

Module 4: Processes

Super important and core

- 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.

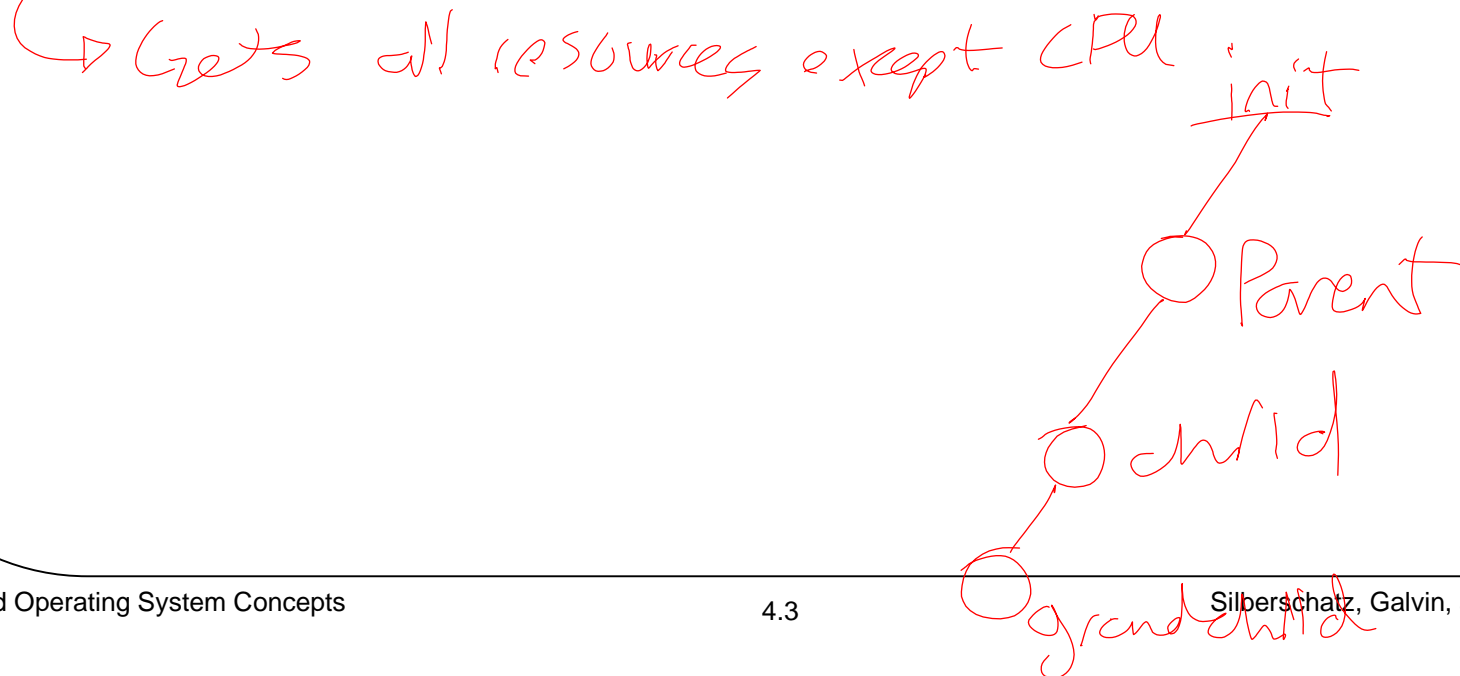
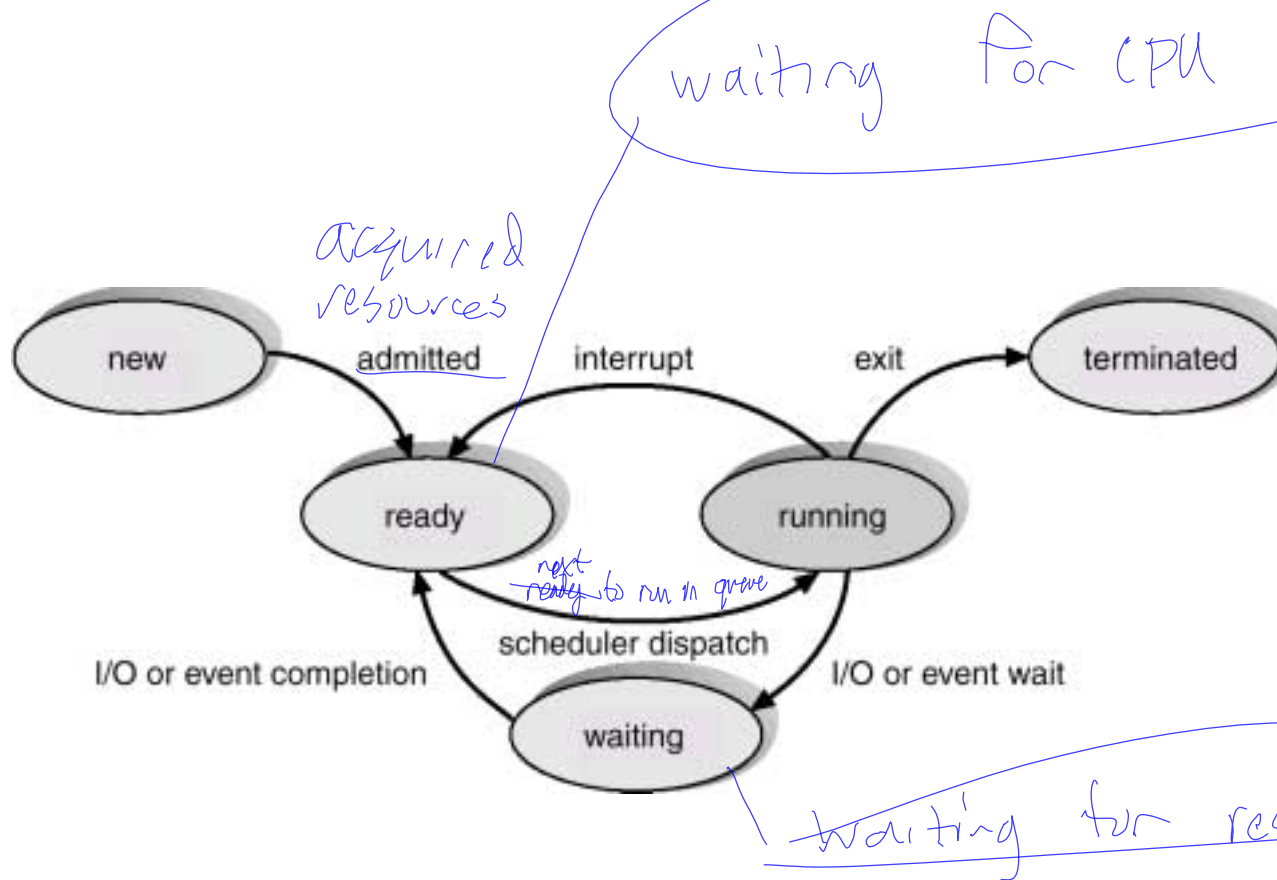


