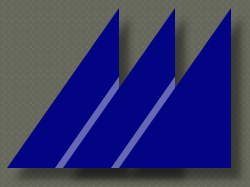

Department of Physics,
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CPSC 410 – Operating Systems I

Process Description & Control

Keith Perkins

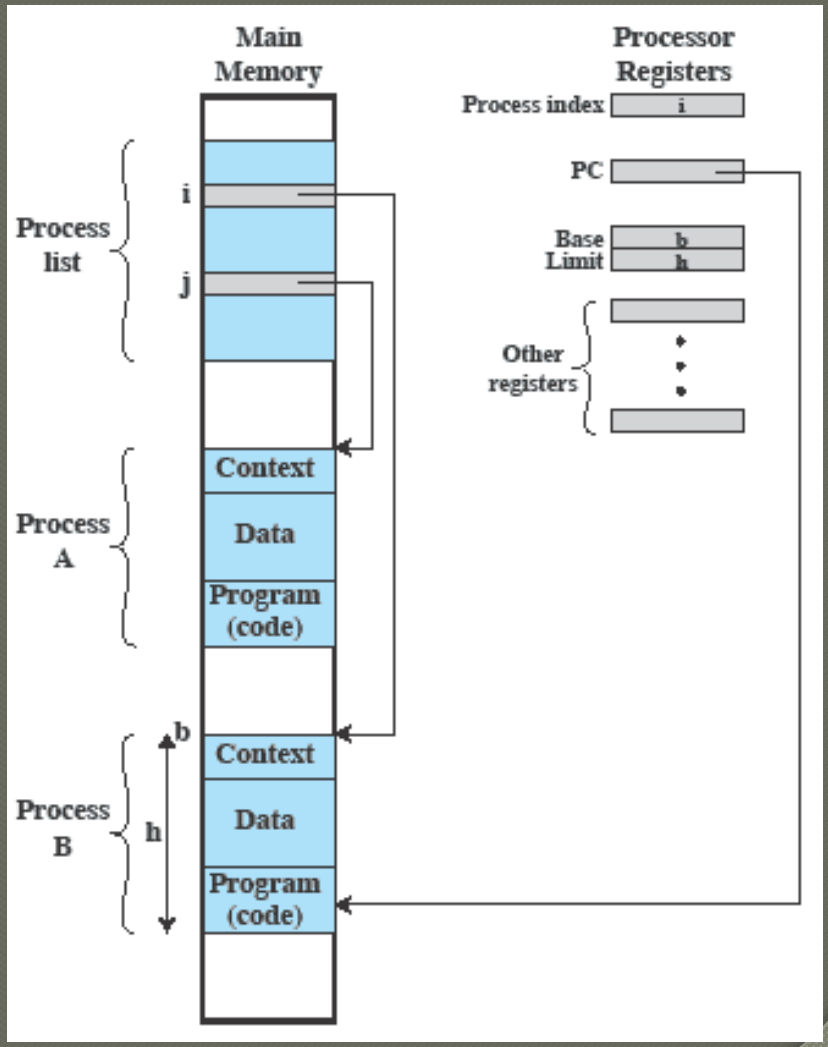
Adapted from original slides by Dr. Roberto A. Flores
Also from “CS 537 Introduction to Operating Systems” Arpaci-Dusseau

Chapter 3 Topics

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

Revisit - Process Management

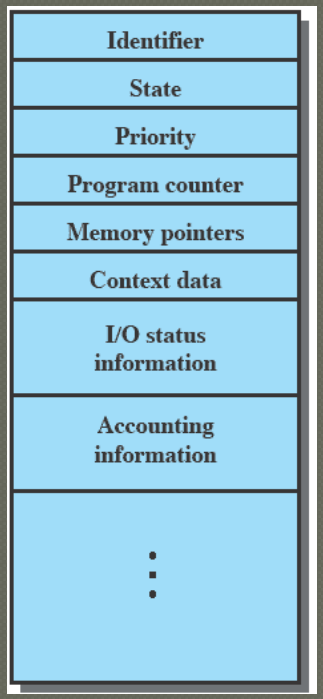
- Scheduler chooses a process to run (more later)
- Dispatcher runs it
- How? What's in the Process List?
- BTW this list is a simplification



Processes

Control Blocks

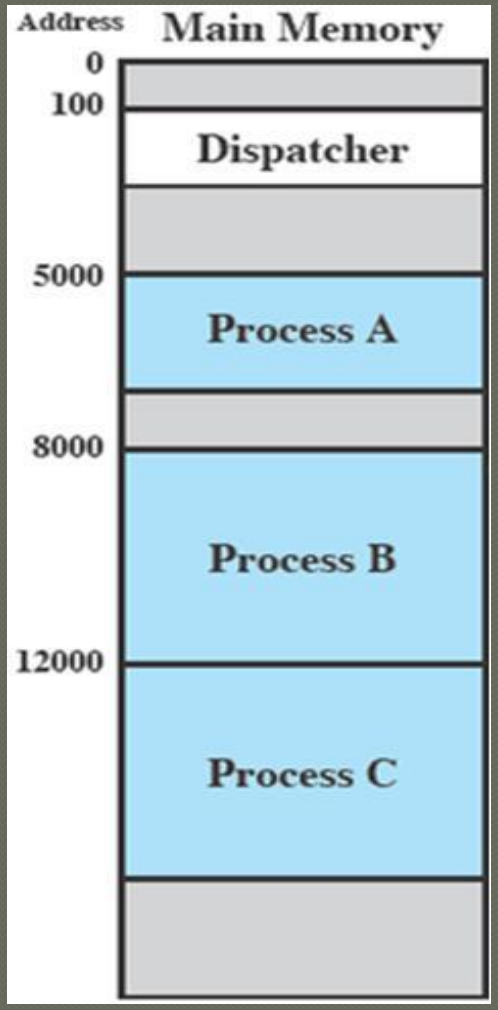
- data structure created & managed by OS
  - Identifier: unique ID
  - State: (e.g., running, blocked)
  - Priority: relative to other processes
  - Program counter: address of next instruction
  - Memory pointers: to code & data
  - I/O status: I/O in use/pending
  - Accounting: CPU time used, IDs,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



