Reading Reference: Text 1 Chapter 8
Text 2 [Processes]

INTRODUCTION TO PROCESS

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CSCE 313 Spring 2021

Process Definition

- Process is an instance of a running programming. This happens through its **Abstraction**
  - *Also defined as "A Program in Action"*
  - *Aka, an "instance" of a program, much like an **object** is an instance of a **class** in OOP*
  - *Provided by the OS and used by the program*
- To the OS, Process is a **data structure (and more)** representing a running program
  - *Used to save a program's state*
  - *A program can be kicked out and restored using it*

Process Data Structures

- How does the OS represent a process in the kernel?
  - *Using a data structure called Process Control Block (PCB)*
  - *Because of PCB, the OS can **"kickout"** a process and **"bring it back"** as if nothing has happened*

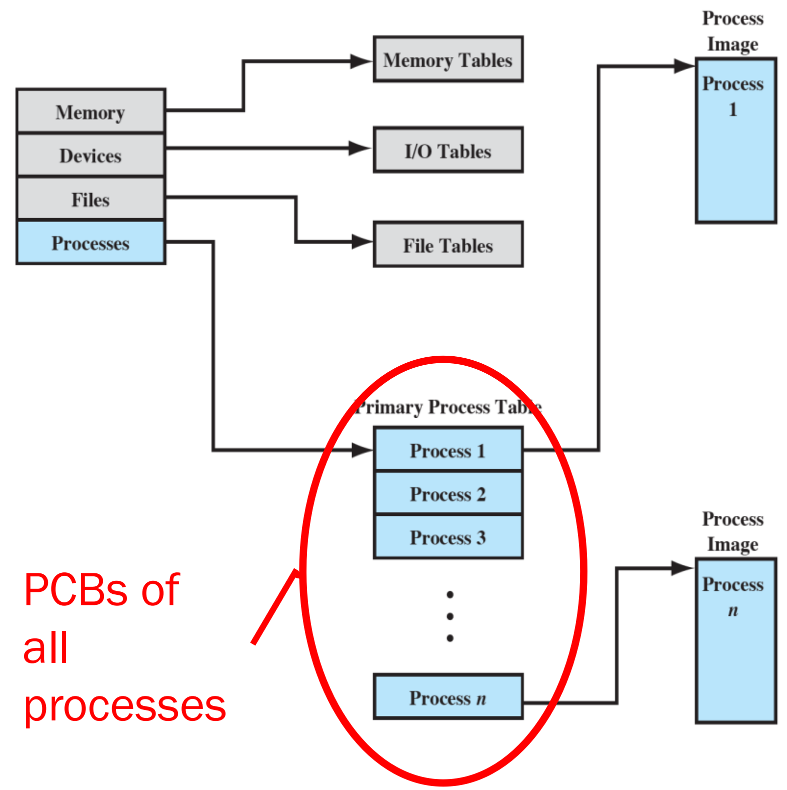
process identification *(use: to **locate** a processes)*	• process id • parent process id • user id

processor state information
*(use: to **restore** a processes as it was)*
	• register set
	    • All general regs
	    • Specials (e.g., PC, SP, EFLAGS)
	• condition codes
	    • Overflow, jump to take or not
	• processor status

process control information *(use: to **treat/run** a processes appropriately)*	• process state • scheduling information • event (wait-for) • memory-management information • owned resources (e.g., list of opened files)

OS's Internal Tables

- An OS keeps a lot of information in the main memory, much of this info is about:
  - *Resources (e.g., devices, memory state)*
  - *Running programs/processes*
- Note that program data is not same as PCB
  - *PCB is like a process's metadata*
  - *Program's data (variables, allocated memory) and code are kept in the process image (i.e., address space), which is separate and usually bigger in footprint*