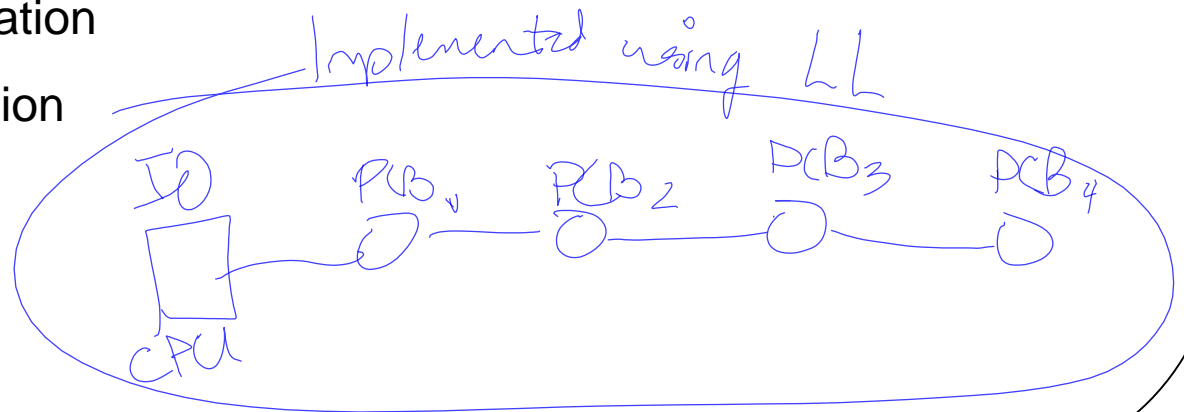
Diagram of Process State



Process Control Block (PCB)

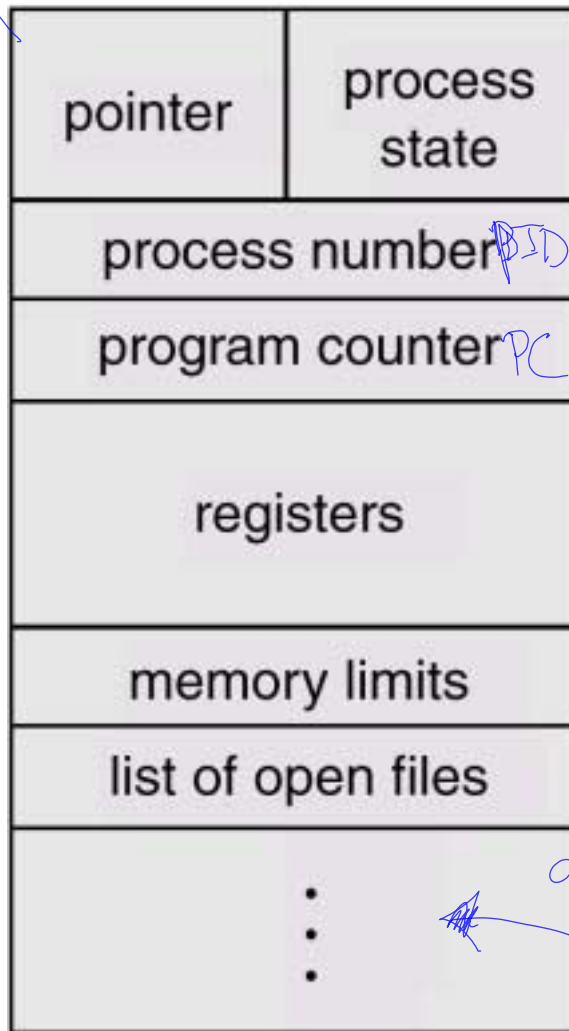
Information associated with each process.