Control blocks
States
Description
Control

Processes

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



Process dispatching mechanism

OS dispatching loop:

```
while(1) {
    run process for a while;
    save process state;
    next process = schedule (ready processes);
    load next process state;
}
```

Q1: how to gain control?

Q2: what state must be saved?

Q3: where to find processes?

Processes

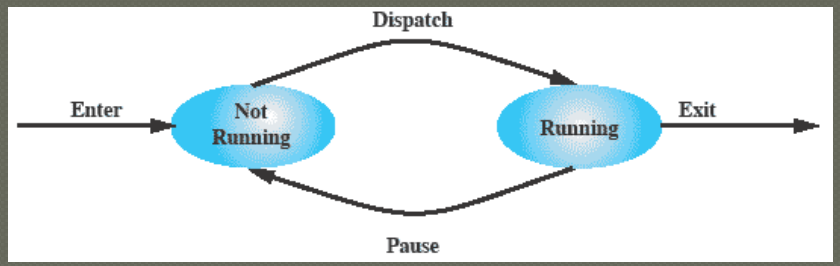
- States
  - Trace
    - Instructions executed by a process
    - In multiprogramming:
      - interleaving of instructions as processes alternate using the CPU
  - The pale blue lower right is dispatcher code
  - Process switches because of Interrupts (timer, I/O)

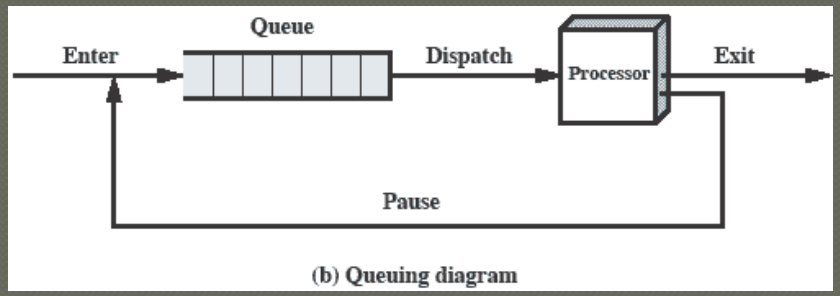
(a) Trace of Process A	(b) Trace of Process B	(c) Trace of Process C
5000	8000	12000
5001	8001	12001
5002	8002	12002
5003	8003	12003
5004		12004
5005		12005
5006		12006
5007		12007
5008		12008
5009		12009
5010		12010
5011		12011

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

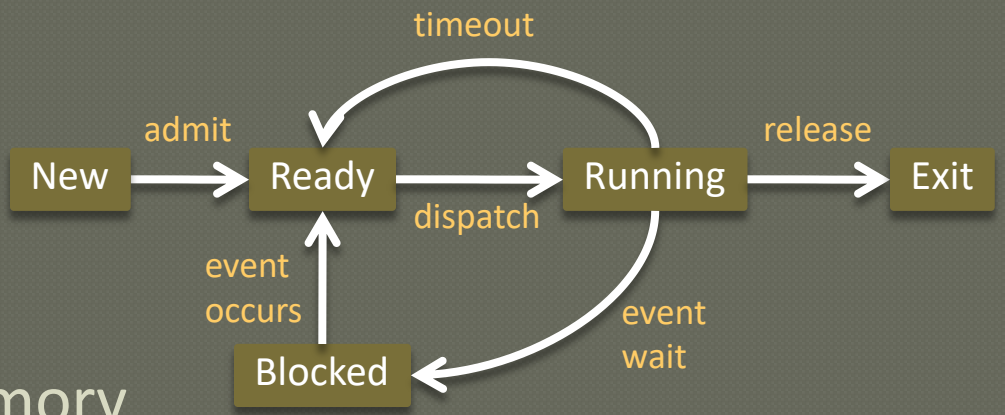
- Where do processes come from?
- When do they stop?