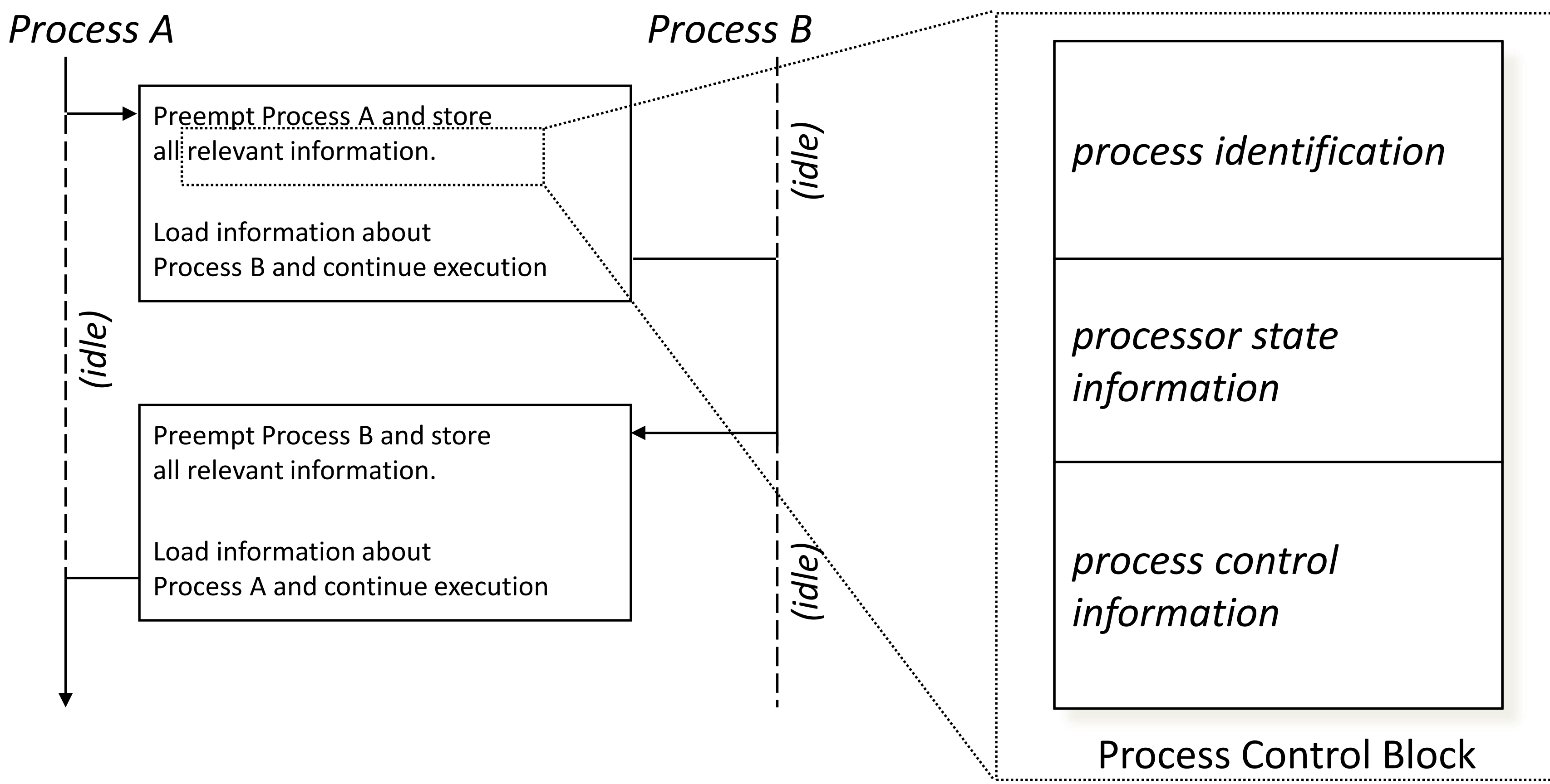


Source: OS – Internals and Design Principles

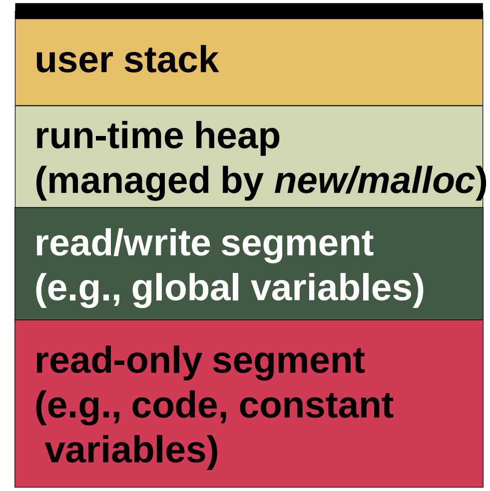
Abstract Mechanism

- Process provides each program with two key abstractions:
  - ***Logical control flow*** *for* ***CPU virtualization***
    - Each program seems to have exclusive use of the CPU
  - ***Private address space*** *for* ***Memory virtualization***
    - Each program seems to have exclusive use of main memory
- How are these illusions maintained?
  - *Process executions* ***interleaved*** *(multiprogramming and timesharing)*
  - *Private address spaces managed by <u>virtual memory system</u> (will describe that in a bit)*

