Module 4: Processes

Super important and special

- 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.

Gets all resources except CPU

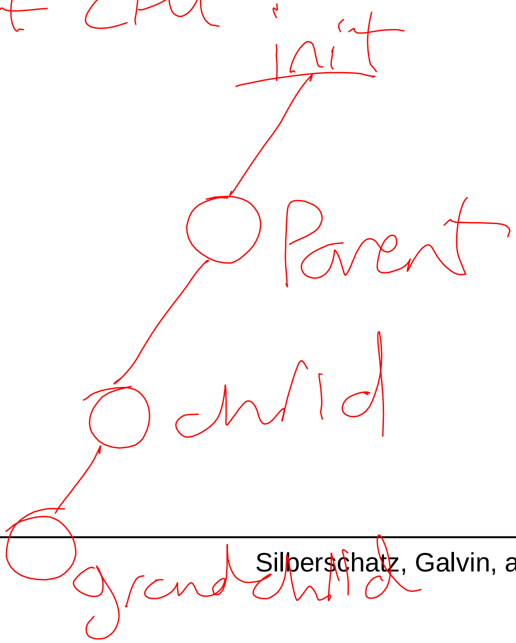
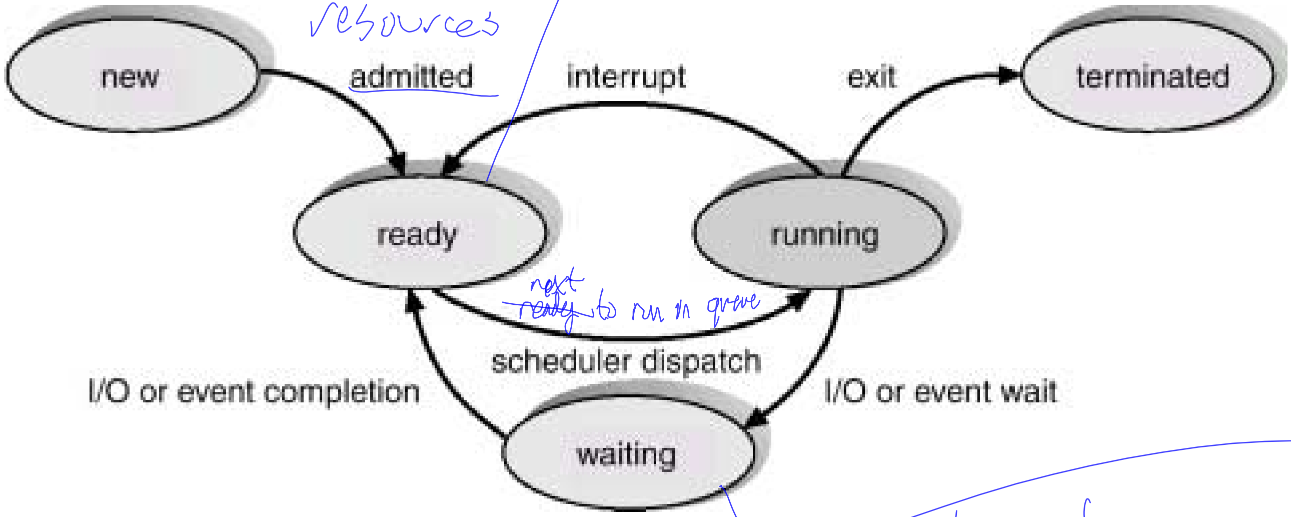


Diagram of Process State

waiting for CPU

acquired resources



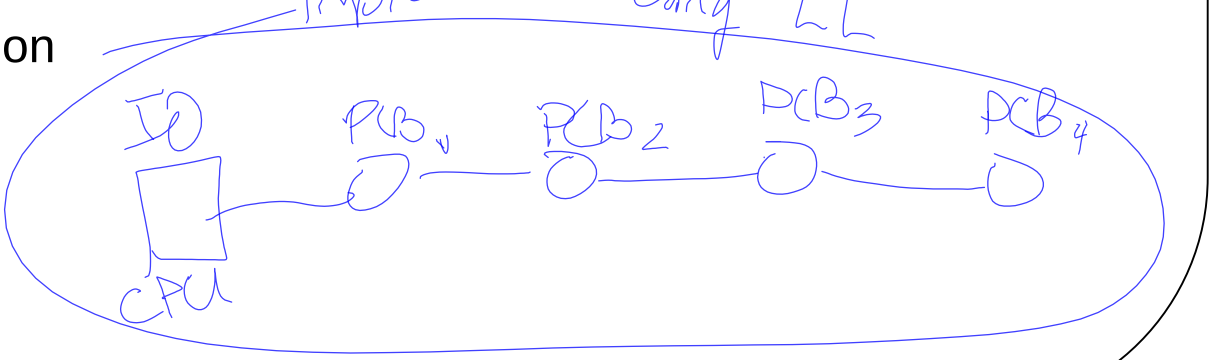
waiting for resource

Process Control Block (PCB)

Information associated with each process.

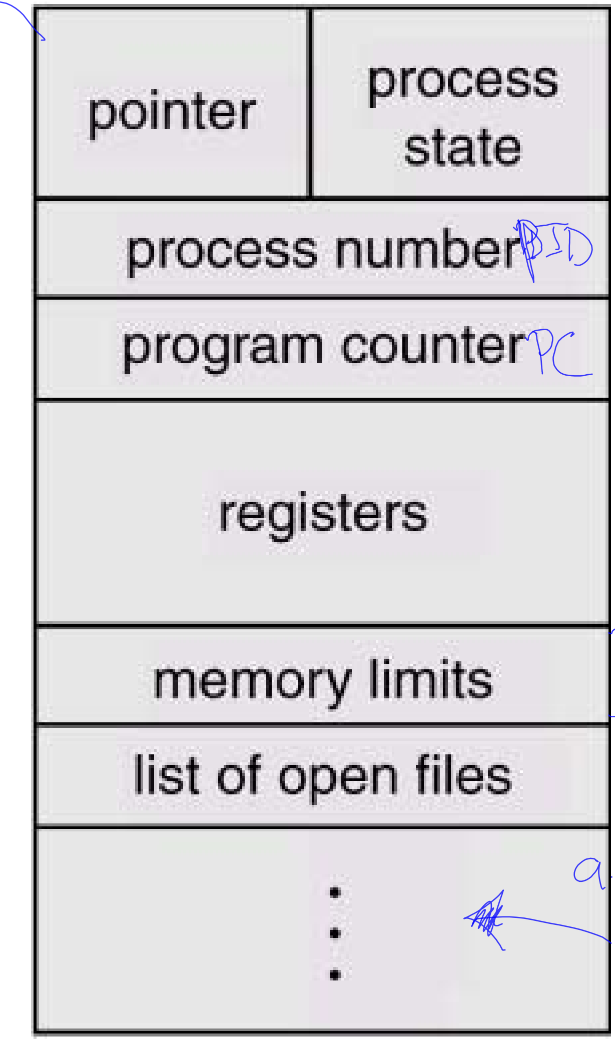
- Process state
- Program counter
- CPU registers
- CPU scheduling information
- Memory-management information
- Accounting information
- I/O status information