- 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

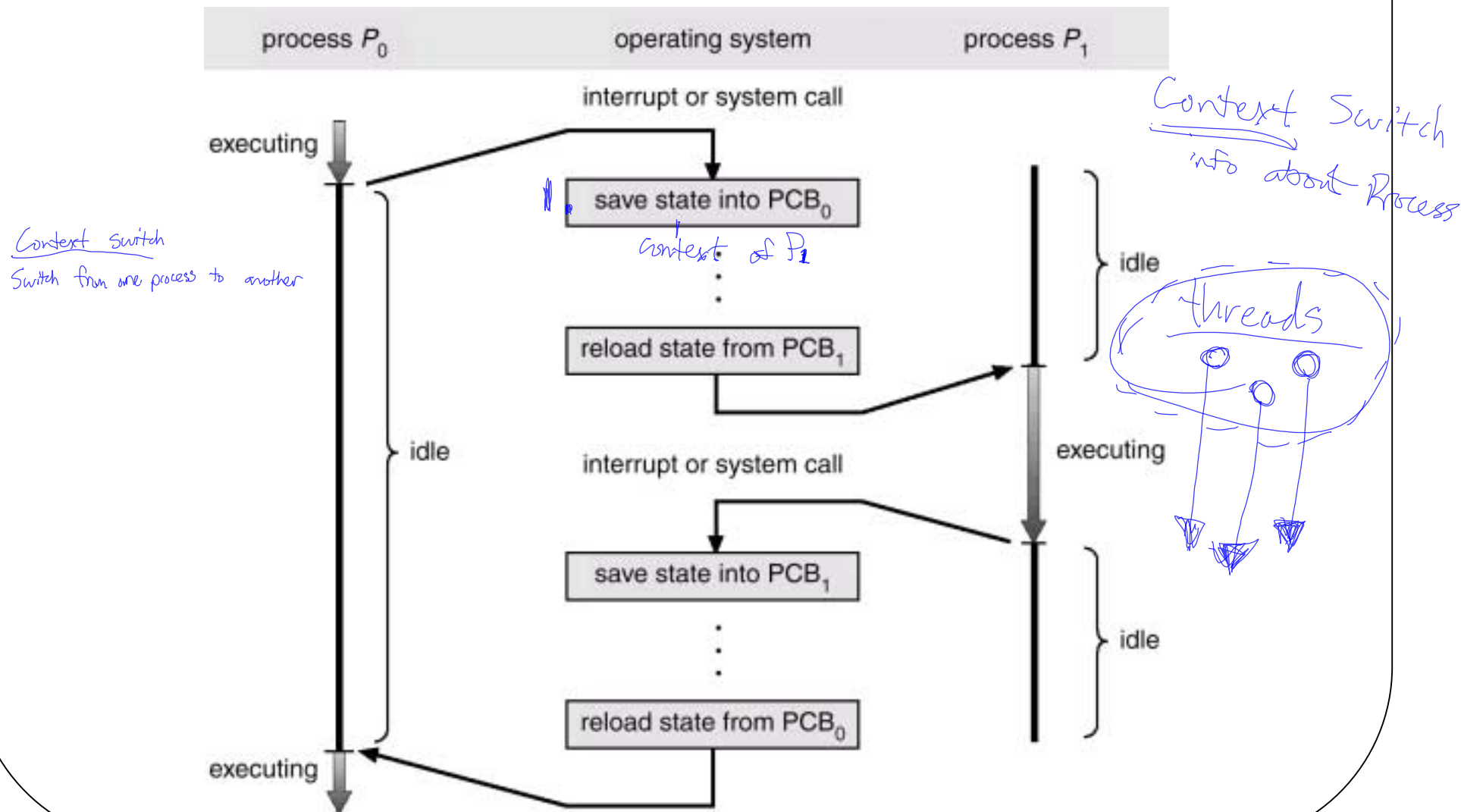


each process
has one
Sometimes used
as a reference

top
SW Interrupt

accounting information
(stats)