Logical Control Flow using Context Switch

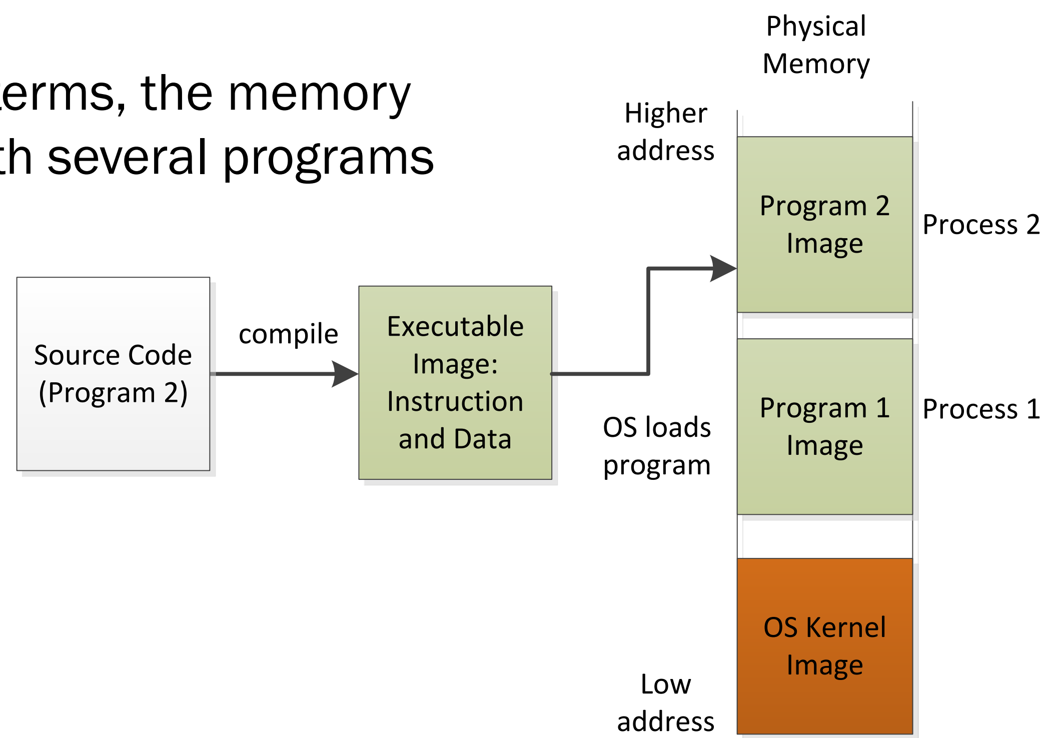


Address Space



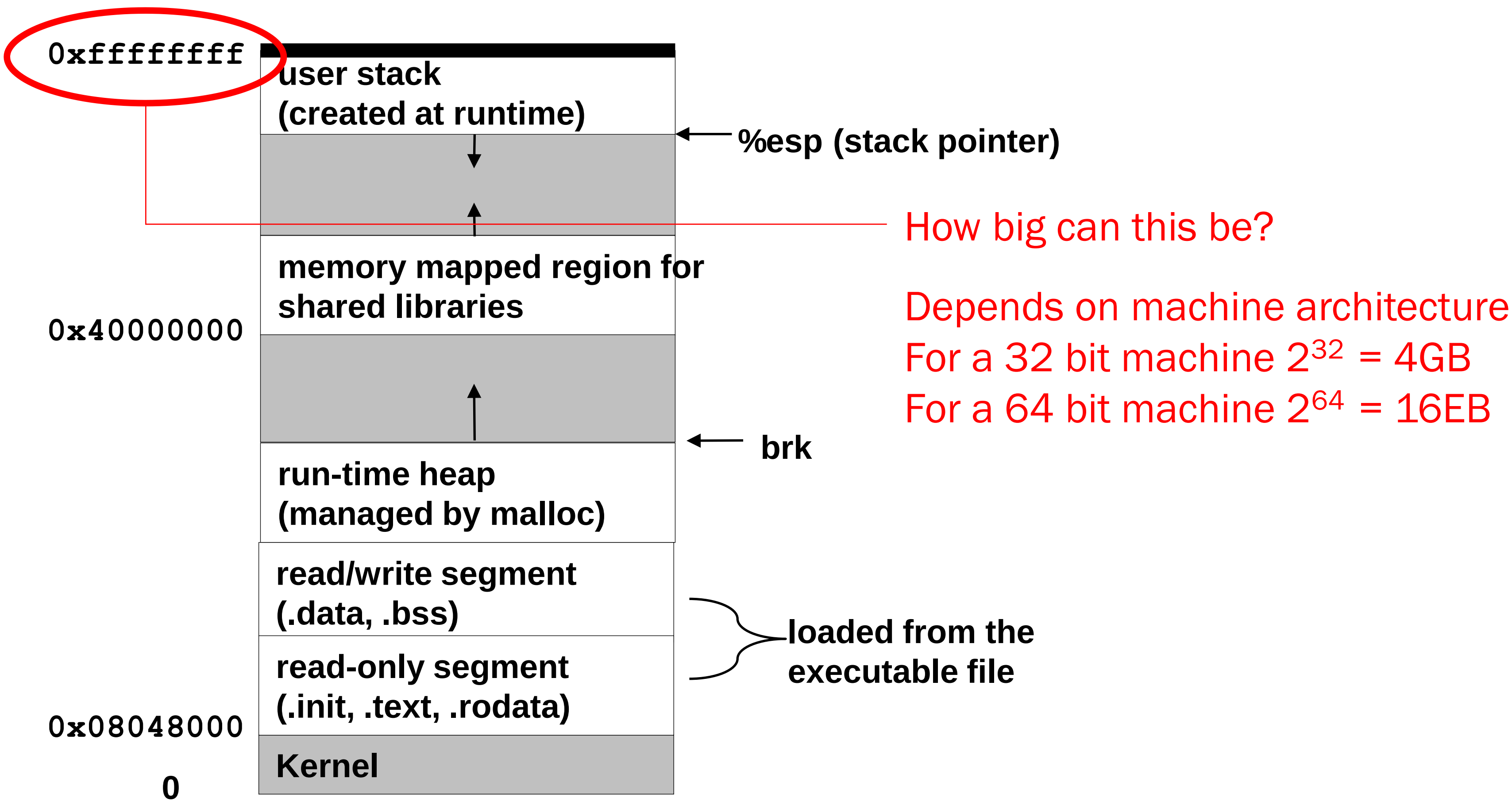
- A program’s data can be divided into different parts; therefore they are loaded as groups into memory

- Therefore, in very simple terms, the memory looks like the following with several programs loaded:



