Module 4: Processes

Super important and cereal

- Process Concept
- Process Scheduling
- Operation on Processes
- Cooperating Processes
- Interprocess Communication

Process Concept

- An operating system executes a variety of programs:
  - Batch system – jobs
  - Time-shared systems – user programs or tasks
- Textbook uses the terms *job* and *process* almost interchangeably.
- Process – a program in execution; process execution must progress in sequential fashion.
- A process includes:
  - program counter
  - stack
  - data section

Process State

- As a process executes, it changes *state*
  - new: The process is being created.
  - running: Instructions are being executed.
  - waiting: The process is waiting for some event to occur.
  - ready: The process is waiting to be assigned to a process.
  - terminated: The process has finished execution.

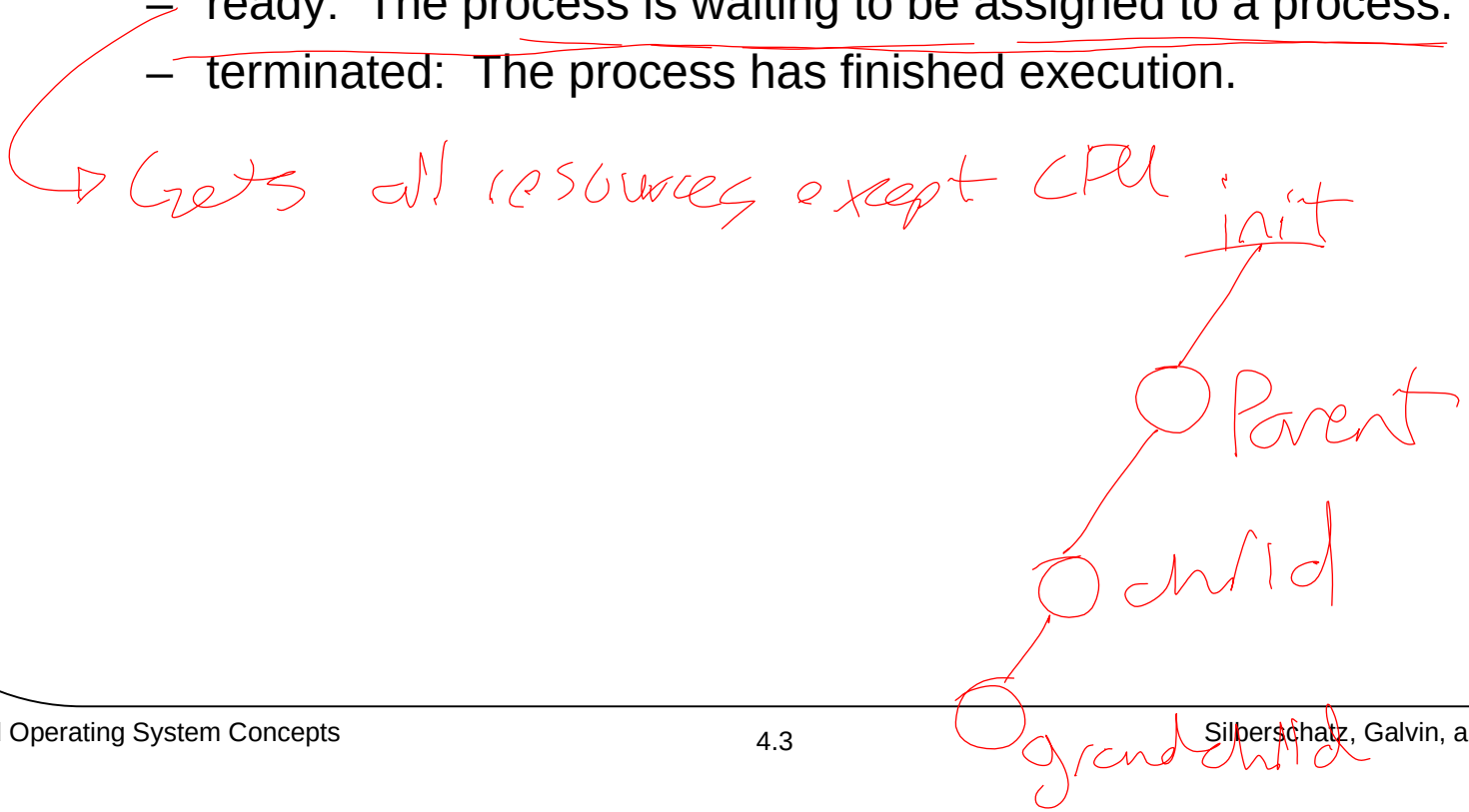
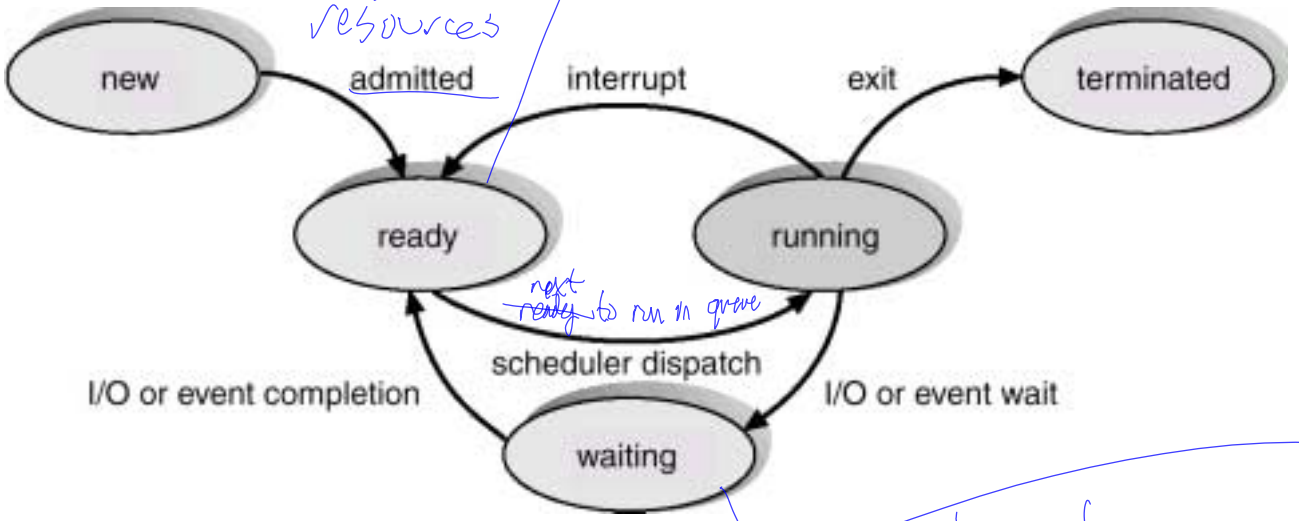