Implemented using LL



Process Control Block (PCB)

Is a queue like a linked list



pointer

process state

process number PID

program counter PC

registers

memory limits

list of open files

•
•
•

each process has one

Sometimes used as a reference

SW trap Interrupt

accounting information (stats)

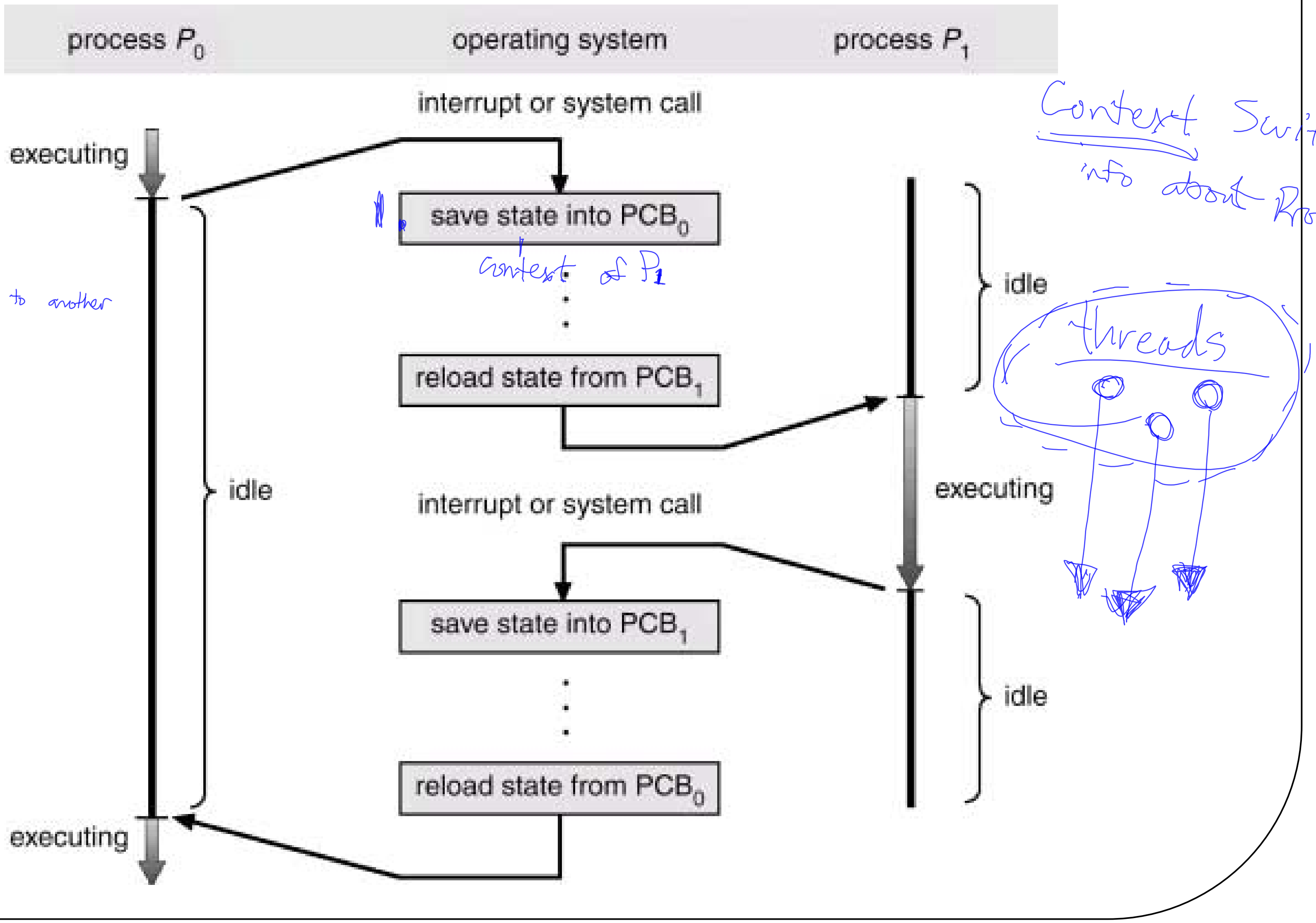
CPU Switch From Process to Process

Context switch

Switch from one process to another

Context Switch

info about Process



process P_0