Private Address Space Illusion

- But each process is made to believe that the memory looks like the following – thanks to Virtual Memory:

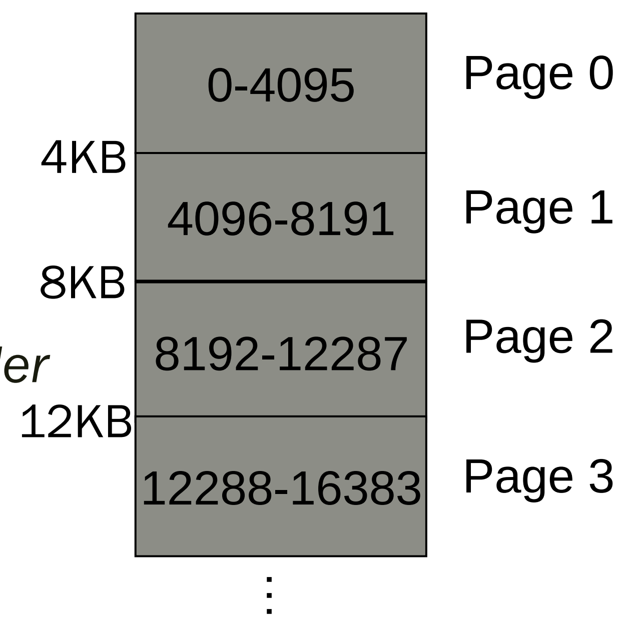


Question

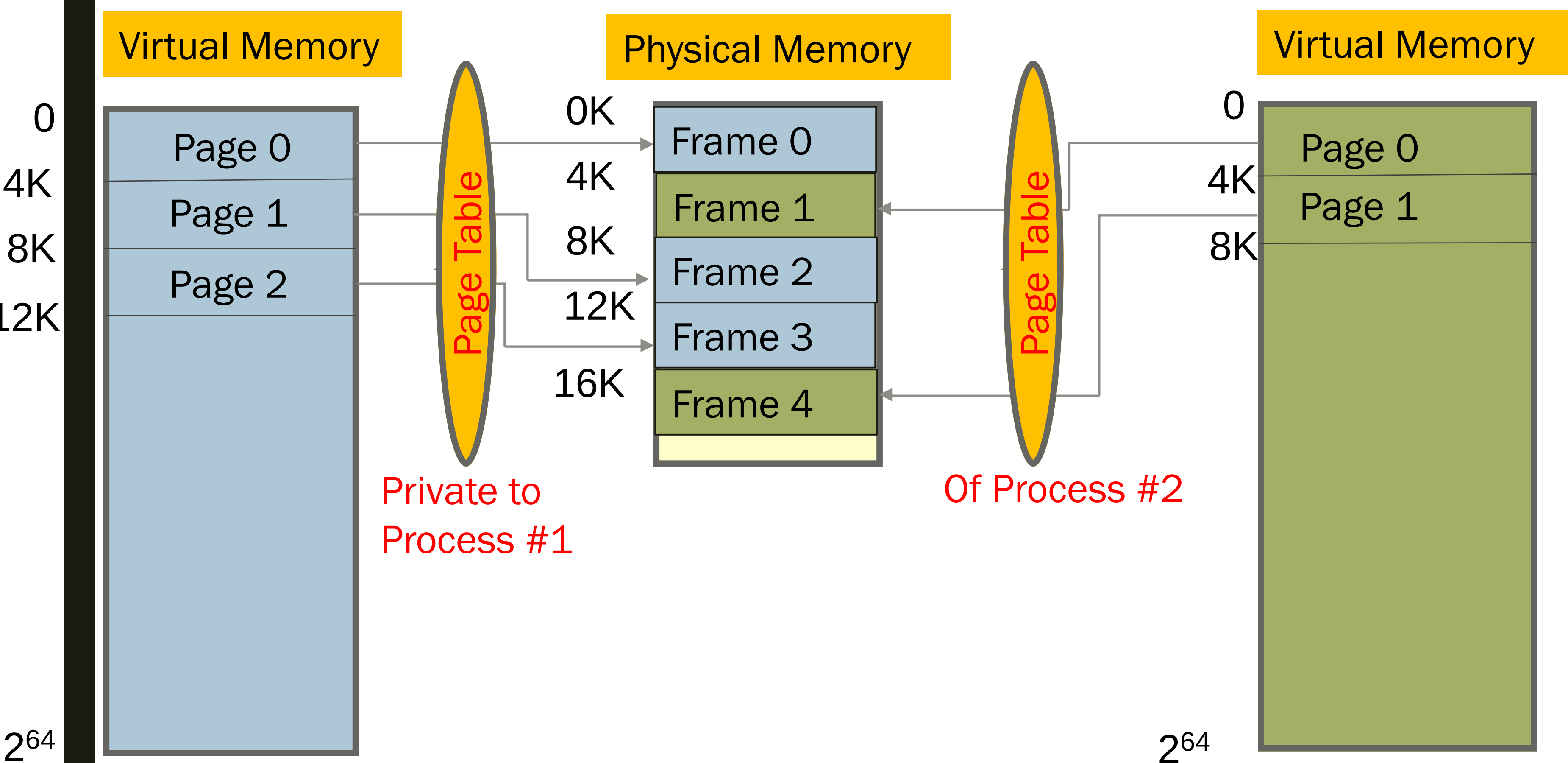
- Is a process image really 2^{32} = 4GB long?
  - *It would be nice for us, programmers*
  - *But typically, physical memory is quite limited*
  - *Virtual memory in action*
- What is then Virtual Memory?
  - *For that, we now need to a little understanding on how memory is organized in a system*