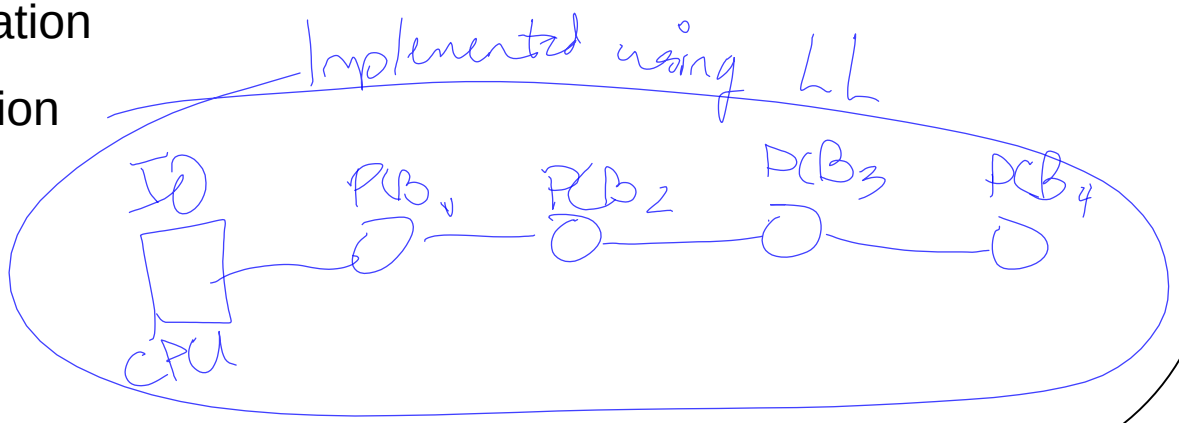
Diagram of Process State



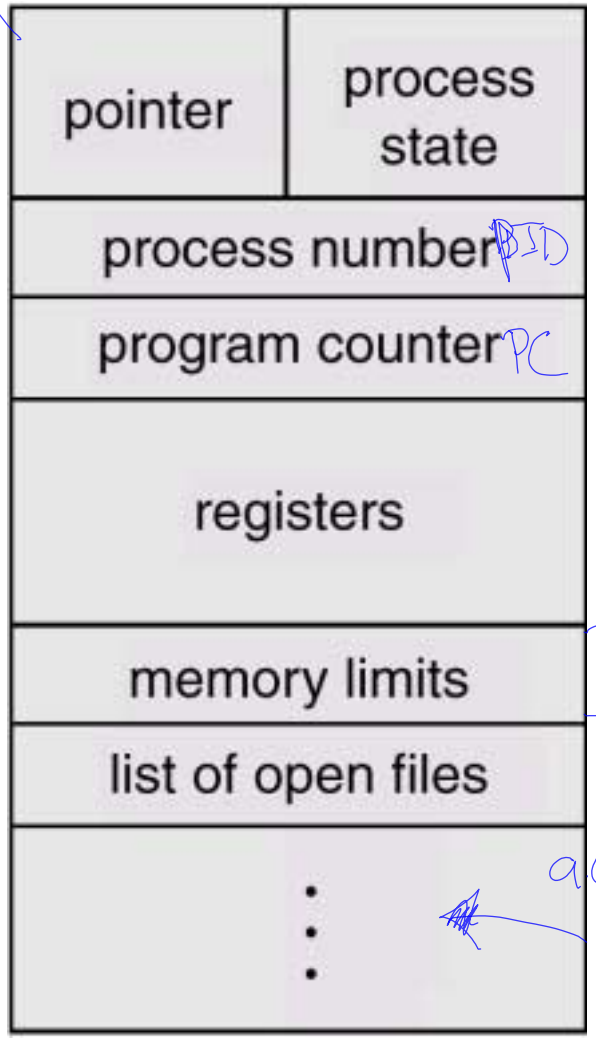
Process Control Block (PCB)

Information associated with each process.

- Process state
- Program counter
- CPU registers
- CPU scheduling information
- Memory-management information
- Accounting information
- I/O status information



Process Control Block (PCB)



Is a queue like a linked list

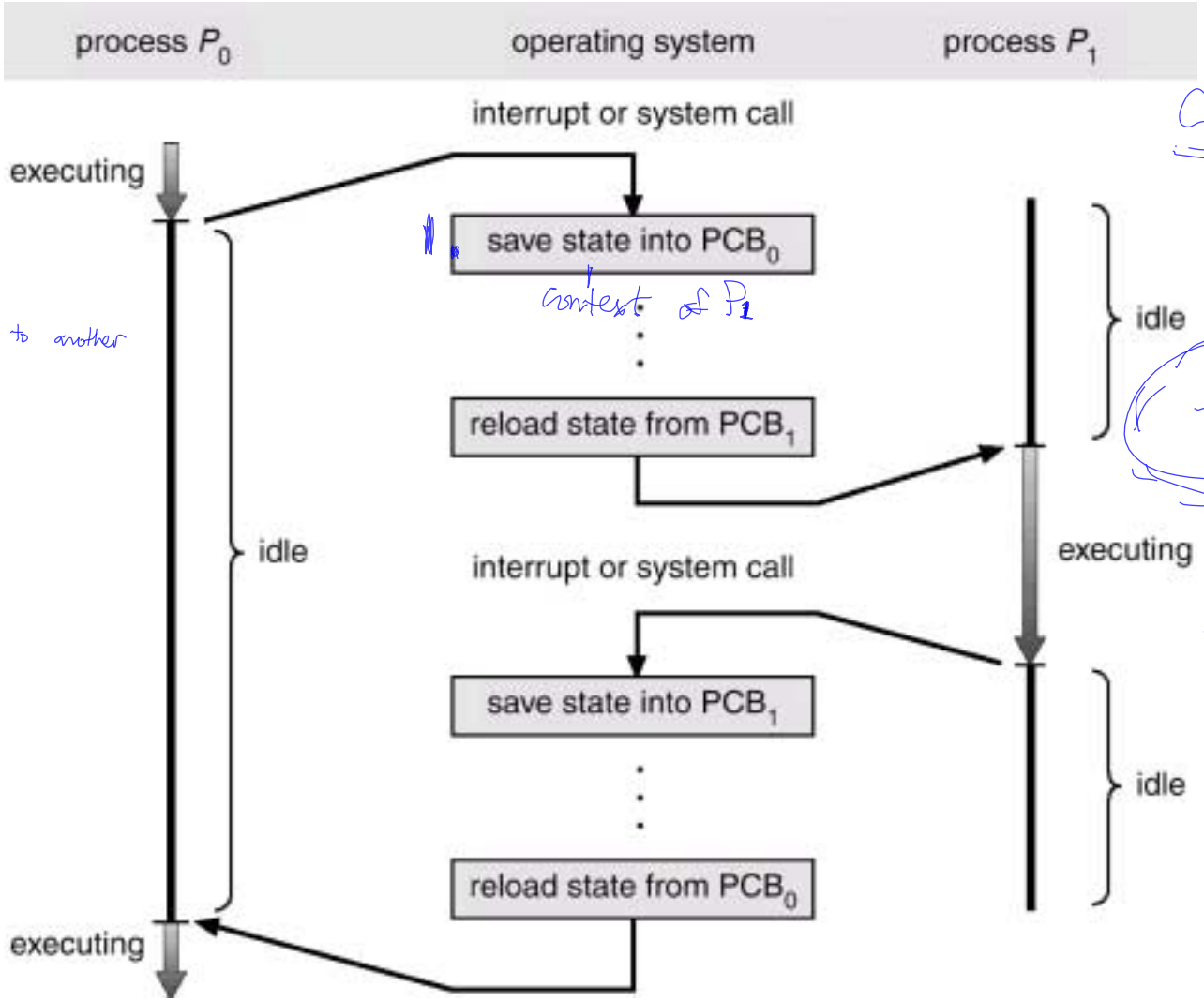
each process has one

Sometimes used as a reference

SW trap interrupt

accounting information (stats)