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

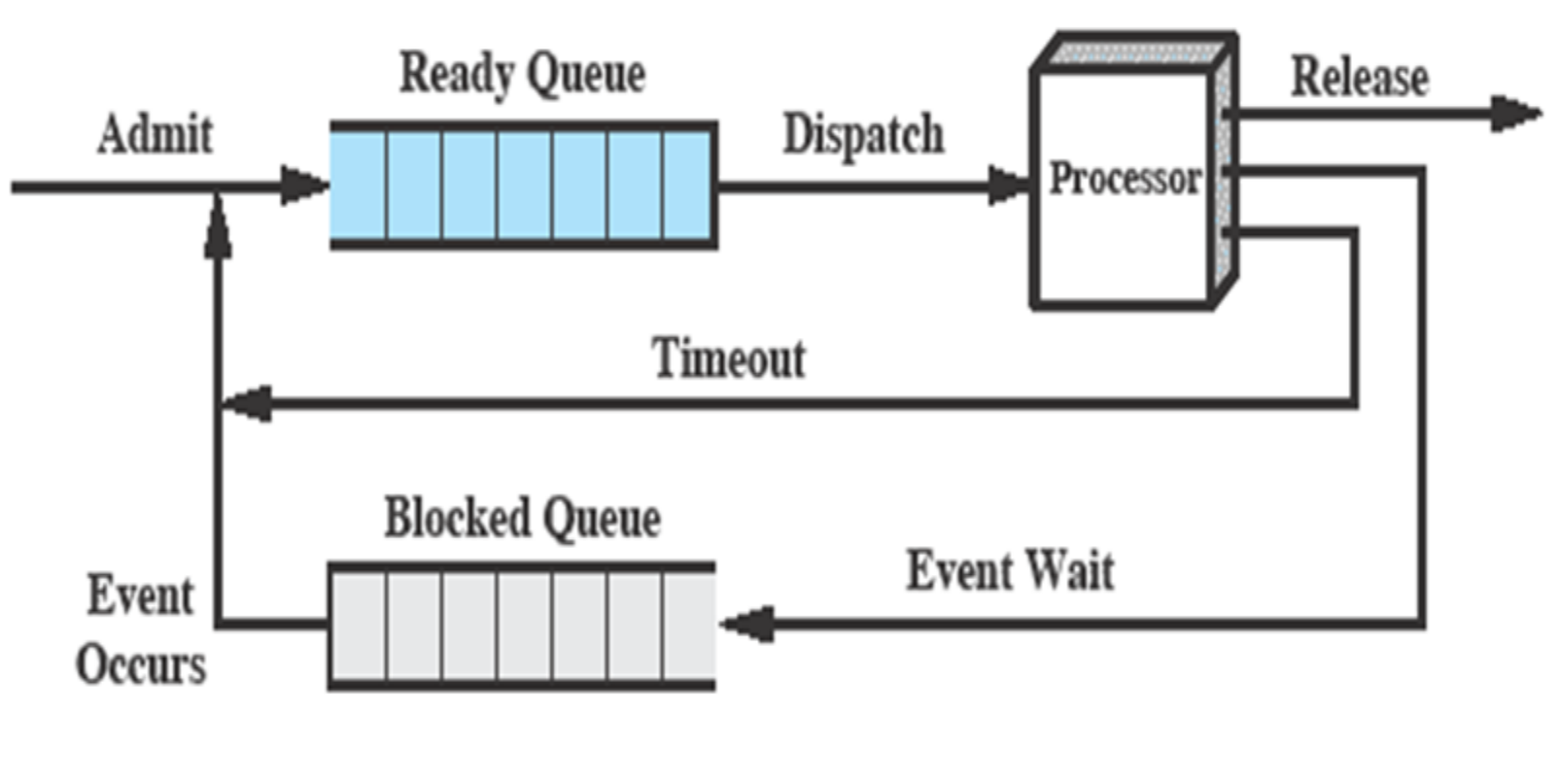
Processes

- States (5 states)



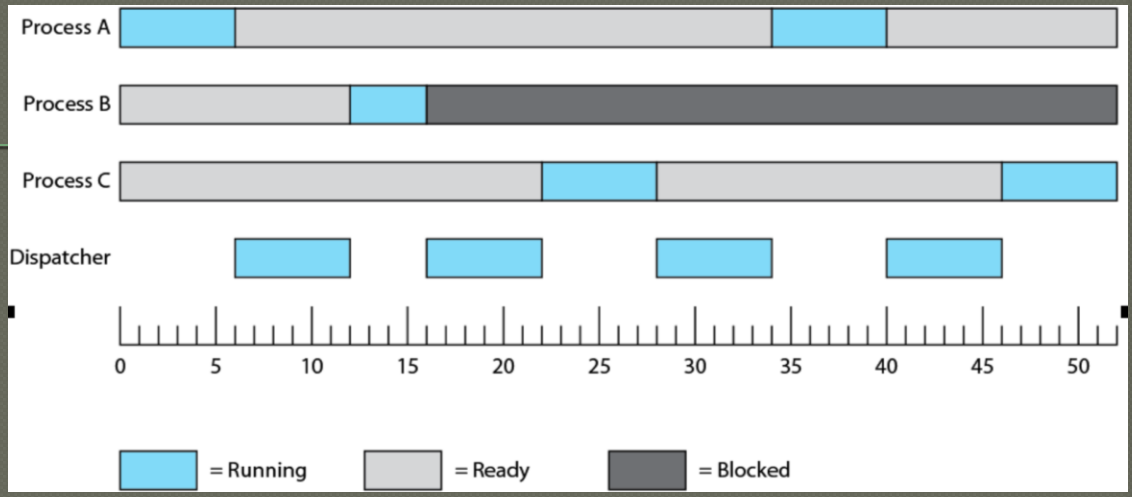
- New: not yet in memory
- Ready: awaiting its turn
- Running: CPU time!
- Blocked: waiting for I/O
- Exit: done & gone