Memory Organization

- Memory is logically divided into *pages*, which are fixed in size and aligned regions of memory
  - *Typical size: 4KB/page*
- But pages are associated to a process only when necessary (i.e., read or written)
  - *When not necessary, they are evicted to the disk. Therefore, eviction does not mean data loss*
- This on-demand allocation is also called **lazy allocation**
- The mechanism of such **lazy-allocation** is through **Page Fault**
  - *If a non-existent page is accessed (R/W), a page fault happens and the fault-handler allocates the required page in physical memory*



Mapping from Virtual to Physical Memory



Summarizing Virtual Memory

- The private address space of a process is made up of pages
  - *These pages can be spread according to the wish of the kernel*
  - *Contiguous memory blocks in processes' view are not necessarily contiguous in physical memory – they can be physically scattered, but* ***stitched*** *together by Virtual Memory system*
- Because memory is scarce, the whole private address space does not need to be allocated all the time:
  - *Actual pages can be allocated/mapped only when needed (i.e., read or written) through* ***page faults***
  - *Even allocated but inactive pages can be swapped back to disk to make room for more active pages*
- Memory accesses can be slowed down by Page Table accesses
  - *Each address must be translated to physical address by looking up in the process's page table, which is also in memory*
  - *Thus each memory access is actually* ***2 memory accesses****: 1 for page table, another for the actual memory access*
  - *There is a cache called Translation Lookaside Buffer (TLB) which stores popular translations – thus hiding the double latency*

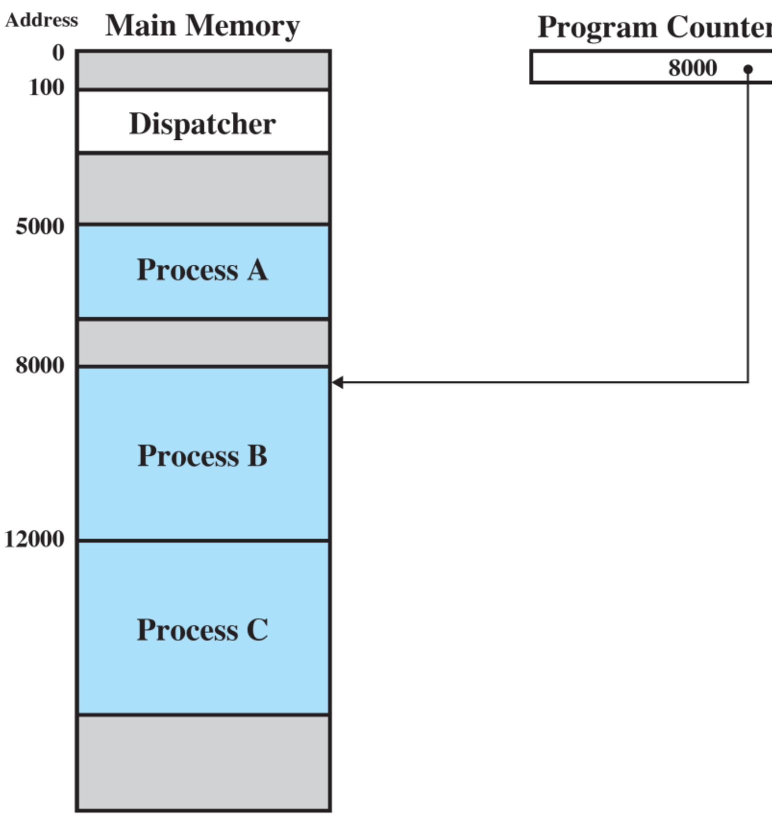
Virtual Memory – An Interesting Video

- Please watch this video, which is very informative, yet small:

https://www.youtube.com/watch?v=qlH4-oHnBb8

Process States - An Example

- Assume the following processes A, B, C are loaded in memory
- PC points to the physical address of the to-execute instruction
  - *For simplicity, do not consider virtual address*



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
(a) Trace of Process A	**(b) Trace of Process B**	**(c) Trace of Process C**

5000 = Starting address of program of Process A
8000 = Starting address of program of Process B
12000 = Starting address of program of Process C

Process Trace

- **Trace:** The sequence of instructions that execute for a process

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

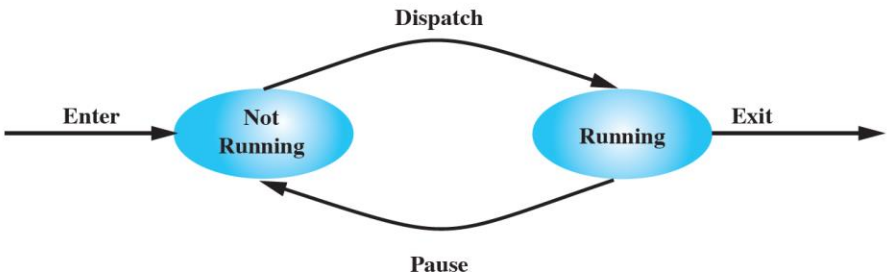
1	5000
2	5001
3	5002
4	5003
5	5004
6	5005
-------------------Timeout	
7	100
8	101
9	102
10	103
11	104
12	105
13	8000
14	8001
15	8002
16	8003
-------------- I/O Request	
17	100
18	101
19	102
20	103
21	104
22	105
23	12000
24	12001
25	12002
26	12003
27	12004
28	12005
-------------------Timeout	
29	100
30	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	