CPU Switch From Process to Process



Context Switch
Switch from one process to another

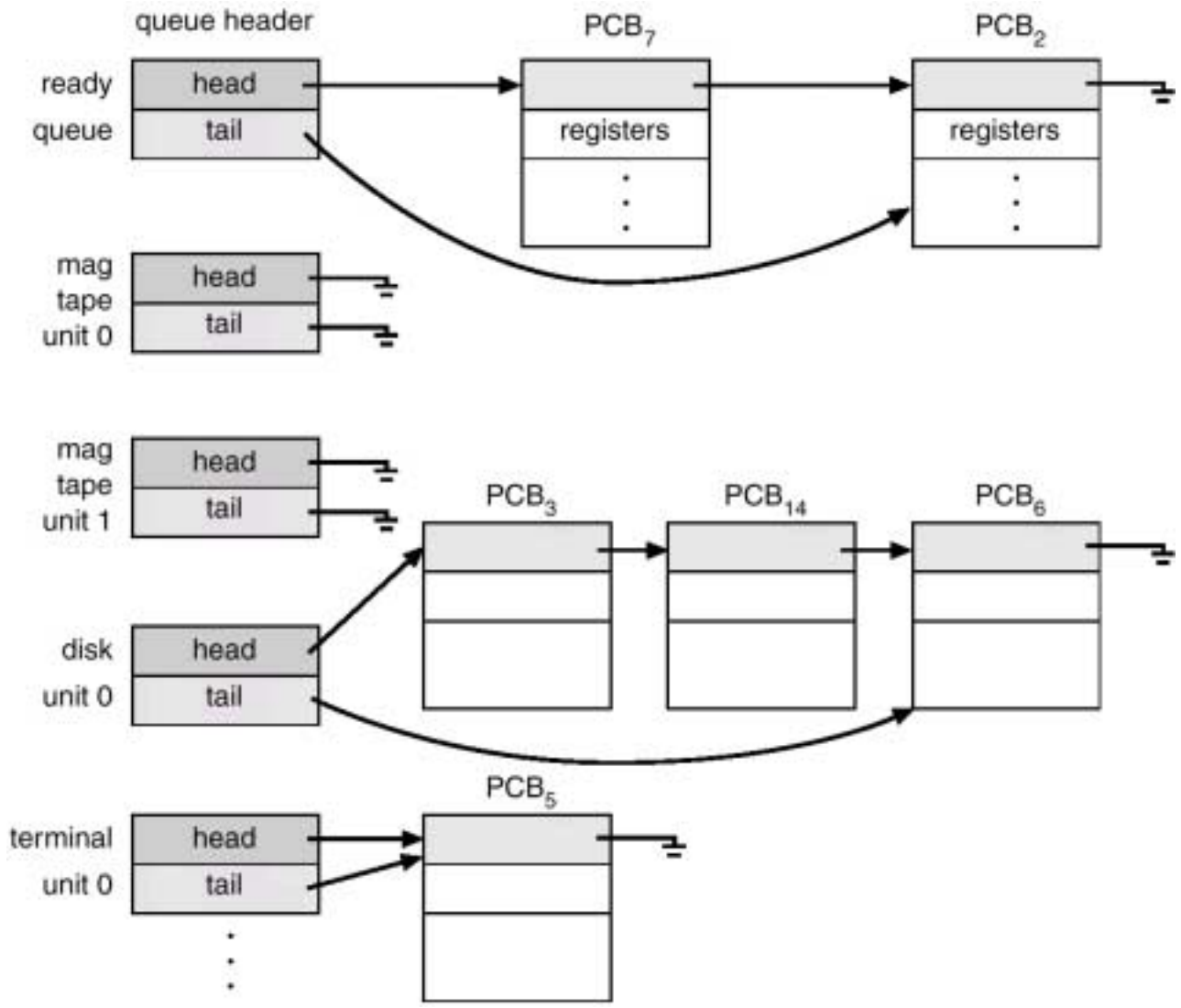
Context Switch
info about Process

Threads

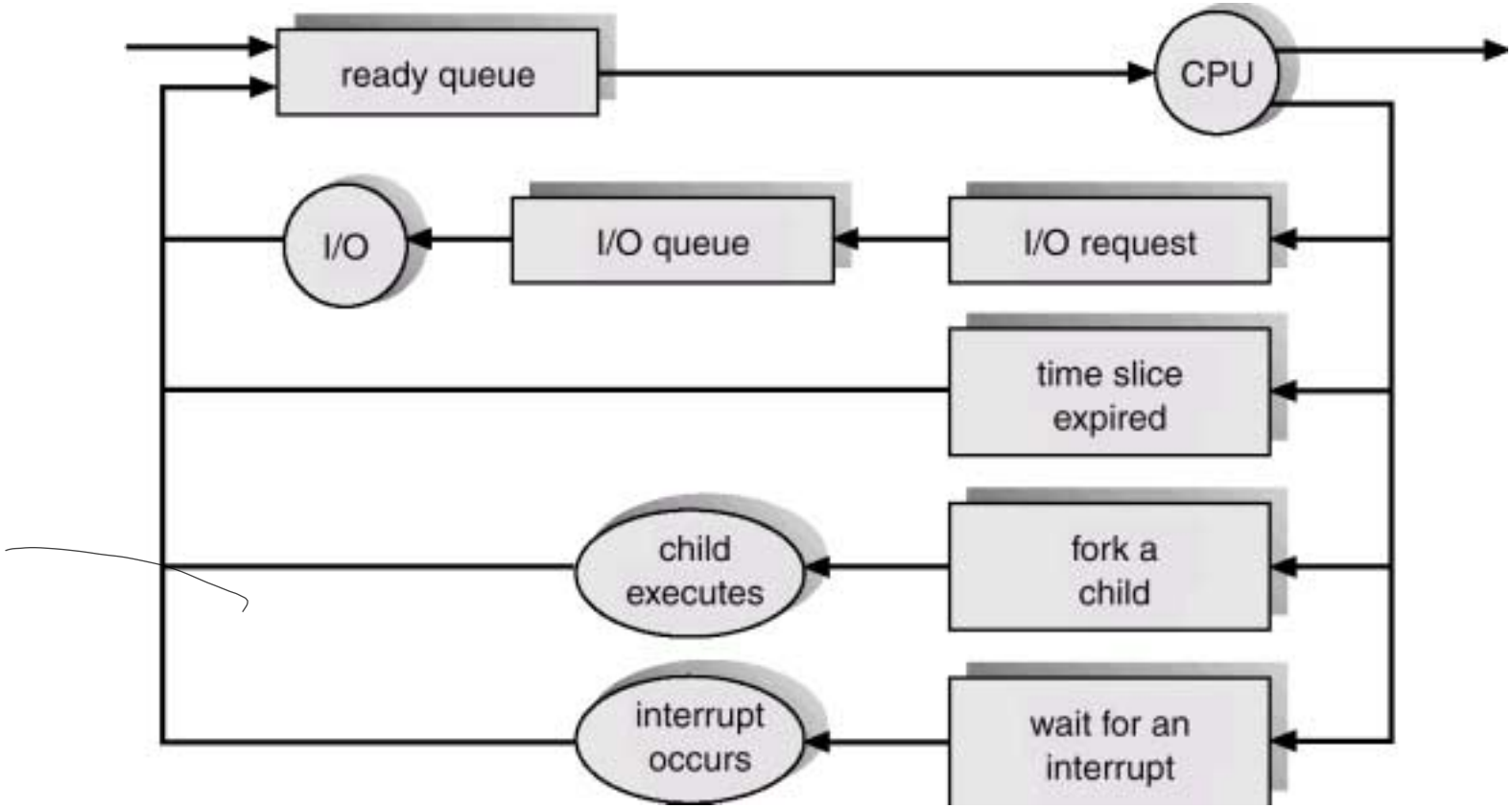
Process Scheduling Queues

- Job queue – set of all processes in the system.
- Ready queue – set of all processes residing in main memory, ready and waiting to execute.
- Device queues – set of processes waiting for an I/O device.
- Process migration between the various queues.

Ready Queue And Various I/O Device Queues

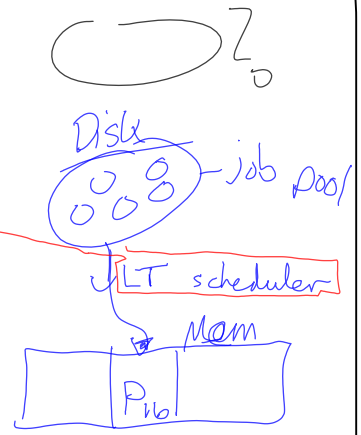


Representation of Process Scheduling



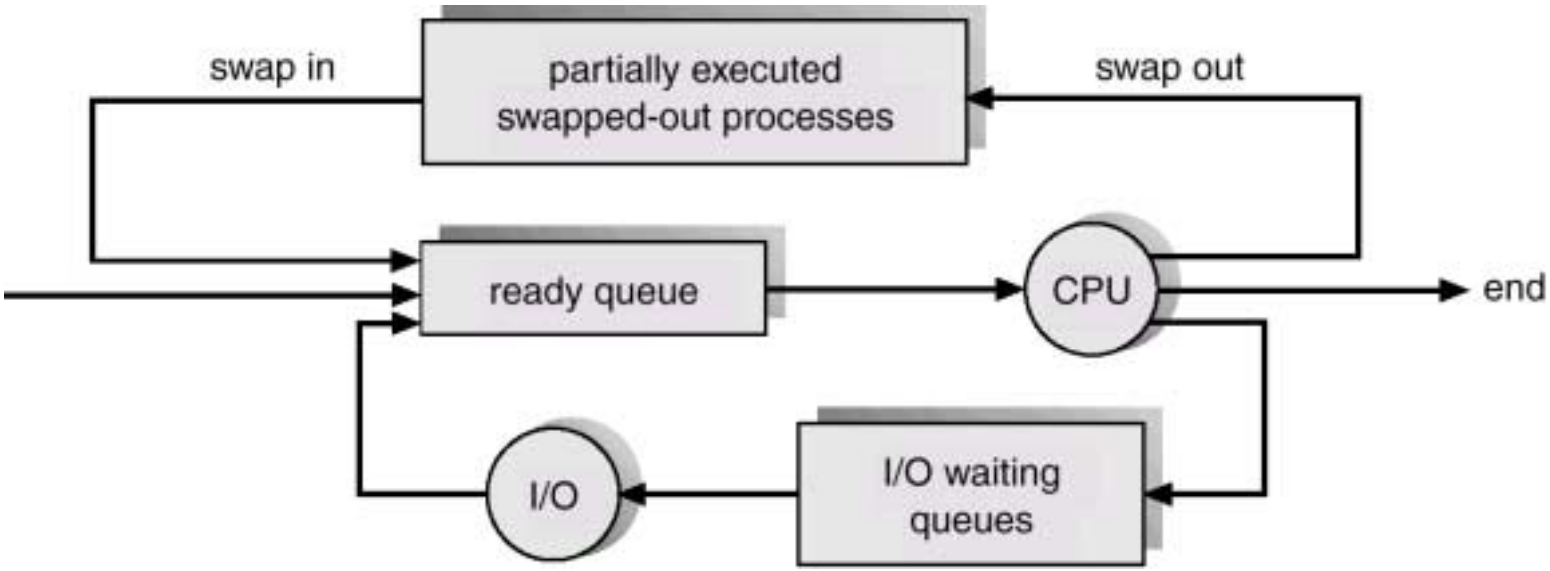
Schedulers

- Long-term scheduler (or job scheduler) – selects which processes should be brought into the ready queue.
- Short-term scheduler (or CPU scheduler) – selects which process should be executed next and allocates CPU.