Using Two Queues

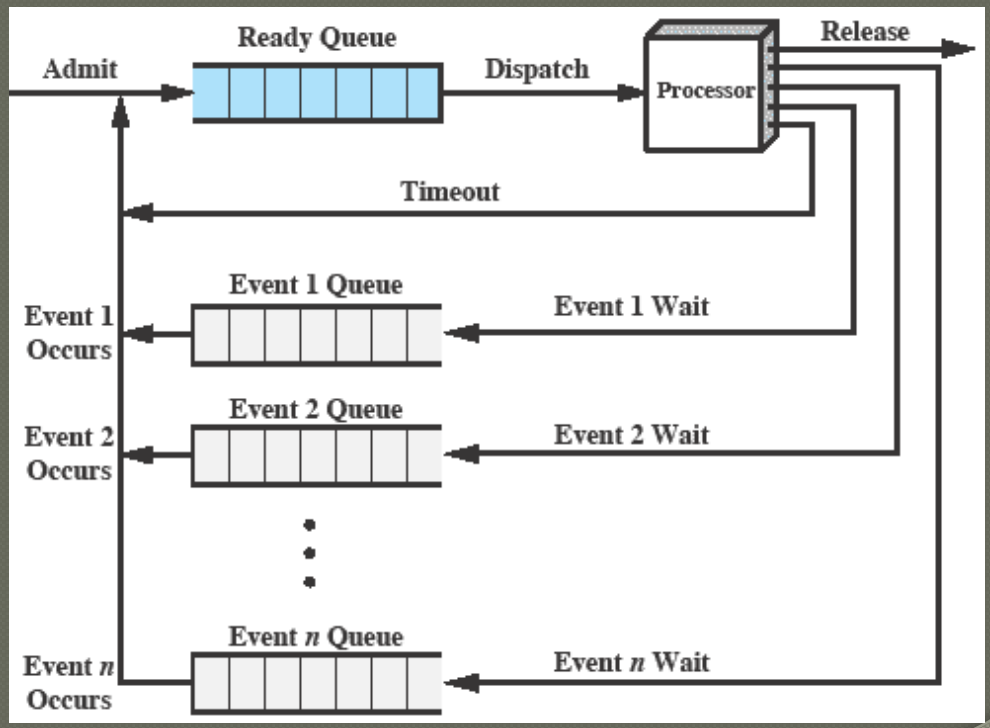


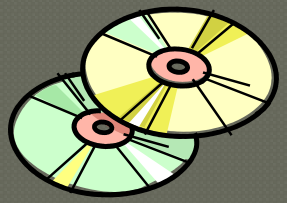
States (5 states)

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



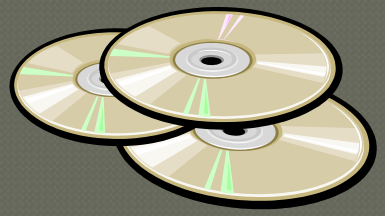
- Multiple block queues (1 per I/O device)





Suspended Processes

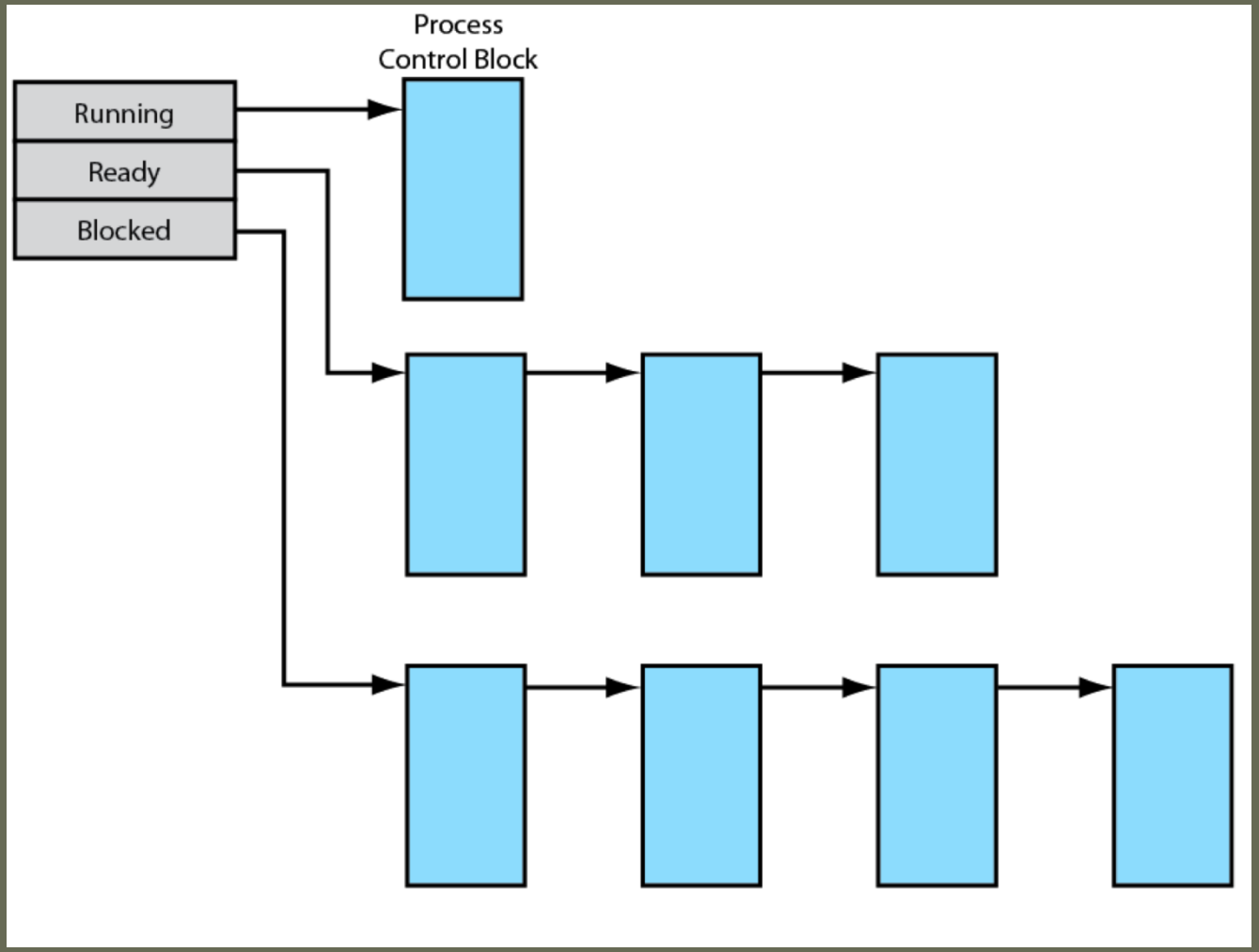
- Swapping
  - involves moving part of all of a process from main memory to disk
  - when none of the processes in main memory is in the Ready state, the OS swaps one of the blocked processes out on to disk into a suspend queue