operating system

process P_1

interrupt or system call

executing

save state into PCB_0

context of P_1

reload state from PCB_1

idle

idle

executing

interrupt or system call

save state into PCB_1

reload state from PCB_0

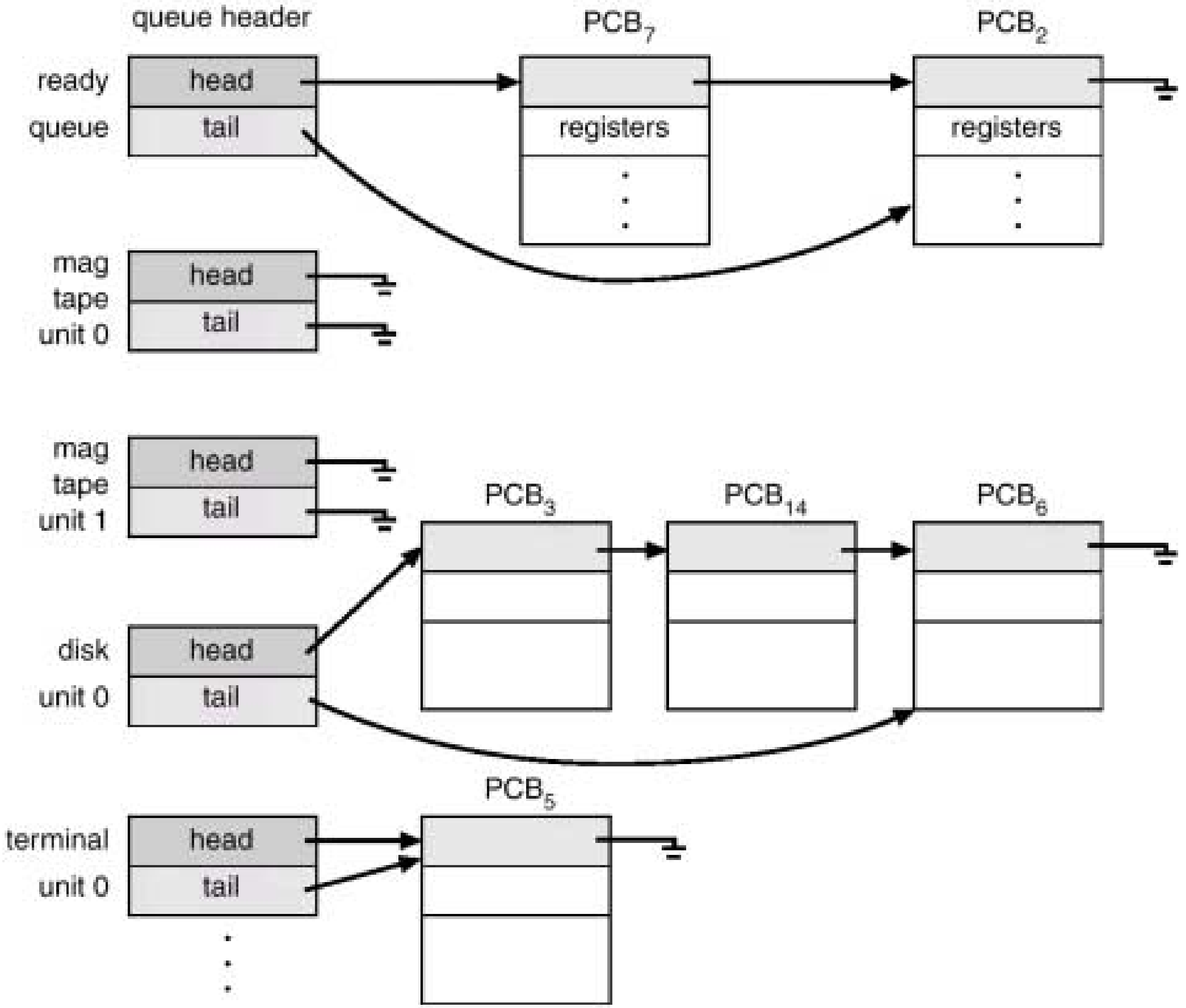
idle

executing

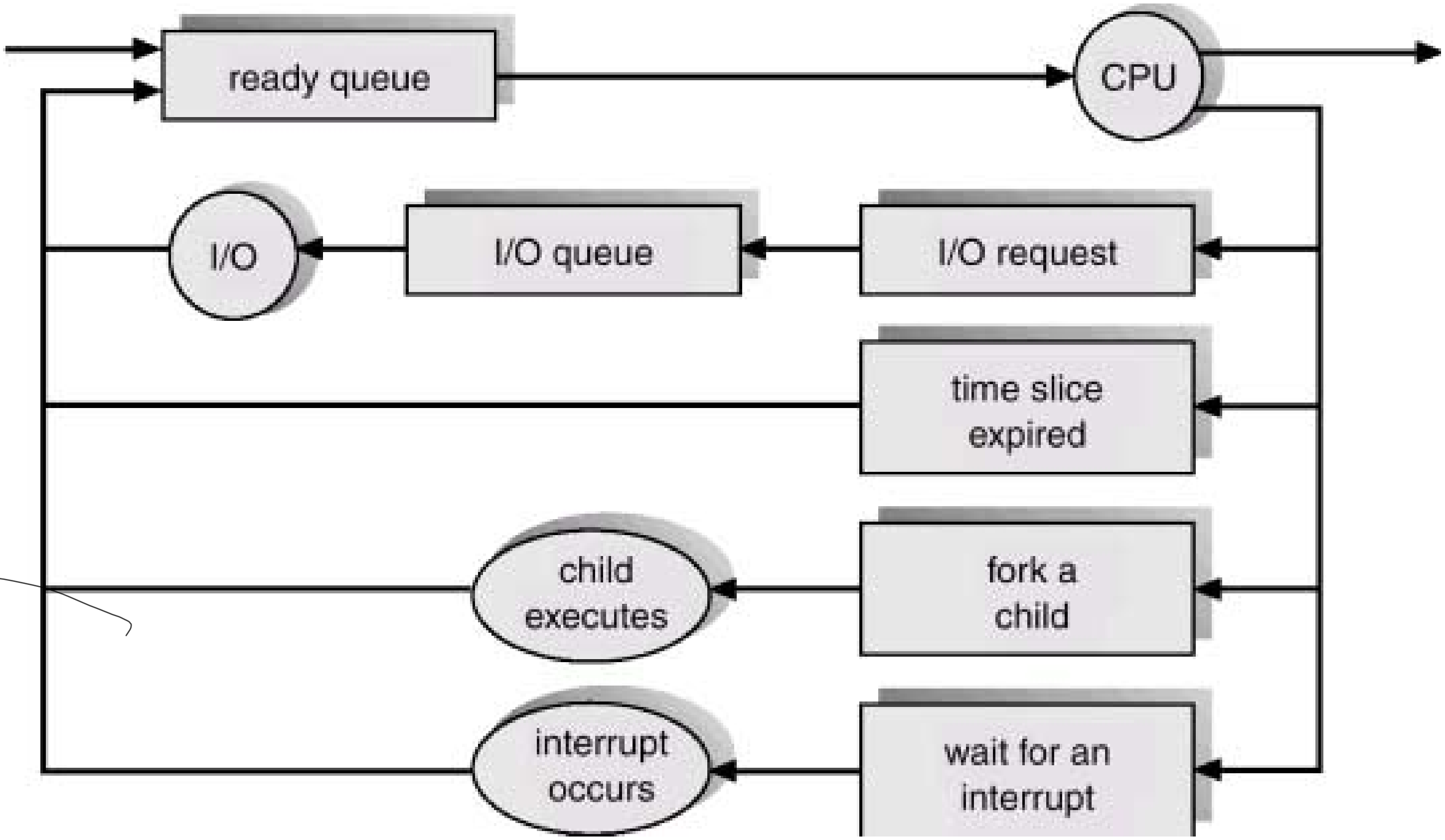
Process Scheduling Queues

- 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

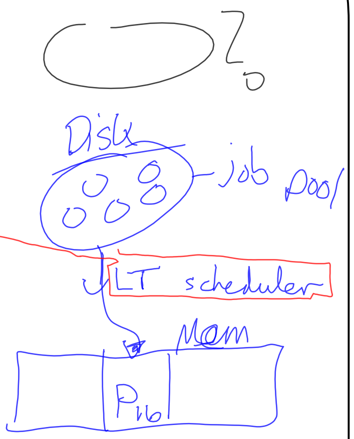


Representation of Process Scheduling