Medium Term sch - Swaps in/out partially executed processes

Addition of Medium Term Scheduling



Schedulers (Cont.)

- Short-term scheduler is invoked very frequently (milliseconds) $\Rightarrow$ (must be fast).
- Long-term scheduler is invoked very infrequently (seconds, minutes) $\Rightarrow$ (may be slow).
- The long-term scheduler controls the *degree of multiprogramming.*
- Processes can be described as either:
  - I/O-*bound process* – spends more time doing I/O than computations, many short CPU bursts.
  - CPU-*bound process* – spends more time doing computations; few very long CPU bursts.

Context Switch

- When CPU switches to another process, the system must save the state of the old process and load the saved state for the new process.
- Context-switch time is overhead; the system does no useful work while switching.
- Time dependent on hardware support.

Process Creation

- Parent process creates children processes, which, in turn create other processes, forming a tree of processes.
- Resource sharing
  - Parent and children share all resources.
  - Children share subset of parent's resources.
  - Parent and child share no resources.
- Execution
  - Parent and children execute concurrently.
  - Parent waits until children terminate.

wait (NULL)

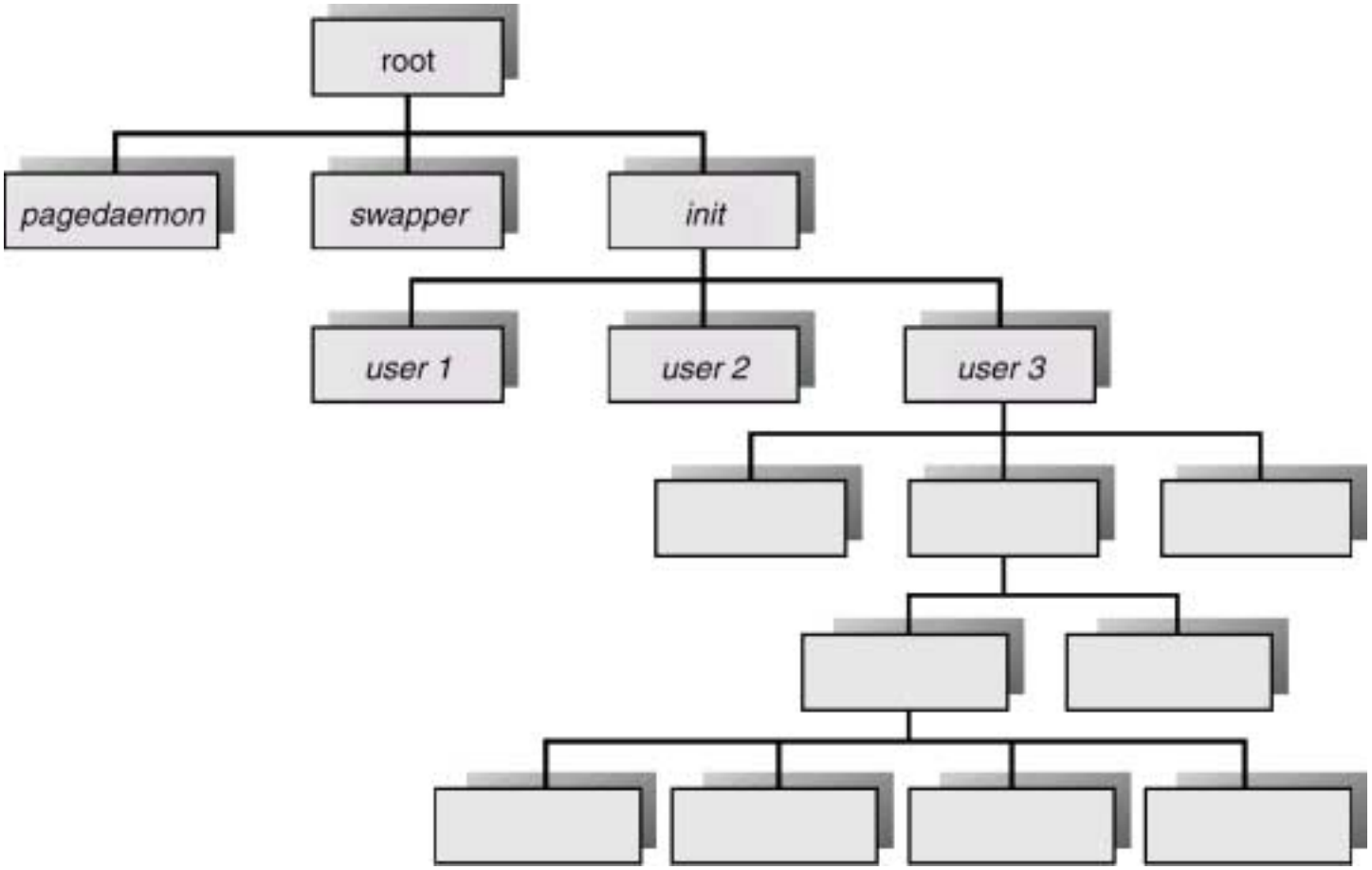
How does process know to continue?

OS sends SIGCHLD signal.

Process Creation (Cont.)

- Address space
  - Child duplicate of parent.
  - Child has a program loaded into it.
- UNIX examples
  - **fork** system call creates new process
  - **execve** system call used after a **fork** to replace the process' memory space with a new program.

A Tree of Processes On A Typical UNIX System



Process Termination

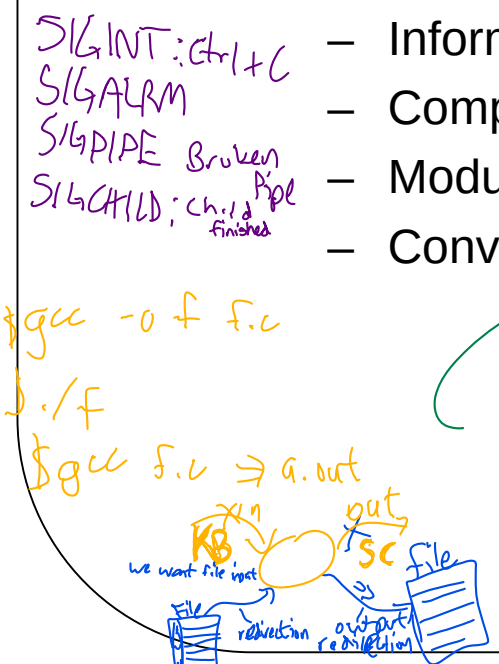
- Process executes last statement and asks the operating system to decide it (**exit**).
  - Output data from child to parent (via **wait**).
  - Process' resources are deallocated by operating system.
- Parent may terminate execution of children processes (**abort**).
  - Child has exceeded allocated resources.
  - Task assigned to child is no longer required.
  - Parent is exiting.
    - Operating system does not allow child to continue if its parent terminates.
    - Cascading termination.

wait will release PID

1. child dead & parent alive ∴ Pid taken
   2. Kill parent
2. child alive & parent dead ∴ init adopt