Processes

- States (7 states)
  - What if running I/O intensive processes and all are waiting for I/O?
    - Solution: suspend blocked processes to disk, bring in new (from new or ready/suspend)

Process List Structures

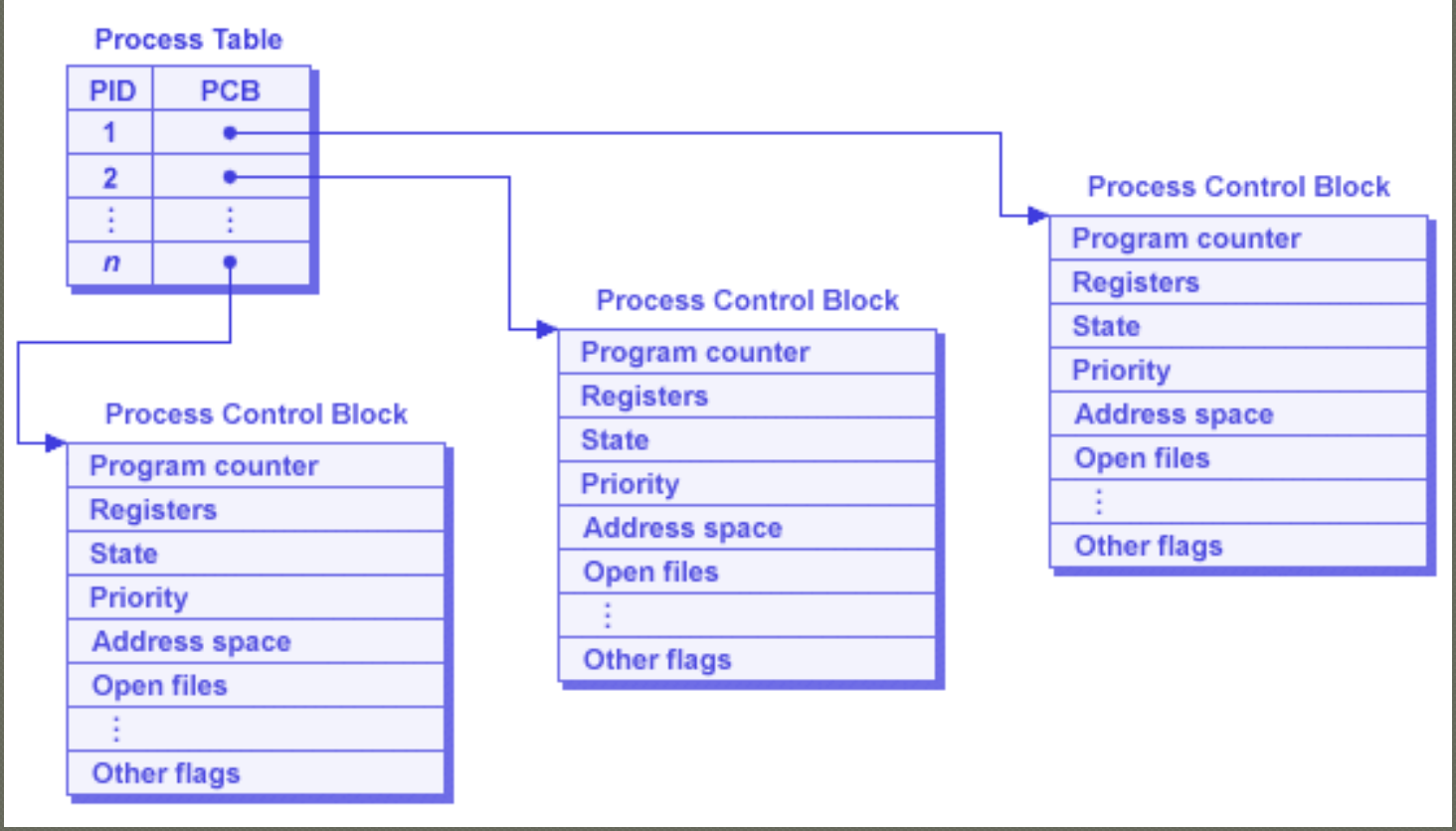


Processes

- Process tables
  - OS keeps list of processes. Each entry tracks data about each process (process image)
    - Heap:
    - Globals:
    - Code: program to execute
    - stack: method call stack frames
    - 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



Processes

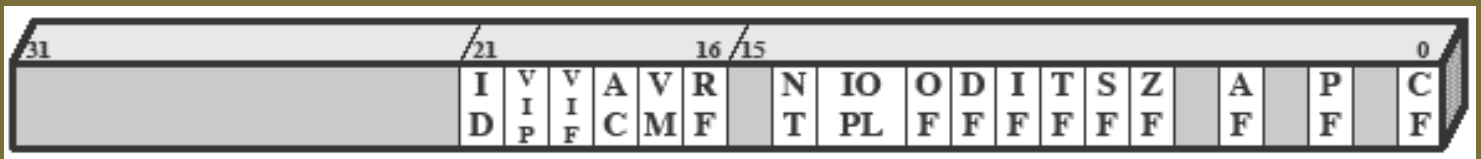
- Process tables

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 to 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
VIP = Virtual interrupt pending
VIF = Virtual interrupt flag
AC = Alignment check
VM = Virtual 8086 mode
RF = Resume flag
NT = Nested task flag
IOPL = I/O privilege level
OF = Overflow flag