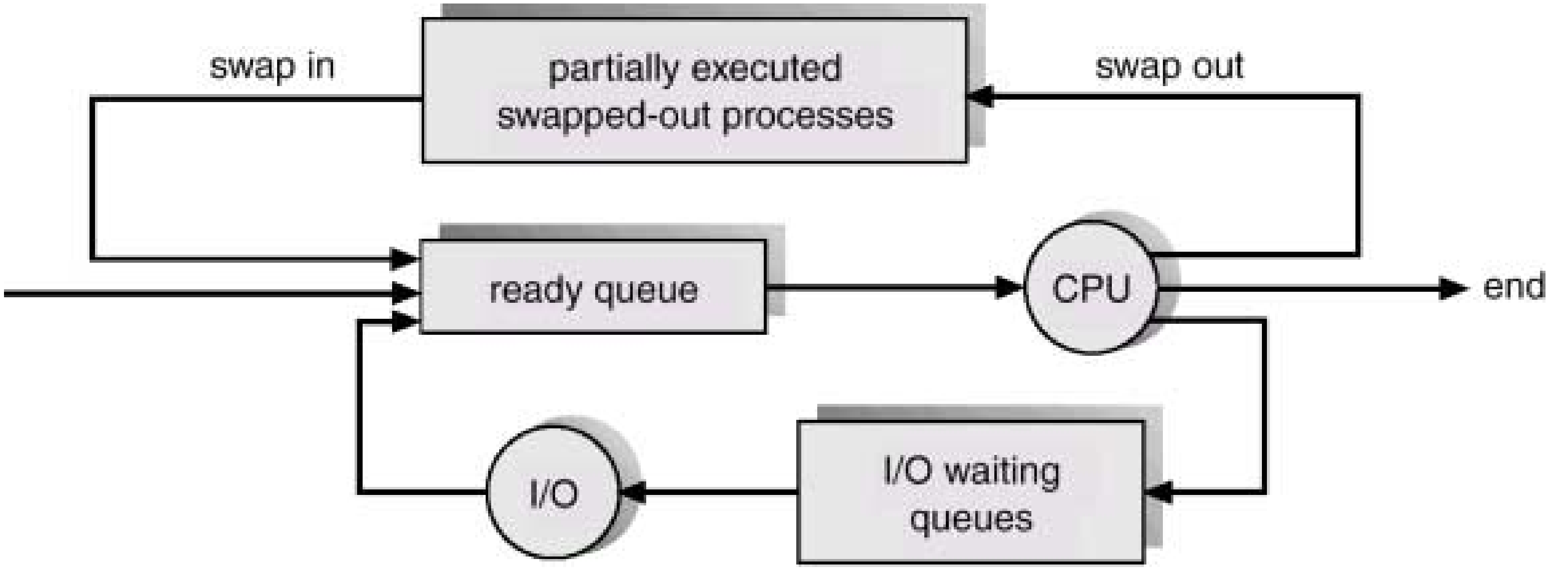
Schedulers

- 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) ⇒ (must be fast).
- Long-term scheduler is invoked very infrequently (seconds, minutes) ⇒ (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)

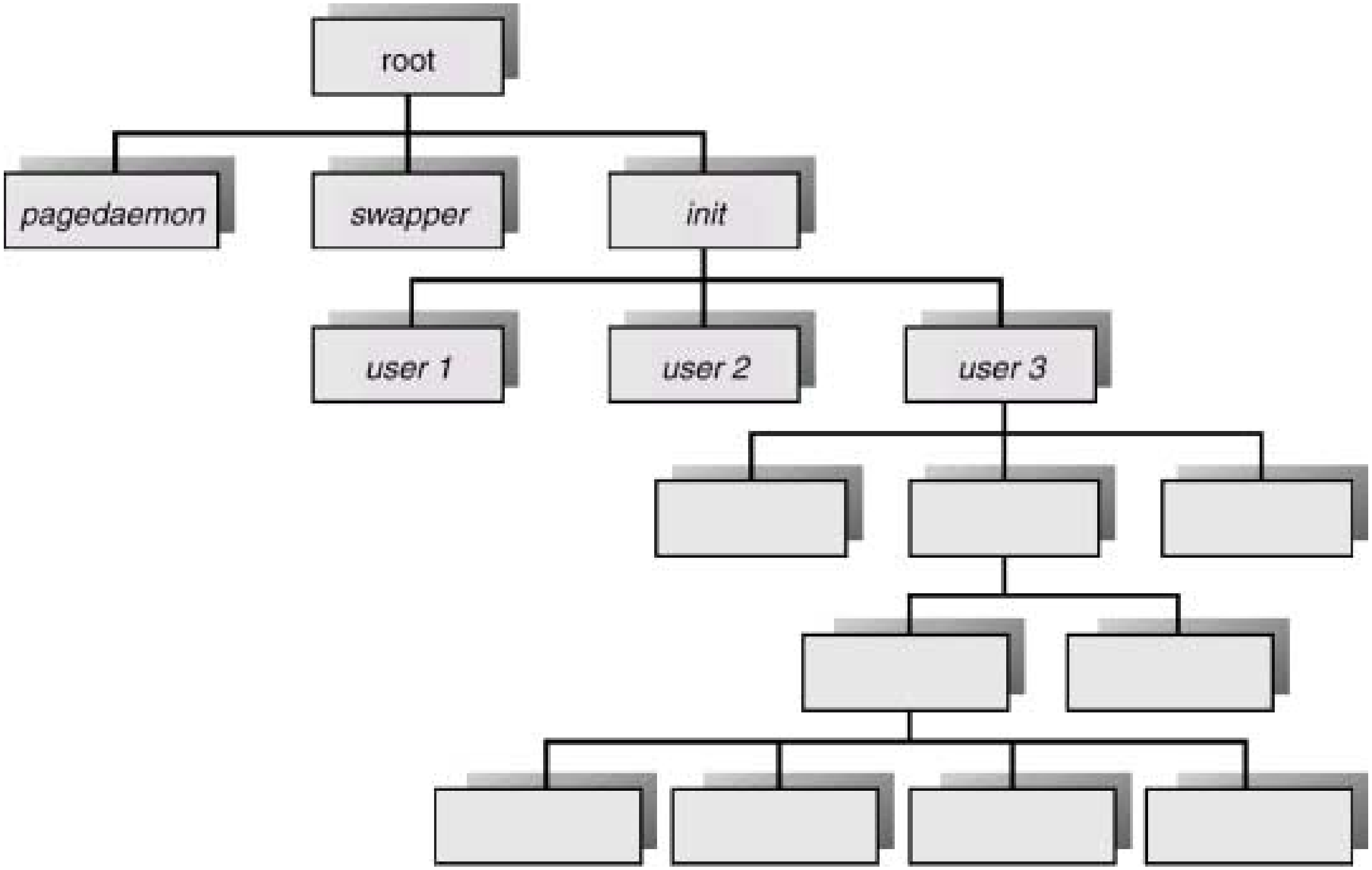
How does process know to continue?

OS sends SIGCHILD 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**). wait will release PID
  - 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.