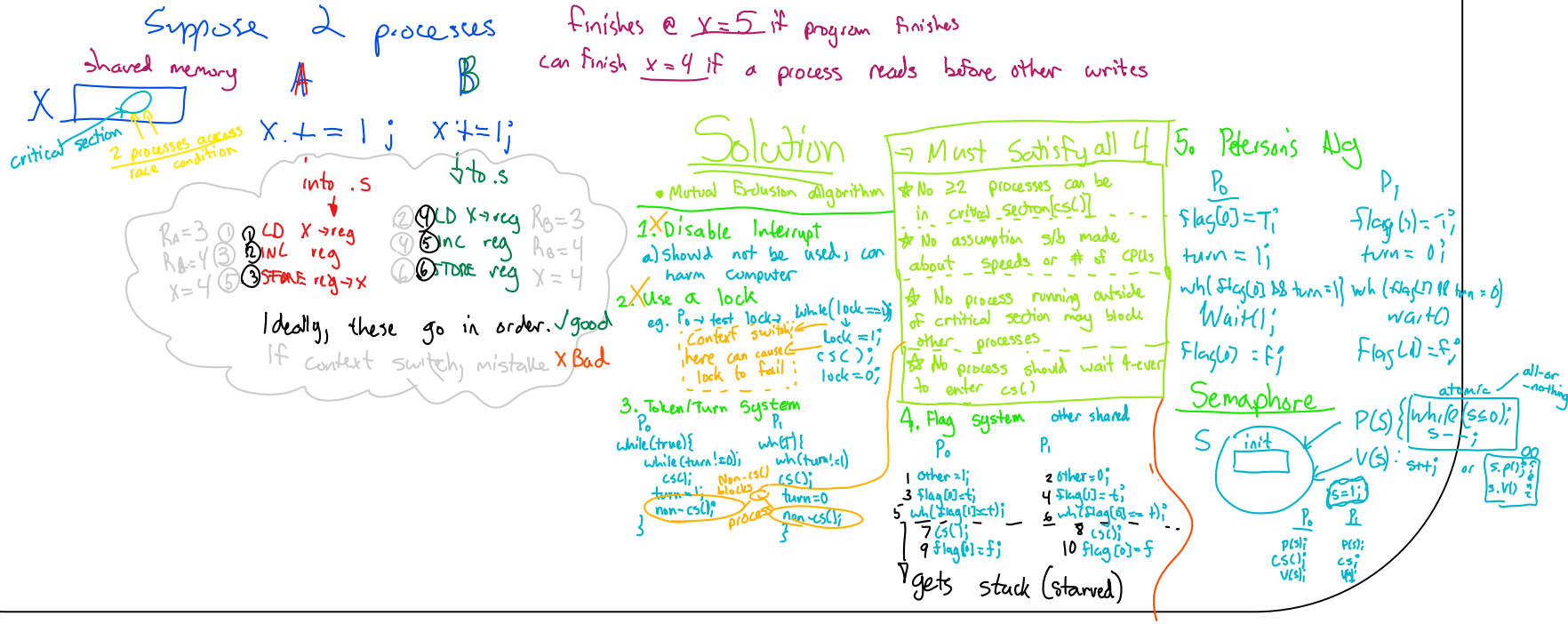
Cooperating Processes

- *Independent* process cannot affect or be affected by the execution of another process.
- *Cooperating* process can affect or be affected by the execution of another process
- Advantages of process cooperation
  - Information sharing
  - Computation speed-up
  - Modularity
  - Convenience

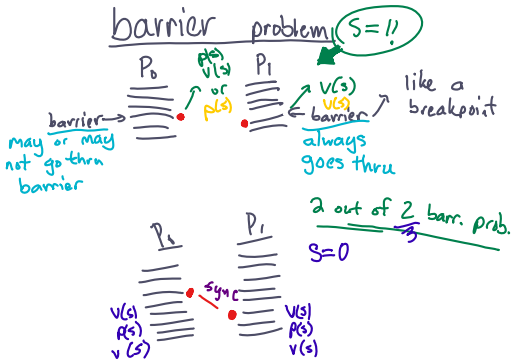


Producer-Consumer Problem

- Paradigm for cooperating processes, *producer* process produces information that is consumed by a *consumer* process.
  - *unbounded-buffer* places no practical limit on the size of the buffer.
  - *bounded-buffer* assumes that there is a fixed buffer size.



Bounded-Buffer – Shared-Memory Solution



- Shared data

  var *n*;

  type *item* = … ;

  var *buffer*. **array** [0..*n*–1] **of** *item*;

  in, out: 0..*n*–1;

- Producer process

  repeat

  …

  produce an item in *nextp*

  …

  while *in*+1 **mod** *n* = *out* **do** *no-op;*

  buffer [*in*] :=*nextp*;

  in :=*in*+1 **mod** *n*;

  until *false*;

Bounded-Buffer (Cont.)

- Consumer process

```
repeat
    while in = out do no-op;
    nextc := buffer [out];
    out := out+1 mod n;
      …
    consume the item in nextc
      …
    until false;
```

- Solution is correct, but can only fill up n–1 buffer.

Interprocess Communication (IPC)

- Mechanism for processes to communicate and to synchronize their actions.
- Message system – processes communicate with each other without resorting to shared variables.
- IPC facility provides two operations:
  - **send**(*message*) – message size fixed or variable
  - **receive**(*message*)
- If *P* and *Q* wish to communicate, they need to:
  - establish a *communication link* between them
  - exchange messages via send/receive
- Implementation of communication link
  - physical (e.g., shared memory, hardware bus)
  - logical (e.g., logical properties)

Implementation Questions

- How are links established?
- Can a link be associated with more than two processes?
- How many links can there be between every pair of communicating processes?
- What is the capacity of a link?
- Is the size of a message that the link can accommodate fixed or variable?
- Is a link unidirectional or bi-directional?

Direct Communication

- Processes must name each other explicitly:
  - **send** (*P, message*) – send a message to process P
  - **receive**(*Q, message*) – receive a message from process Q
- Properties of communication link
  - Lilnks are established automatically.
  - A link is associated with exactly one pair of communicating processes.
  - Between each pair there exists exactly one link.
  - The link may be unidirectional, but is usually bi-directional.

Indirect Communication

- Messages are directed and received from mailboxes (also referred to as ports).
  - Each mailbox has a unique id.
  - Processes can communicate only if they share a mailbox.
- Properties of communication link
  - Link established only if processes share a common mailbox
  - A link may be associated with many processes.
  - Each pair of processes may share several communication links.
  - Link may be unidirectional or bi-directional.
- Operations
  - create a new mailbox
  - send and receive messages through mailbox
  - destroy a mailbox

Indirect Communication (Continued)

- Mailbox sharing
  - P_1, P_2, and P_3 share mailbox A.
  - P_1, sends; P_2 and P_3 receive.
  - Who gets the message?
- Solutions
  - Allow a link to be associated with at most two processes.
  - Allow only one process at a time to execute a receive operation.
  - Allow the system to select arbitrarily the receiver. Sender is notified who the receiver was.

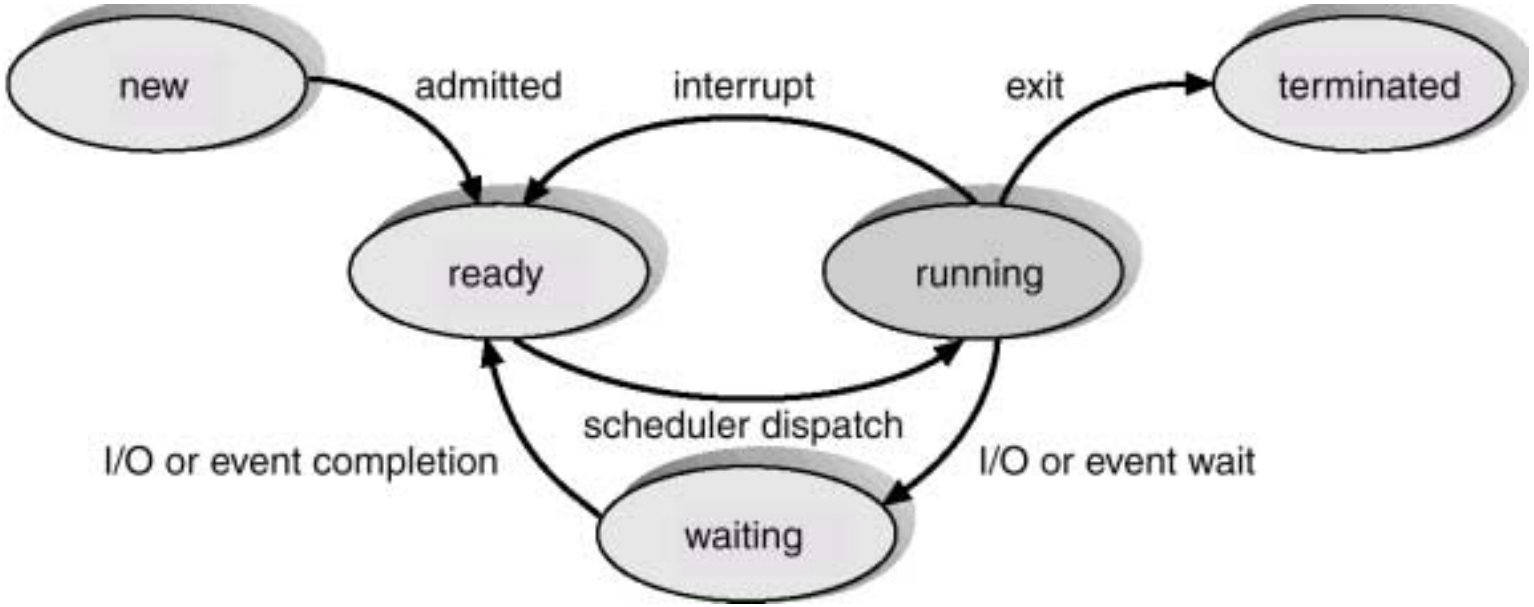
Buffering

- Queue of messages attached to the link; implemented in one of three ways.
  1. Zero capacity – 0 messages
     Sender must wait for receiver (rendezvous).
  2. Bounded capacity – finite length of *n* messages
     Sender must wait if link full.
  3. Unbounded capacity – infinite length
     Sender never waits.