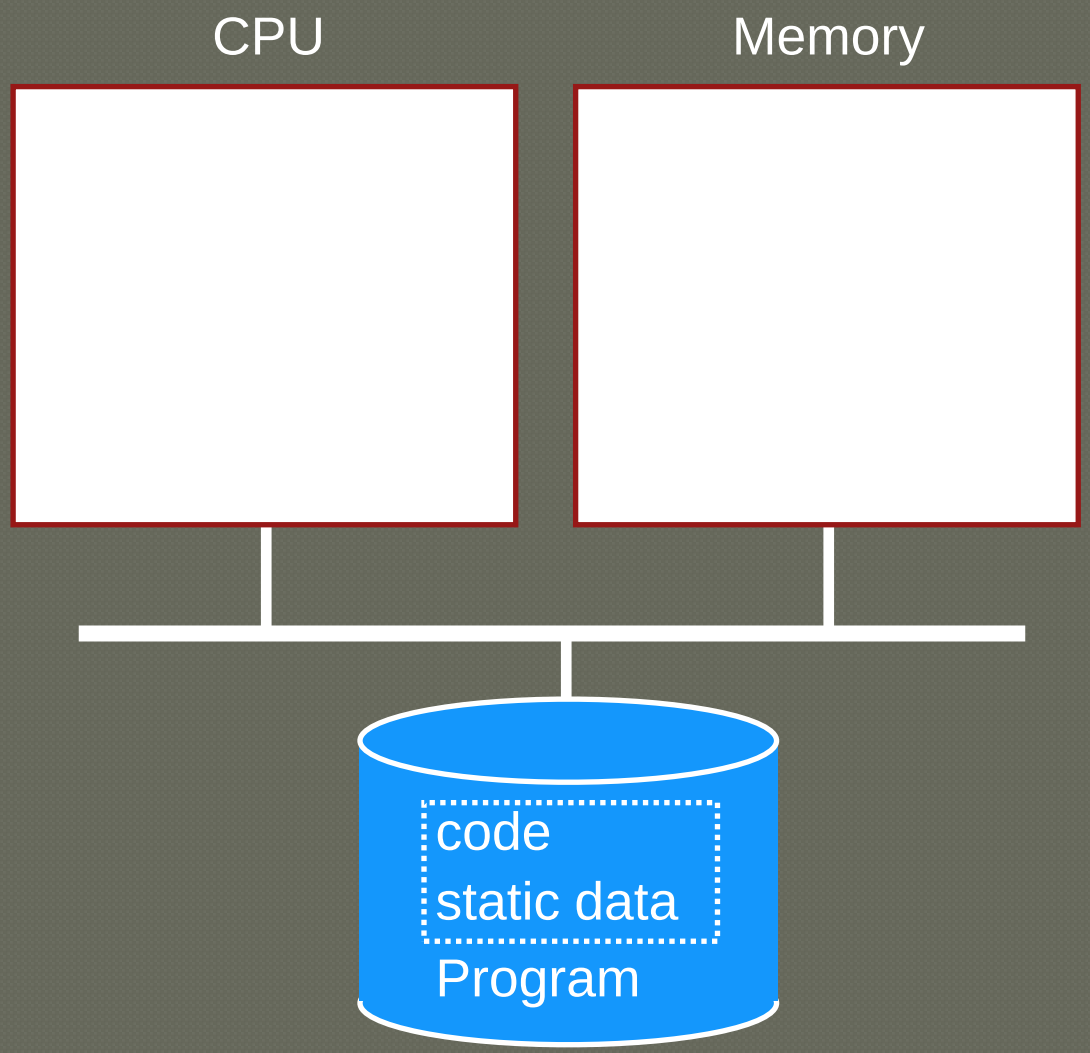
DF = Direction flag
IF = Interrupt enable flag
TF = Trap flag
SF = Sign flag
ZF = Zero flag
AF = Auxiliary carry flag
PF = Parity flag
CF = Carry flag

- processor state information: user/control registers, stack pointers
- process control information: scheduling, inter-process comms, …
- reference (directly/indirectly) memory, I/O & file tables