Process Trace Discussion

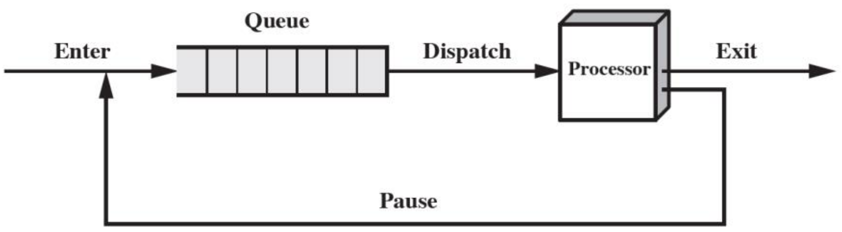
- Dispatcher is show in blue shaded box
  - *The same dispatcher code runs between any 2 processes*
- The figure shows several (52) instruction cycles from the 3 processes
- The trace starts with process A by overwriting PC with 5000, which is the first instruction of A
- The OS allows exactly 6 instruction before the timer fires
  - *i.e., kicks out the currently running process*
  - *This prevents programs from monopolizing the CPU*
- CPU goes from A to B after A is kicked out for the timer
- B gets kicked out because of requesting I/O
- Then the CPU alternates between A and C because B is still waiting for the I/O

Process States

- Let us start with elementary 2-state model
- This queue is some sort of a priority queue, where the priority is on some scheduling metric
- Content of the Queue:
  - *Pointer to PCB*
- Limitation:
  - *Can bring a process that is still waiting on I/O*
  - *The process will stay idle, thus wasting CPU time*