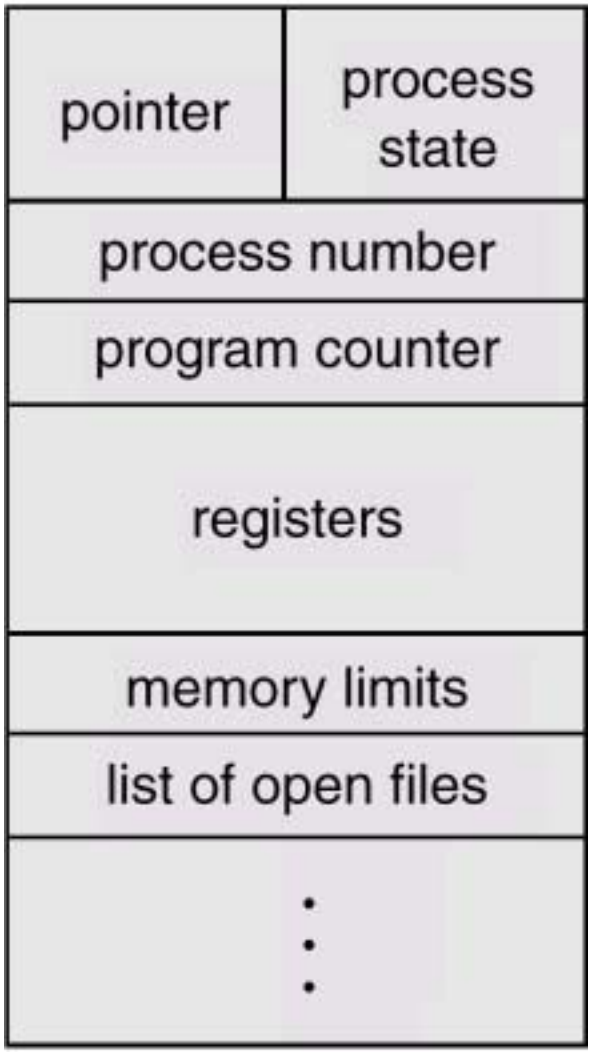
Exception Conditions – Error Recovery

- Process terminates
- Lost messages
- Scrambled Messages

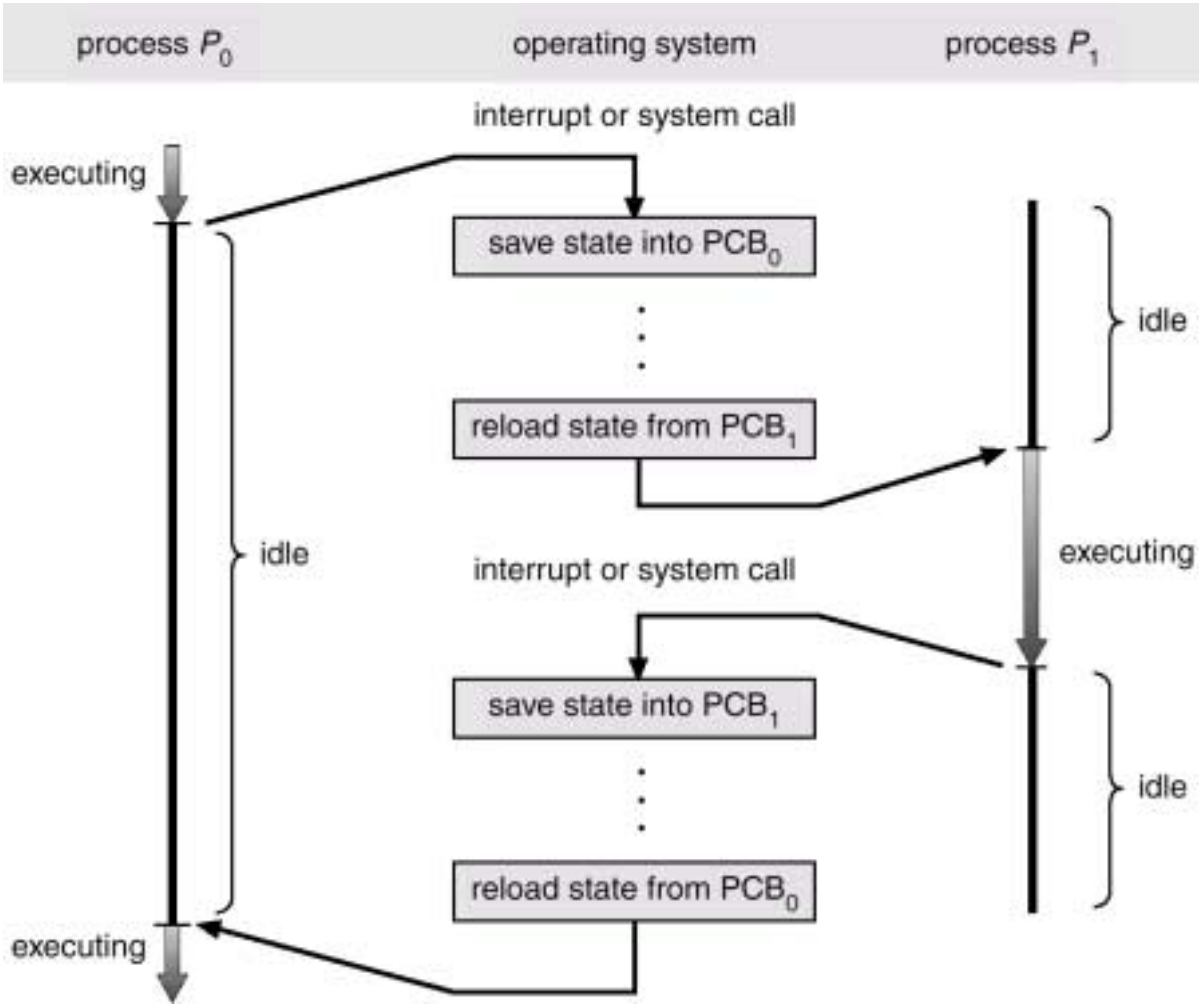
4.01


new
admitted
interrupt
exit
terminated
ready
running
scheduler dispatch
I/O or event completion
I/O or event wait
waiting