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

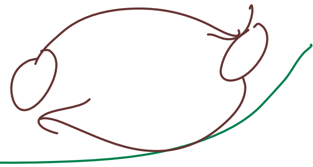
Cooperating Processes

- *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

SIGINT: Ctrl+C
SIGALRM
SIGPIPE Broken Pipe

IPC

1. Shared memory
2. signal
3. Pipe
4. socket (msg-passing)



signal

1. use keyboard Ctrl+C = (SIGINT) Interrupt
Ctrl+\ = (SIGABRT)

2. CMD $KILL -9 5322 pid

3. Syscall kill(pid, SIGSTOP)
5322

SIGALRM

~~alarm(15)~~
alarm(5) will cancel

signal (SIGALRM, g);
alarm(5)

o

g() {

}

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

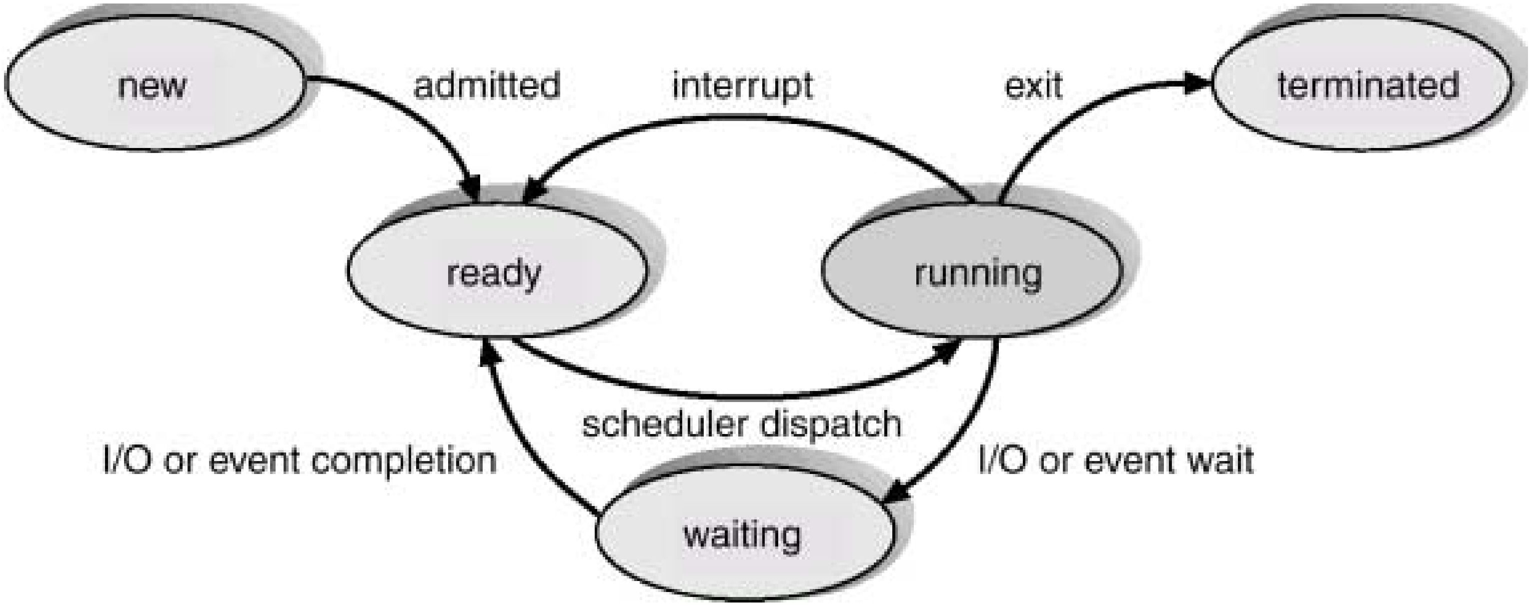
- Queue of messages attached to the link; implemented in one of three ways.

  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.