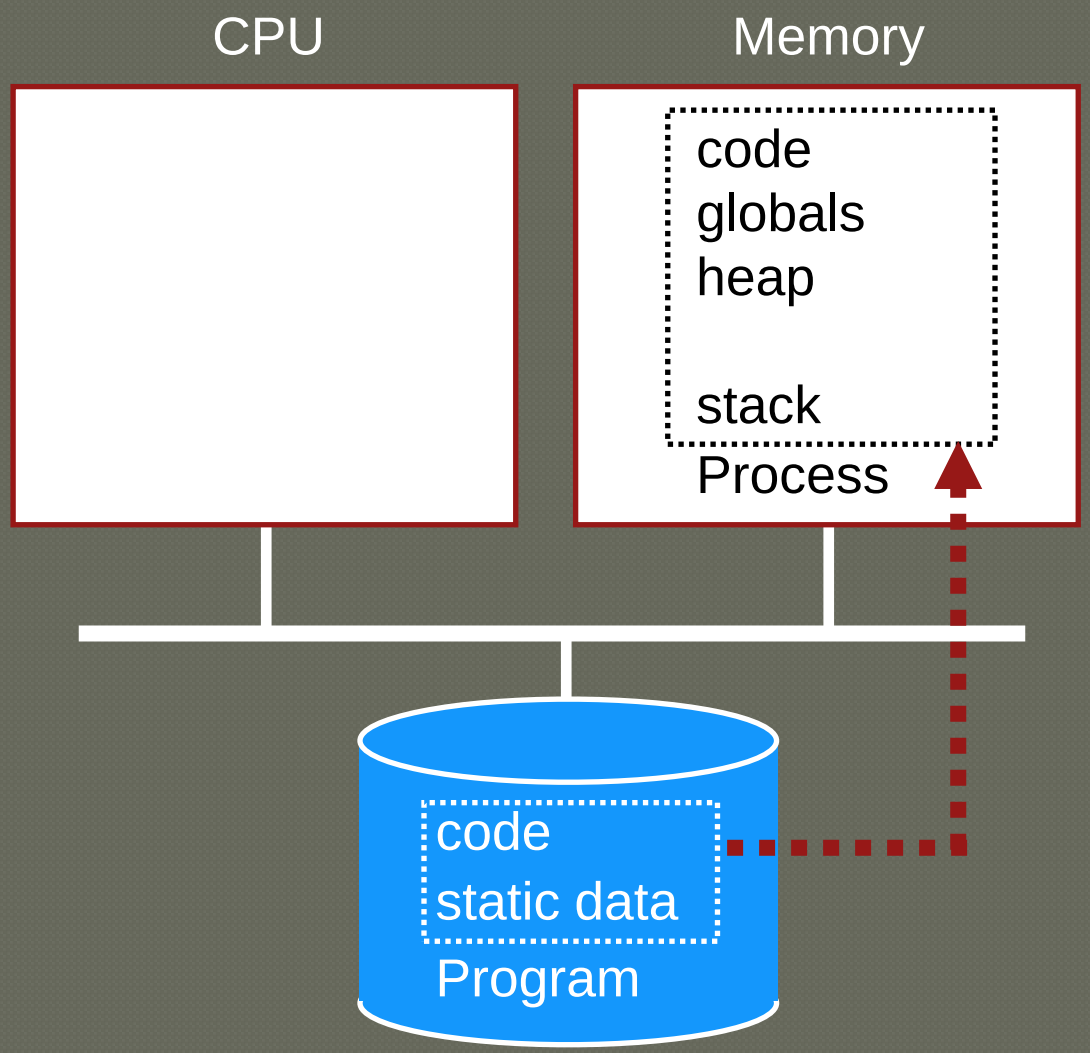
Processes

- 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?

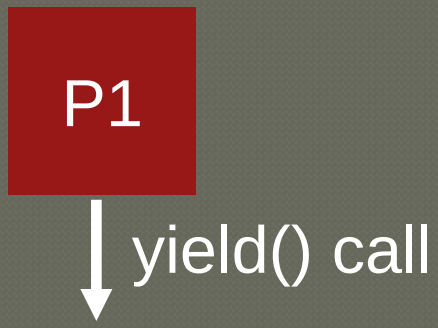
Processes

Q1: How does Dispatcher get CONTROL?