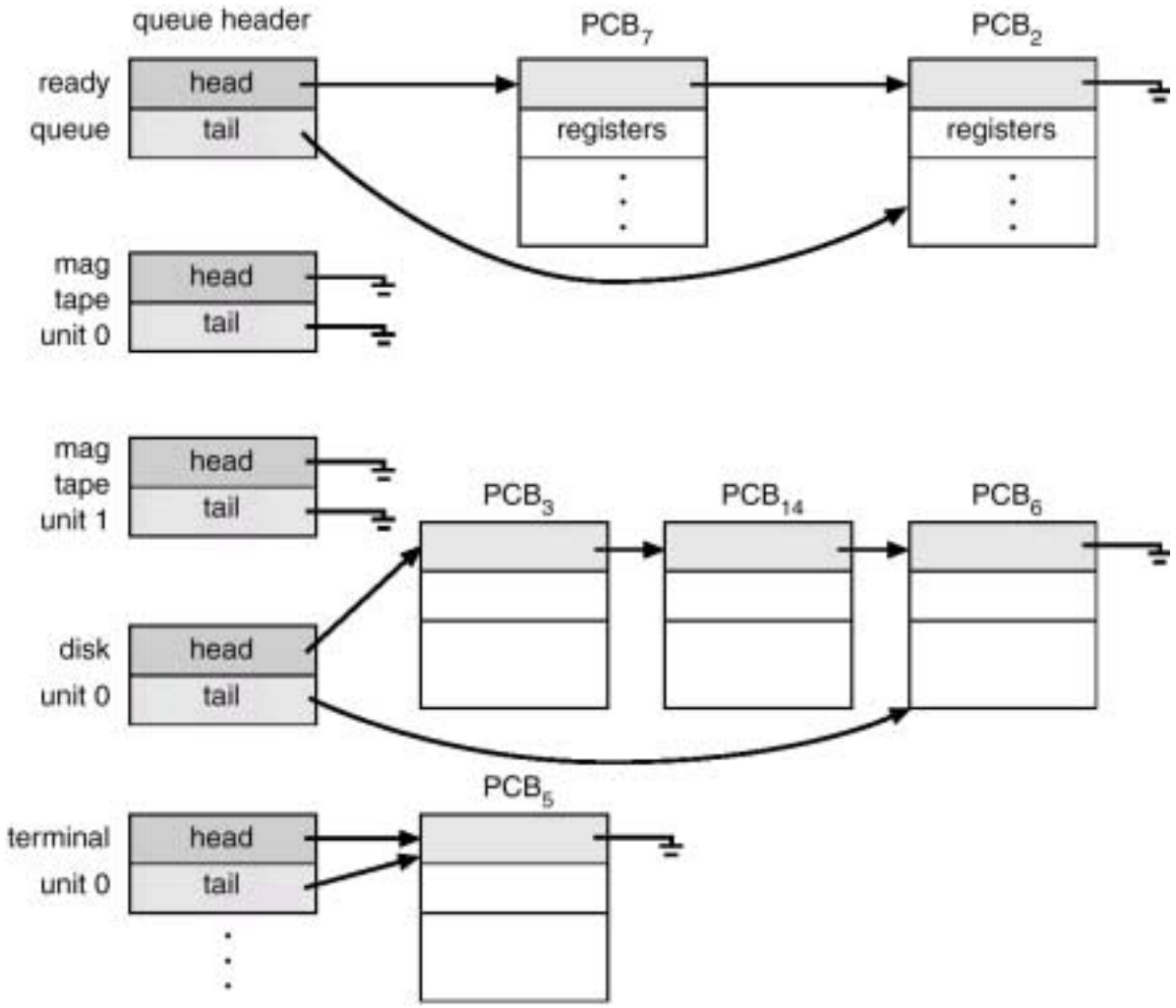
4.02


pointer
process state
process number
program counter
registers
memory limits
list of open files

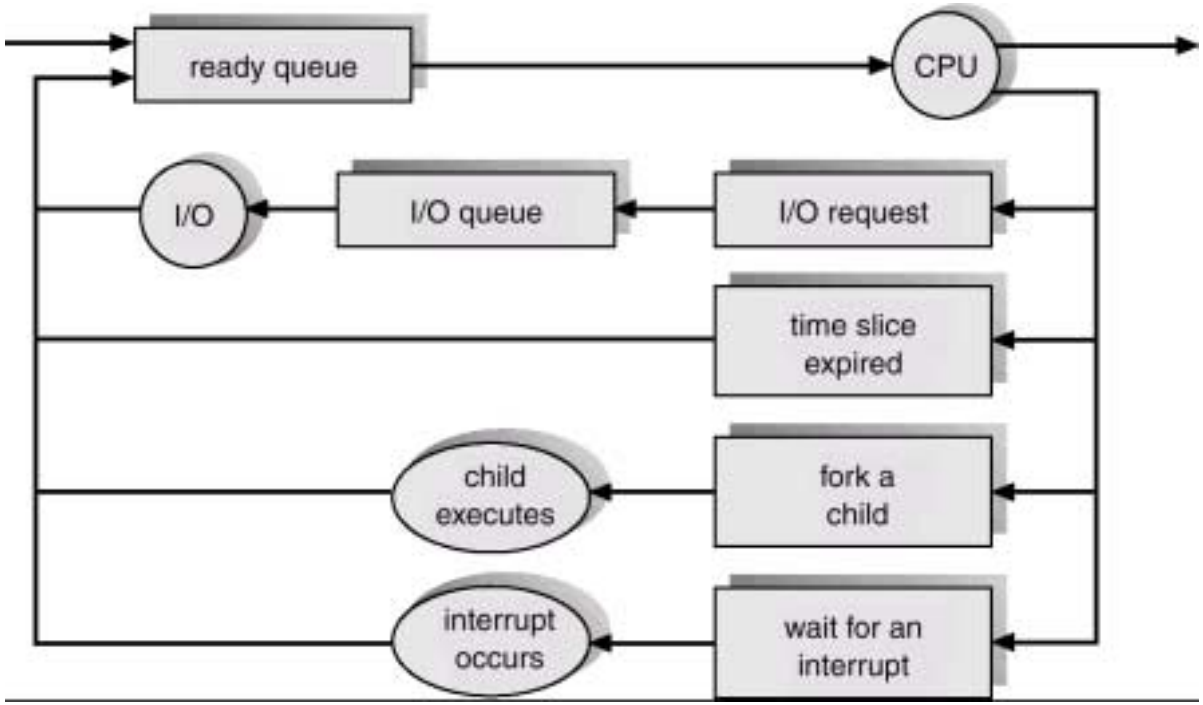
4.03


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
executing
interrupt or system call
save state into PCB_1
idle
reload state from PCB_0
executing

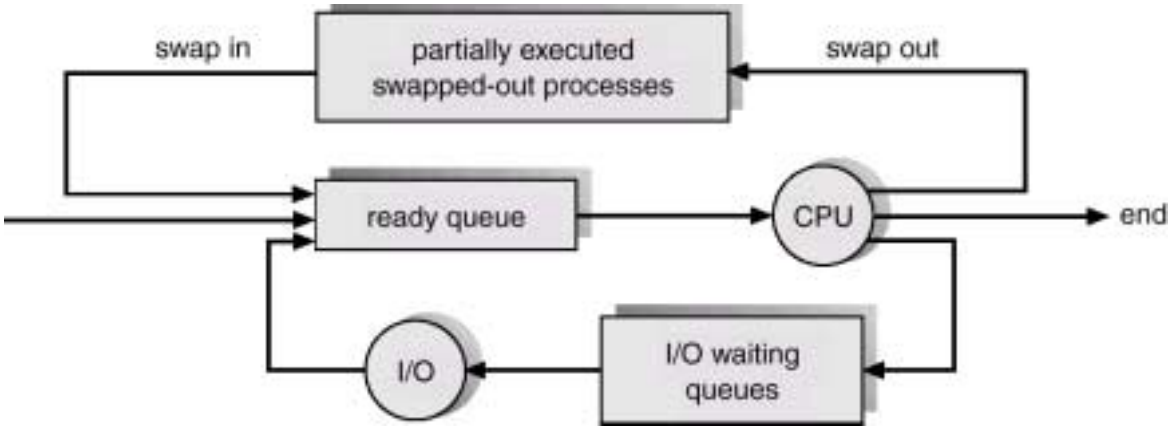
4.04


queue header
PCB7
PCB2
ready
queue
head
tail
registers
registers
mag
tape
unit 0
head
tail
mag
tape
unit 1
head
tail
PCB3
PCB14
PCB6
disk
unit 0
head
tail
PCB5
terminal
unit 0
head
tail