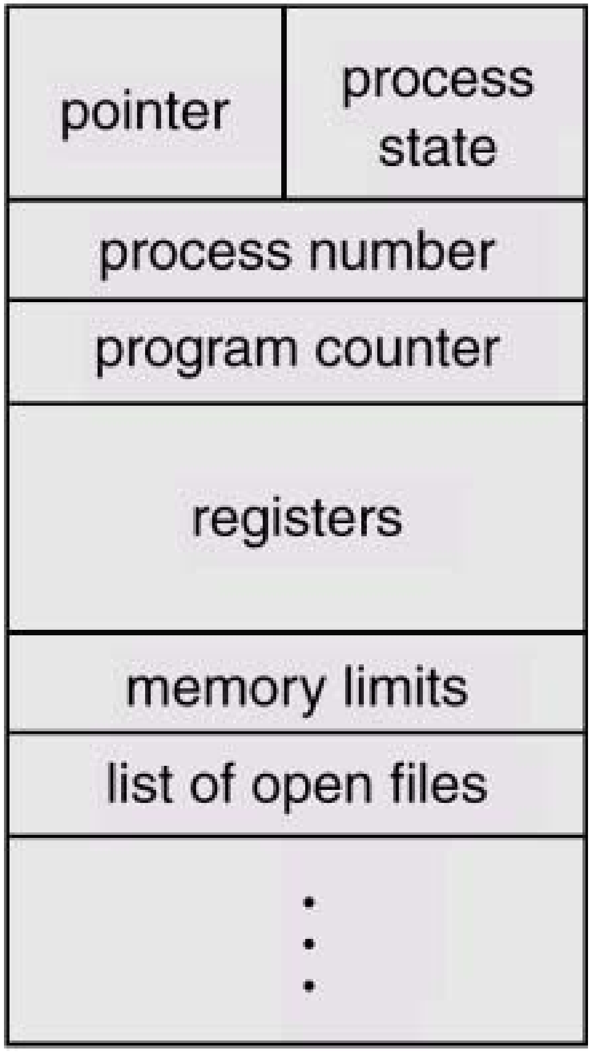
Exception Conditions – Error Recovery

- 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

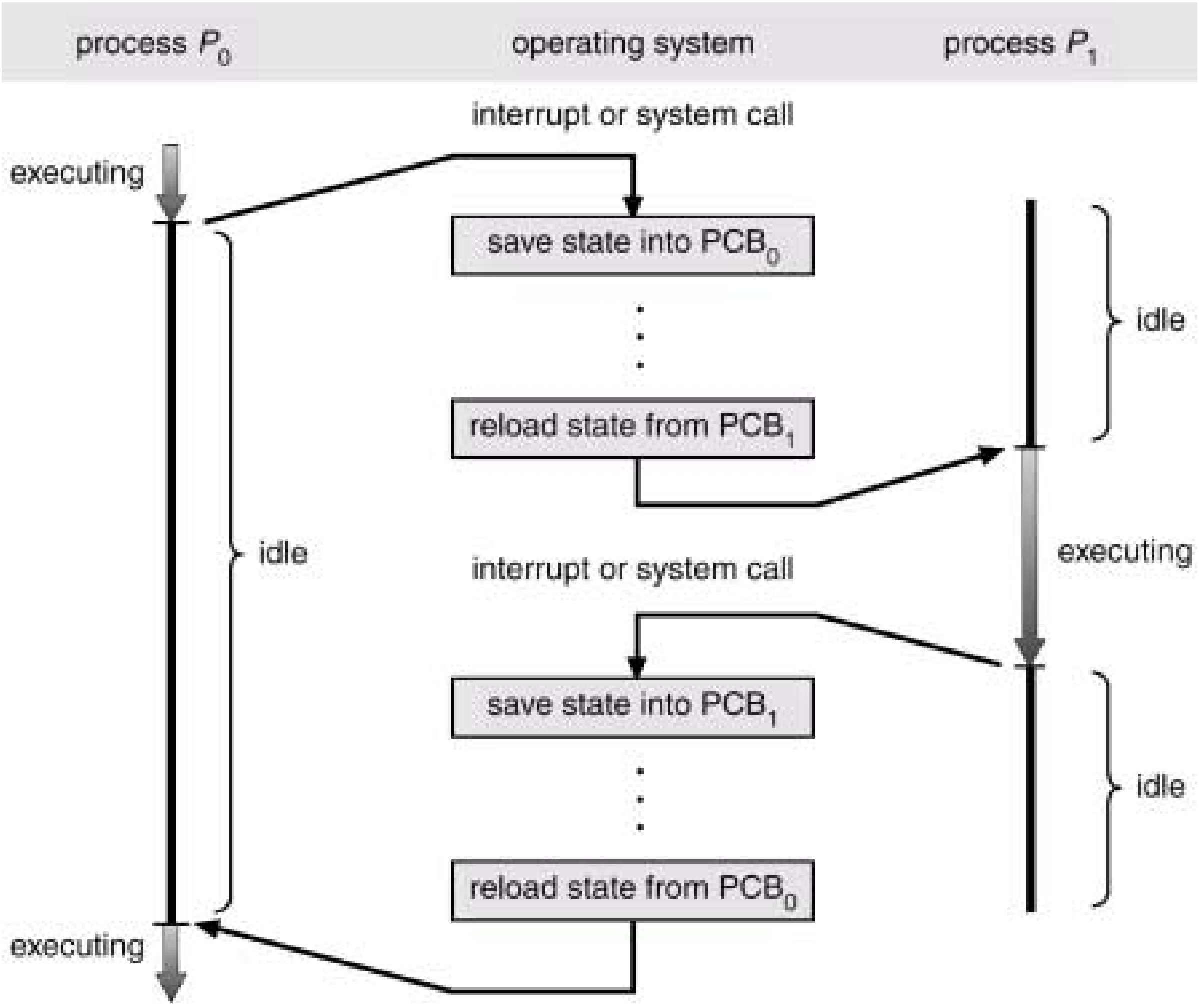
registers

memory limits

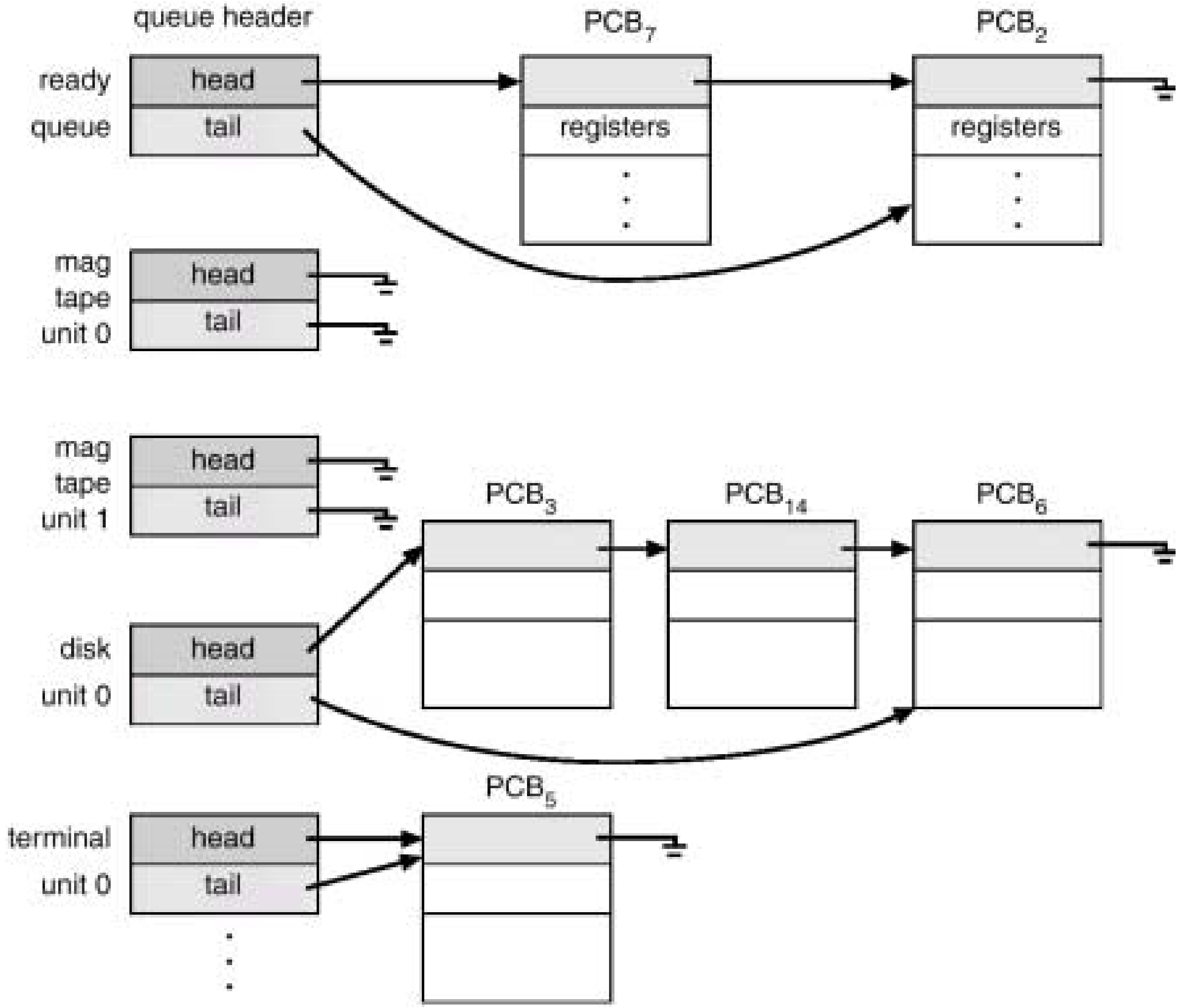
list of open files

•