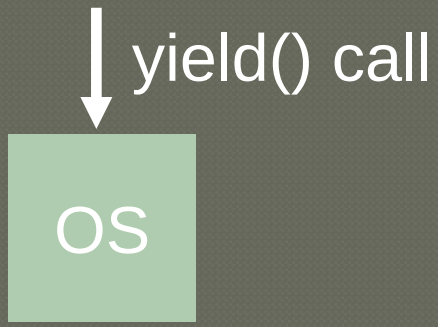
Option 1: Cooperative Multi-tasking

- 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

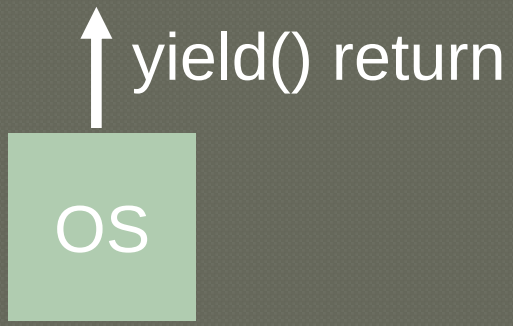
Cooperative Approach



Cooperative Approach

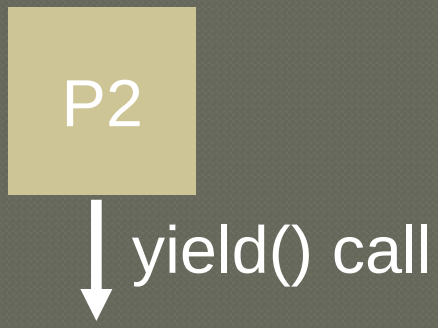


Cooperative Approach



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

Processes

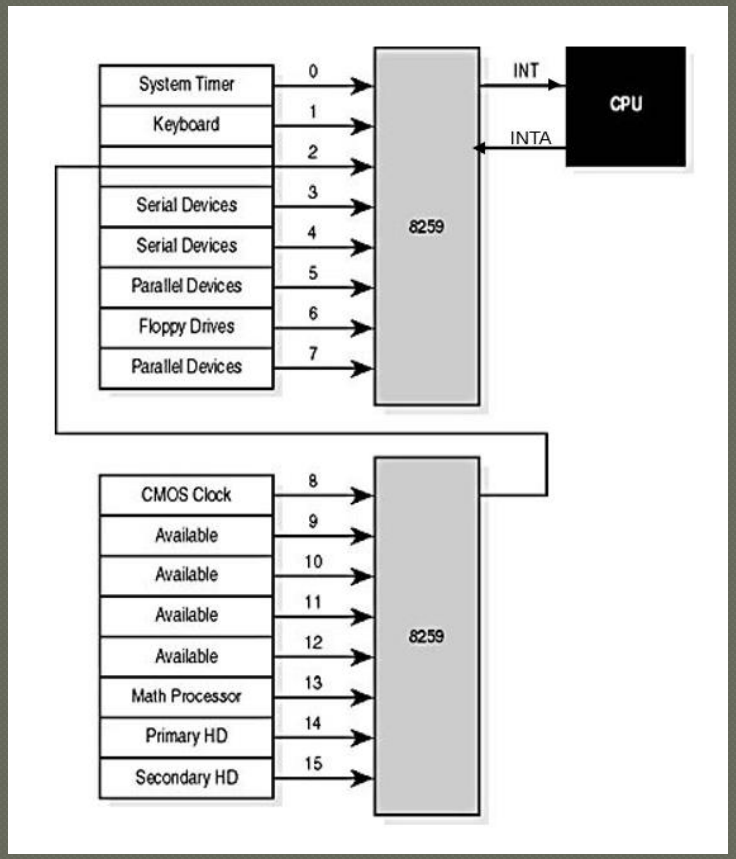
Q1: How does Dispatcher get CONTROL?

Option 2: True Multi-tasking

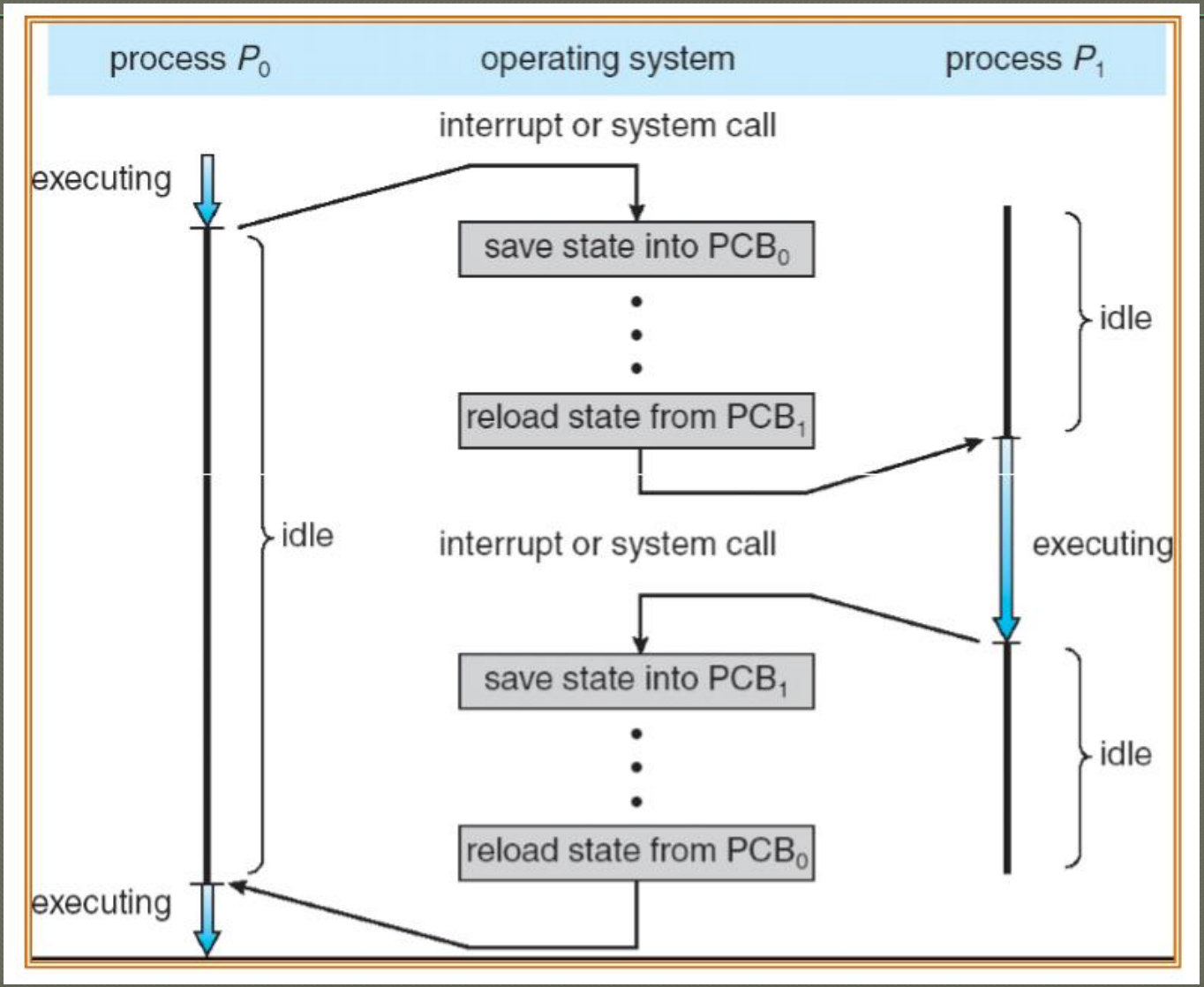
- Guarantee OS can obtain control periodically
- Enter OS by enabling periodic alarm clock
  - Hardware generates timer interrupt (CPU or separate chip)
  - Example: Every 10ms
- User must not be able to mask timer interrupt
- Dispatcher counts interrupts between context switches
  - Example: Waiting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



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

Chapter 3 Topics

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