(a) State transition diagram

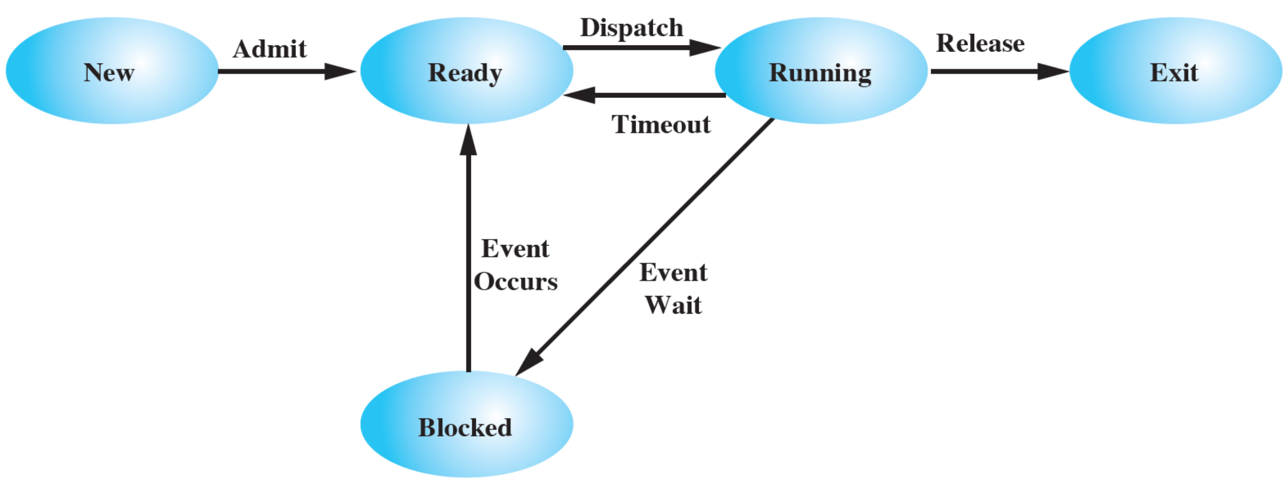


(b) Queuing diagram

Figure 3.5 Two-State Process Model

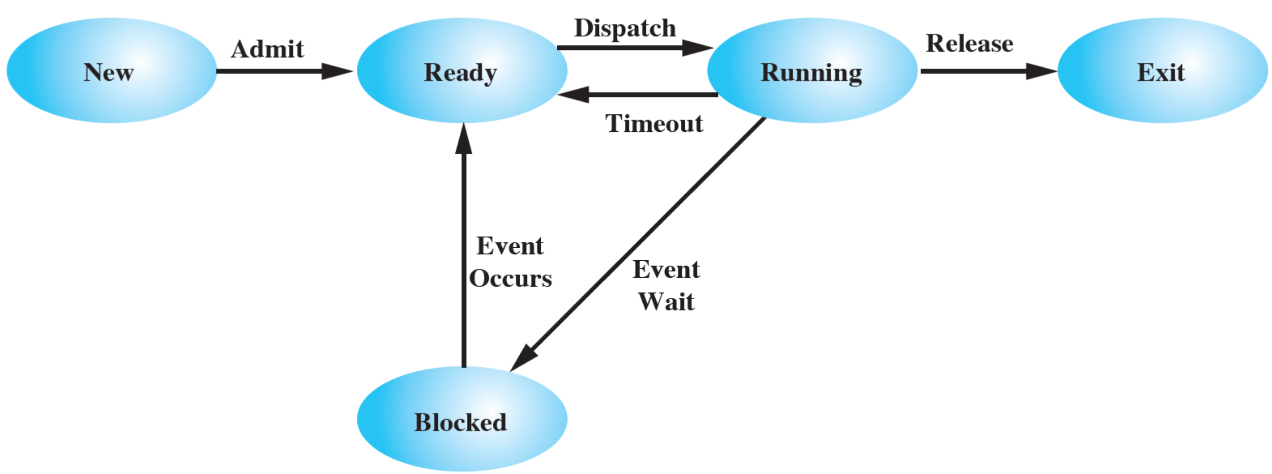
Refined Process State Model

- It has 5 states
  - *Newly added states: “New”, “Blocked”, “Exit”*
- Addition of “Blocked” state is obvious
  - *Avoids bringing the process back to ready queue before I/O operation or the event finishes*
- “New” state is when the PCB is created, but the process is not loaded in memory yet
  - *Either because it is the usual delay*
  - *Or because there is no room in memory*

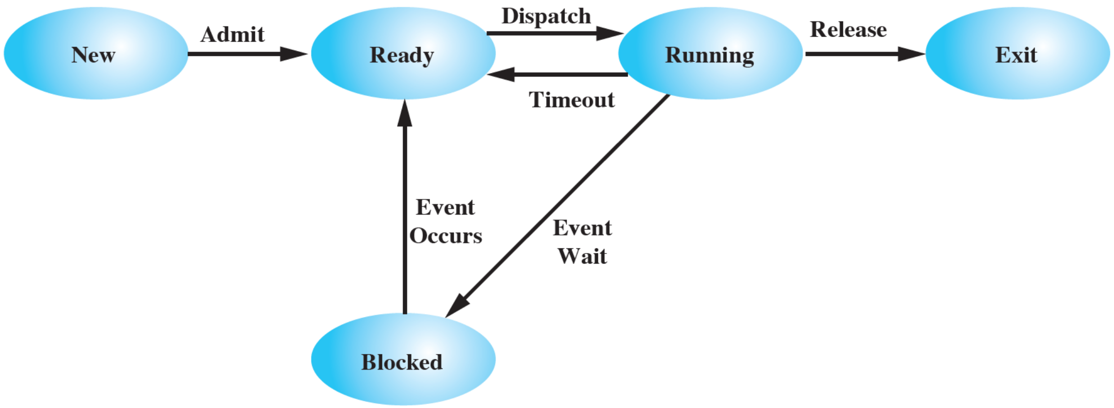


Refined Process State Model (2)

- Exit State: The process is removed from the list of executable processes, but it is held by the OS for collecting some information about it
  - *E.g., an accounting program collecting information about all processes*
- New State: Is used for memory management
  - *The main memory may be full, and no new process may be loaded – for the time being*
  - *The process's PCB is in memory, but not its executable image*



Now, the Transitions



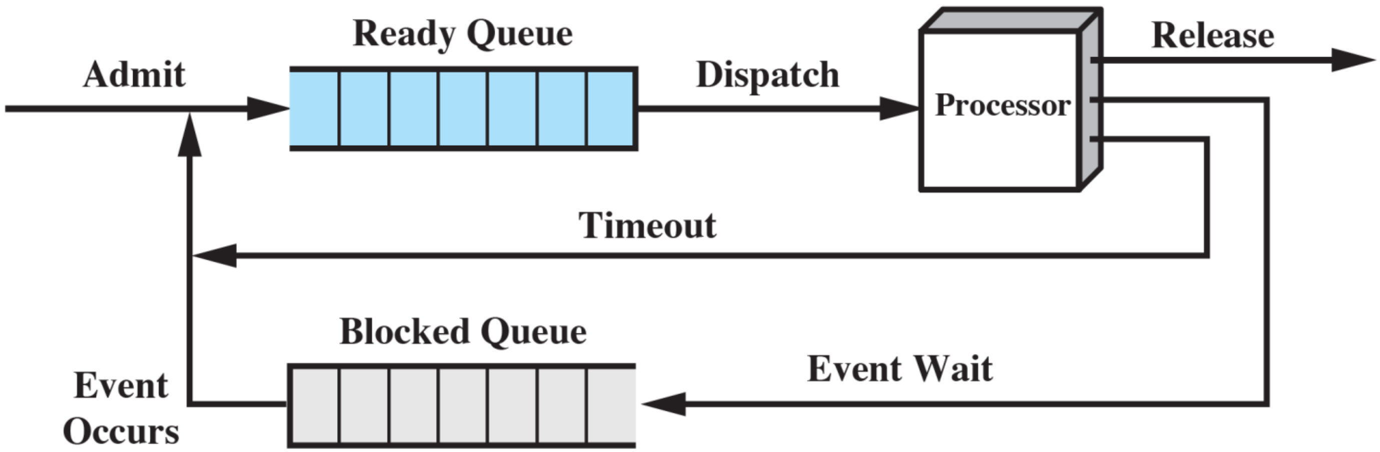
- New->Ready:
  - *When there is room for a new process in memory*
- Ready->Running:
  - *When the scheduler picks this process*
- Running->Exit:
  - *Normal or due to some unavoidable/unrecoverable error (e.g., segmentation fault, divide by 0)*
- Running->Ready:
  - *Timer fired*
  - *A low-priority process is running in CPU and a higher priority process got unblocked for I/O finish*