•
•

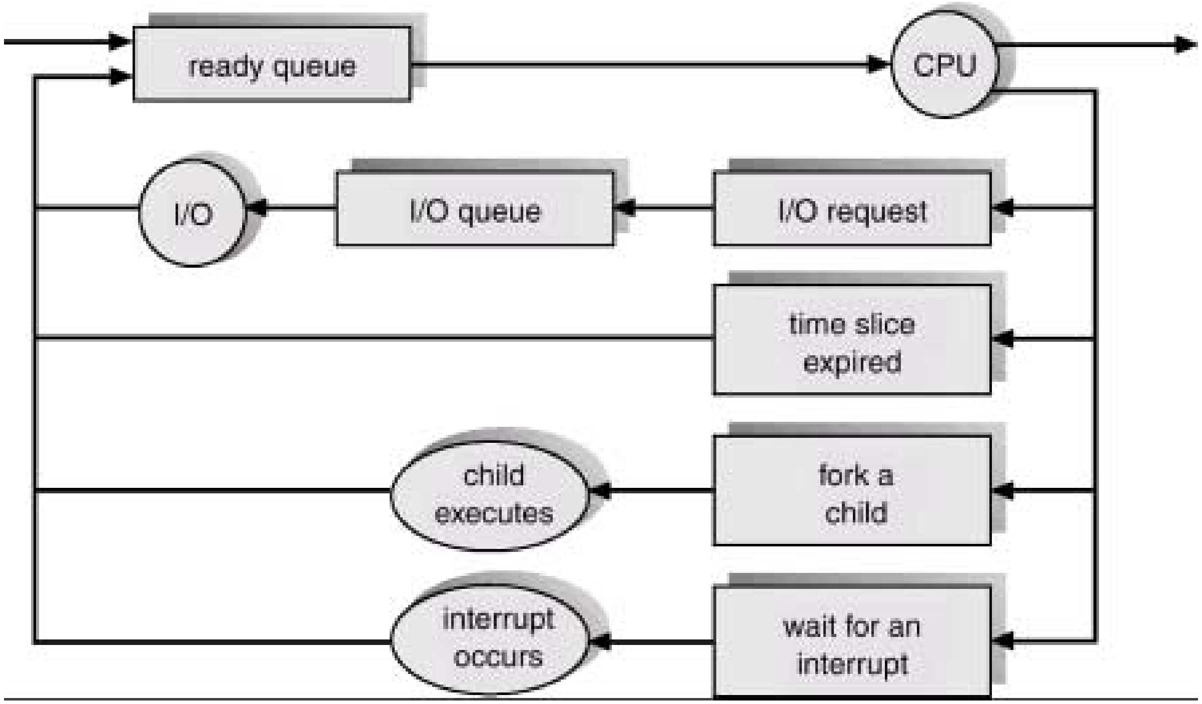
4.03


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

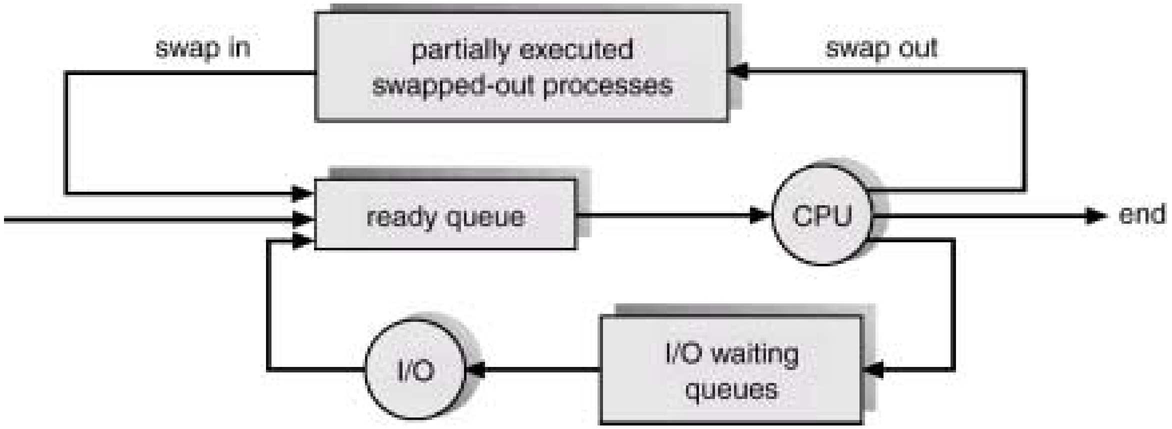
4.04


queue header
ready
queue
head
tail
PCB7
registers
PCB2
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

