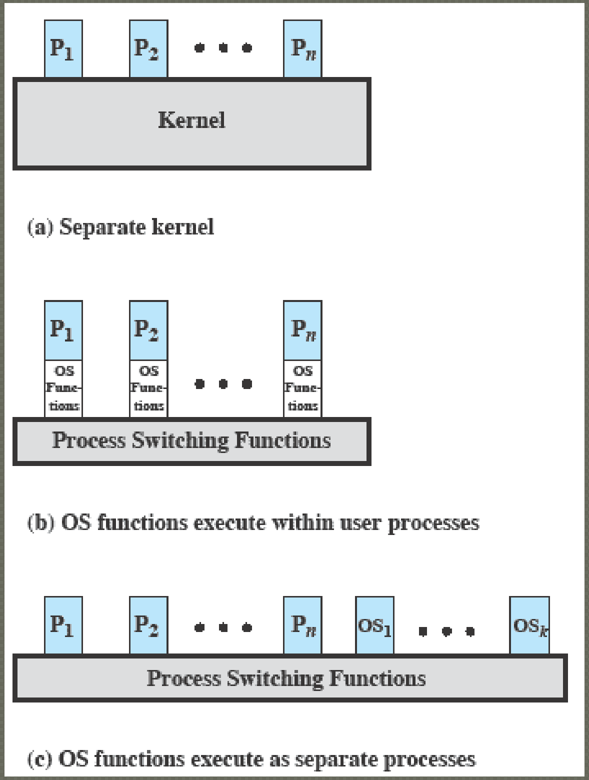
OS Execution

- OS is software, right?
  - How is it different from just another process?
  - How is it controlled?

a) Non-process Kernel
  - Processes are processes.
    The kernel is the kernel.

b) Execution within user processes
  - OS is a bare process
    switching mechanism
  - OS routines are linked to
    user programs (OS data is shared)

c) Process-based OS
  - OS routines run as independent processes
  - Modular approach for parallelism (e.g., OS in one CPU, user processes in another)



Execution *Within* User Processes

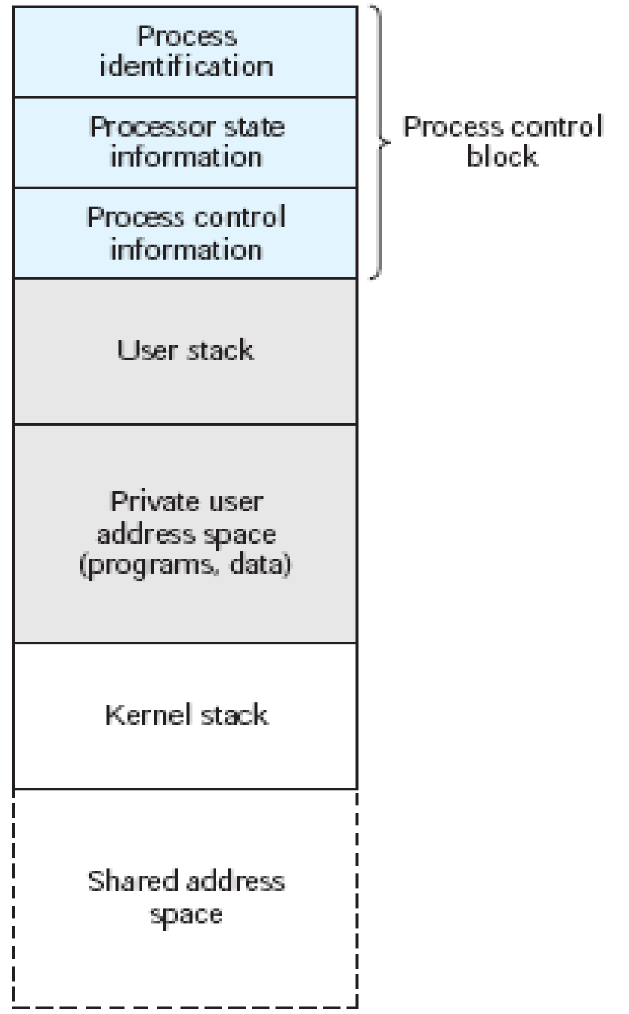


Figure 3.16 Process Image: Operating System Executes within User Space

Chapter 3 Topics

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Done!