Transitions

- Running->Blocked
  - *I/O or other event request that are not ready, or would take time*
- Blocked->Ready
  - *Event on which the process is waiting has finished*
- Ready->Exit
  - *Parent process terminates child before it could even run*
- Blocked->Exit
  - *Parent process killed the child while it was waiting*

Queueing Model for Proc. States

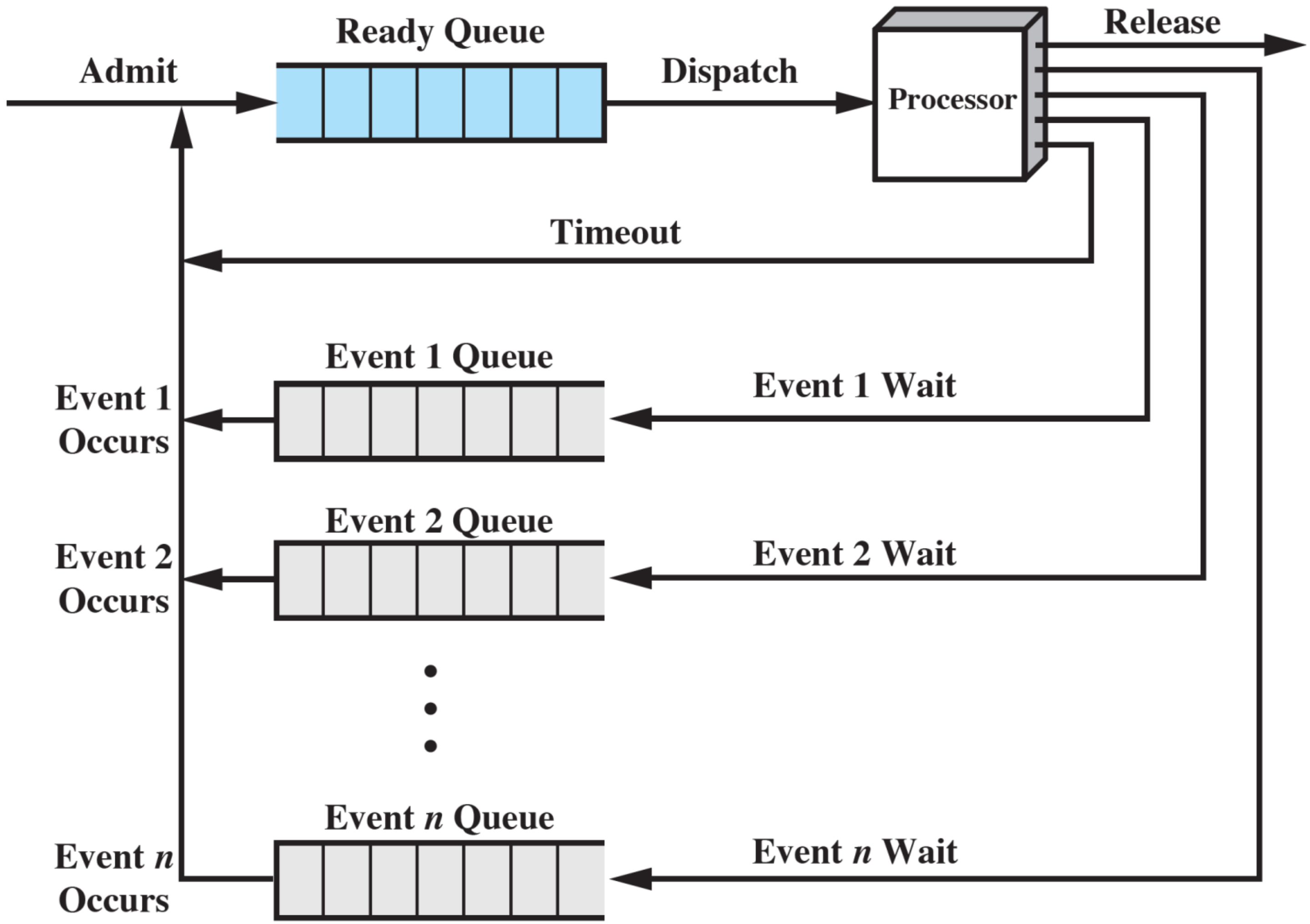
- To implement the 5-state model, we will now need 2 queues



(a) Single blocked queue

- However, 2-queue model is also not enough
  - *Does not make sense to make a file request from disk and URL request behind the Network card wait in the same queue*
- In reality, each I/O device, each lock, and thus each event needs a separate wait queue

Queueing Model (2)



(b) Multiple blocked queues