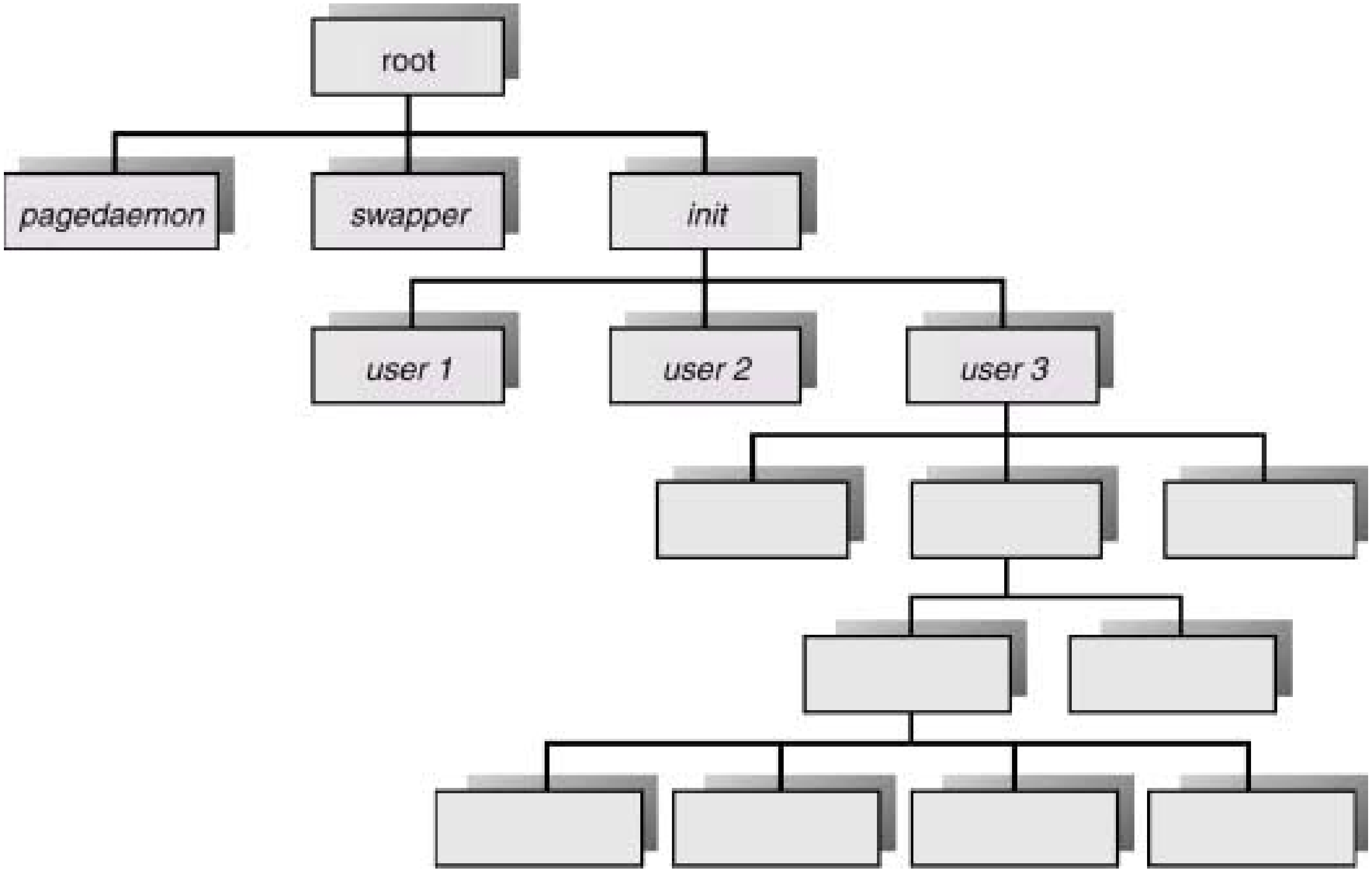
4.05


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

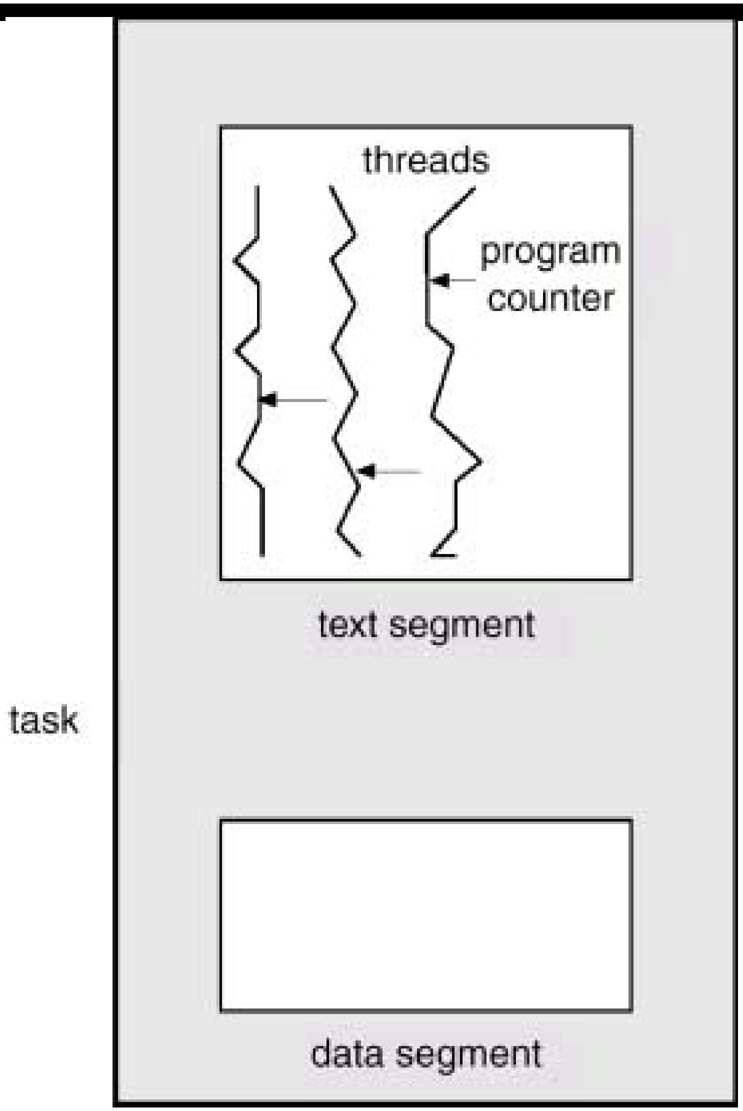
4.06


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

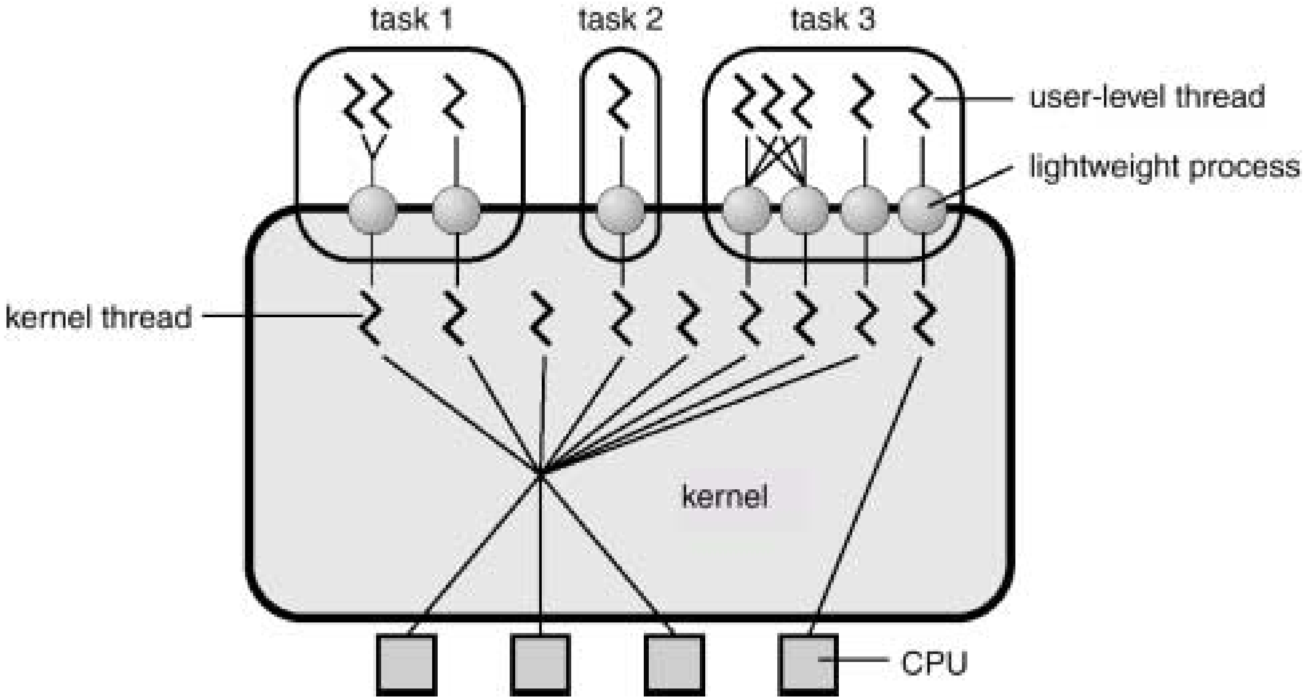
4.07



4.08



4.09


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