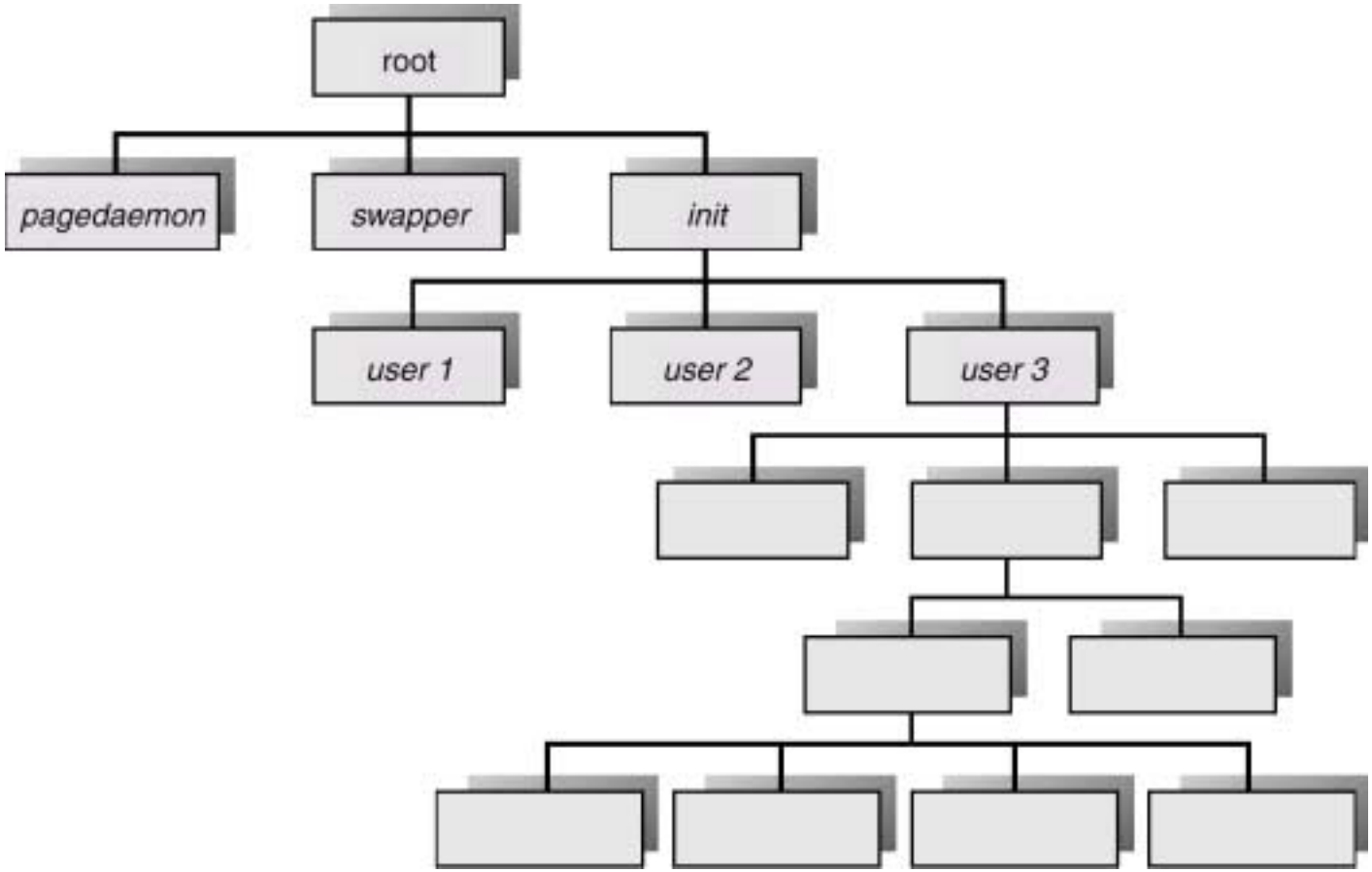
4.05


ready queue
CPU
I/O
I/O queue
I/O request
time slice expired
child executes
fork a child
interrupt occurs
wait for an interrupt

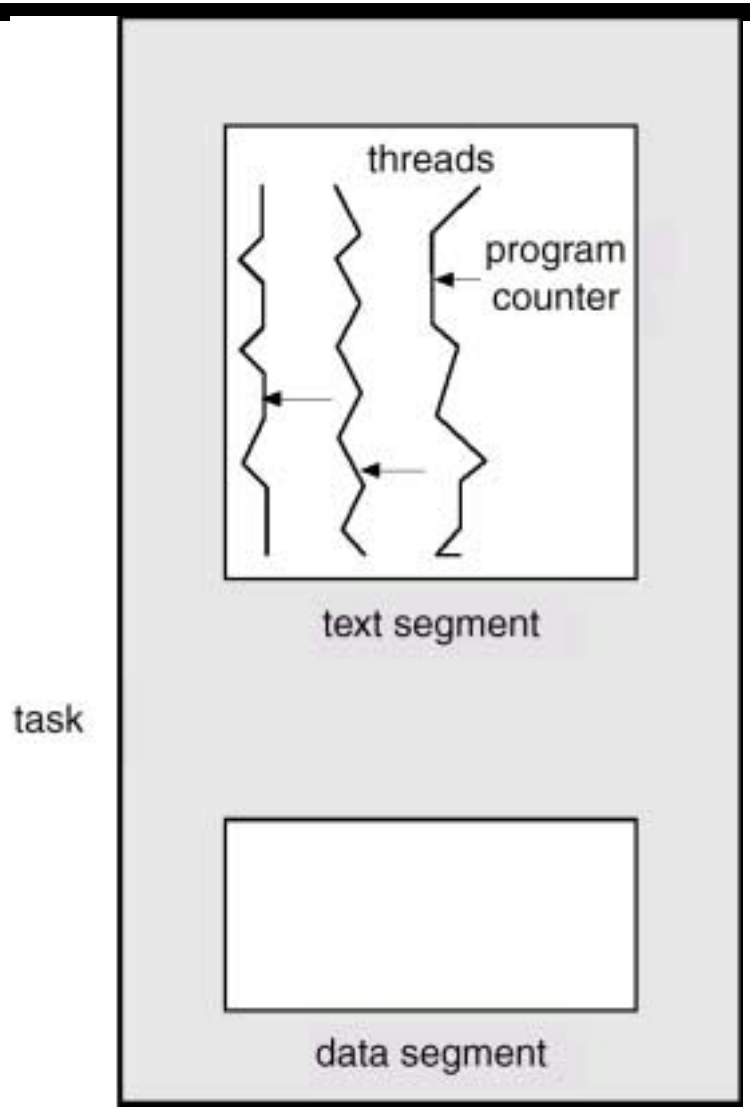
4.06


swap in
partially executed
swapped-out processes
swap out
ready queue
CPU
end
I/O
I/O waiting
queues

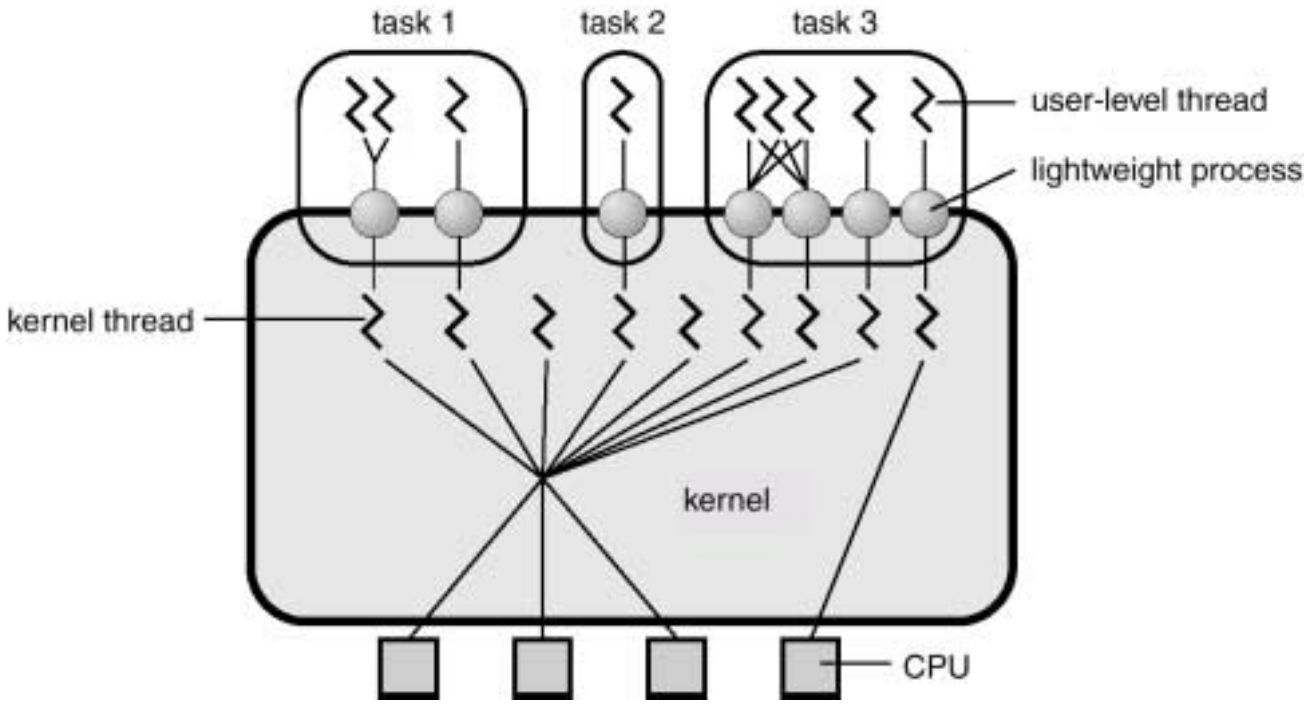
4.07



4.08



4.09


task 1
task 2
task 3
user-level thread
lightweight process
kernel thread
kernel
CPU