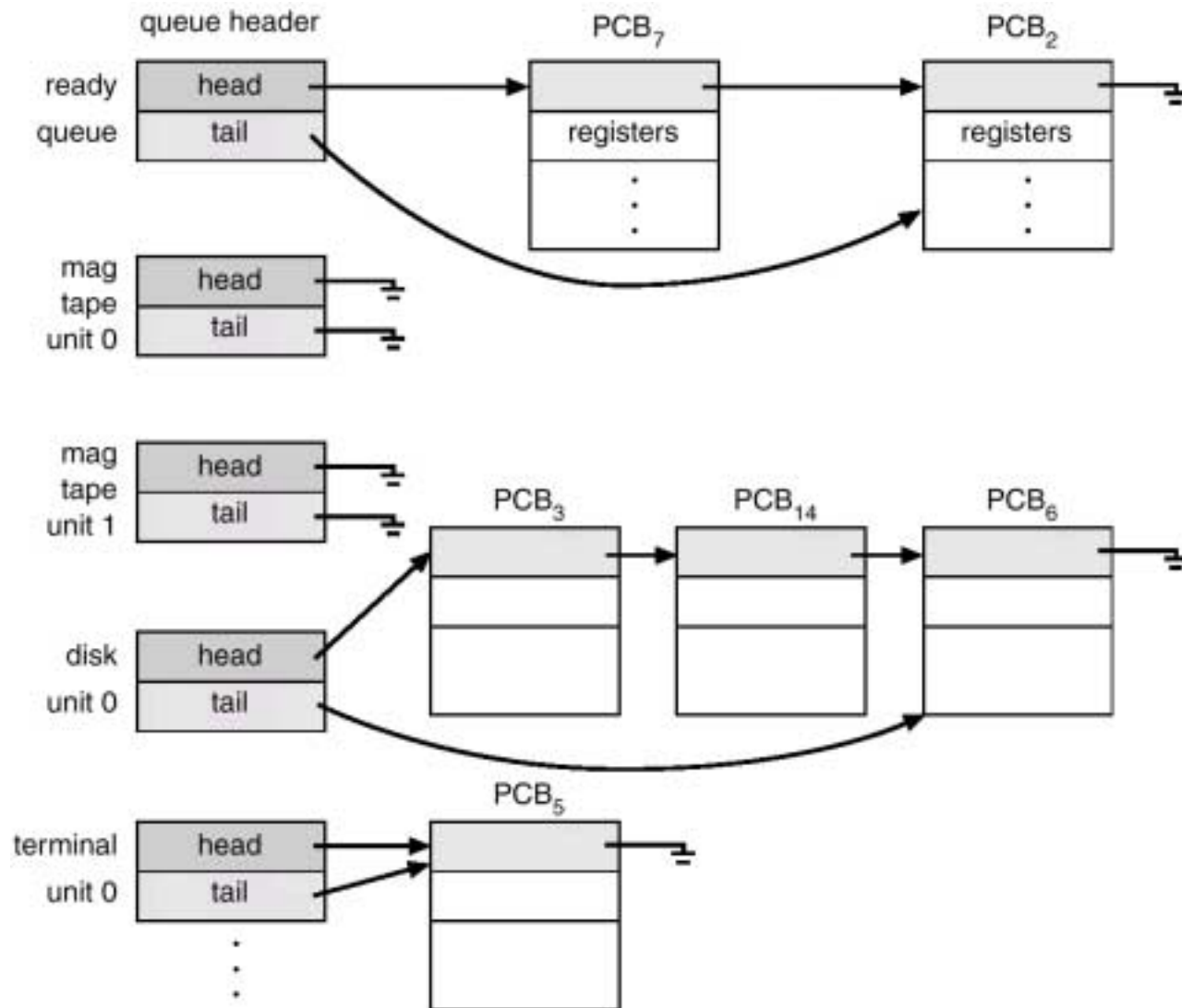
CPU Switch From Process to Process



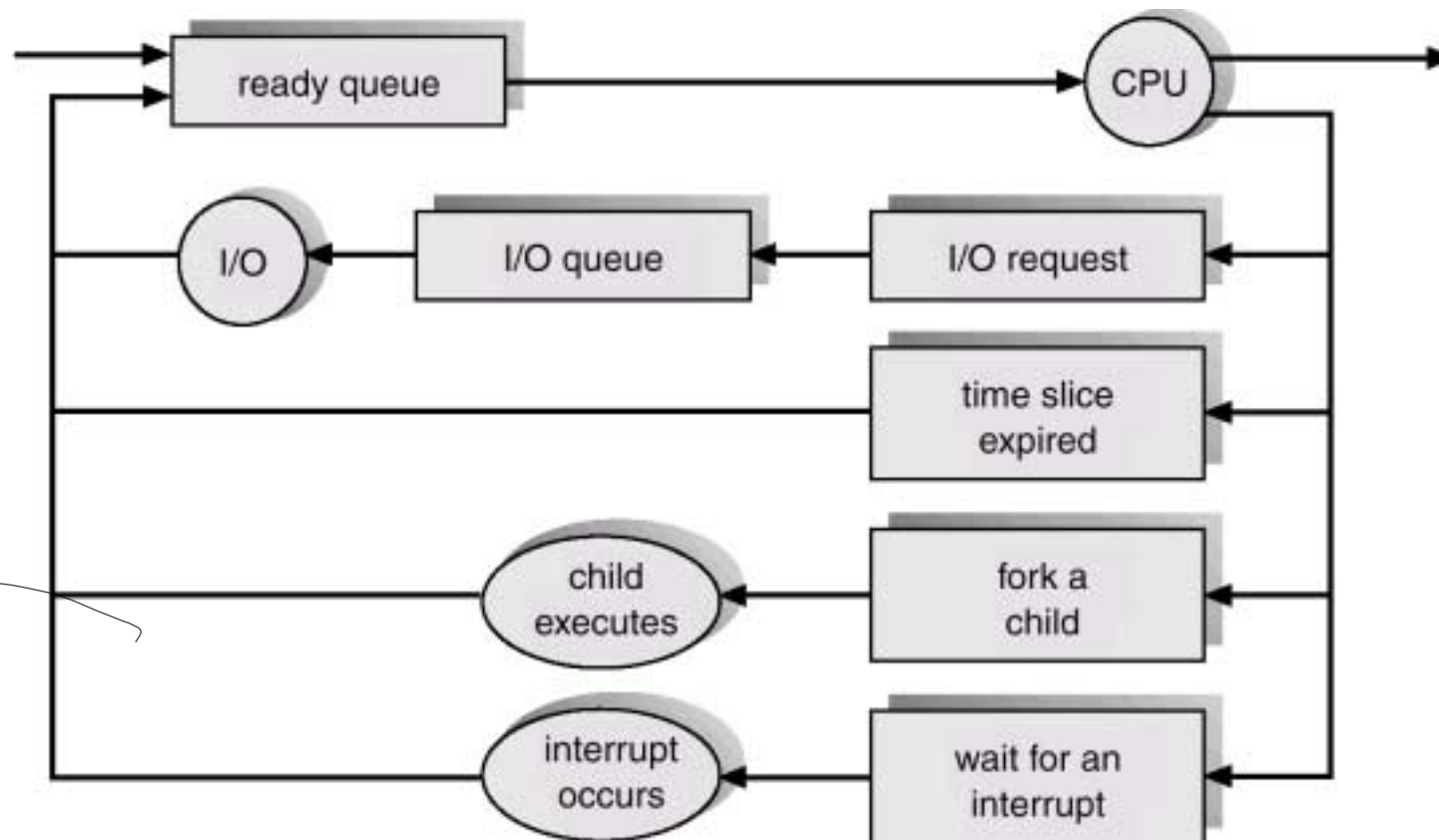
Process Scheduling Queues

- 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

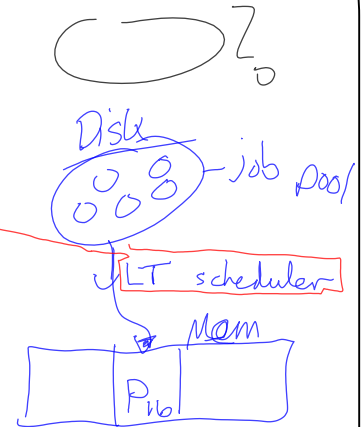


Representation of Process Scheduling



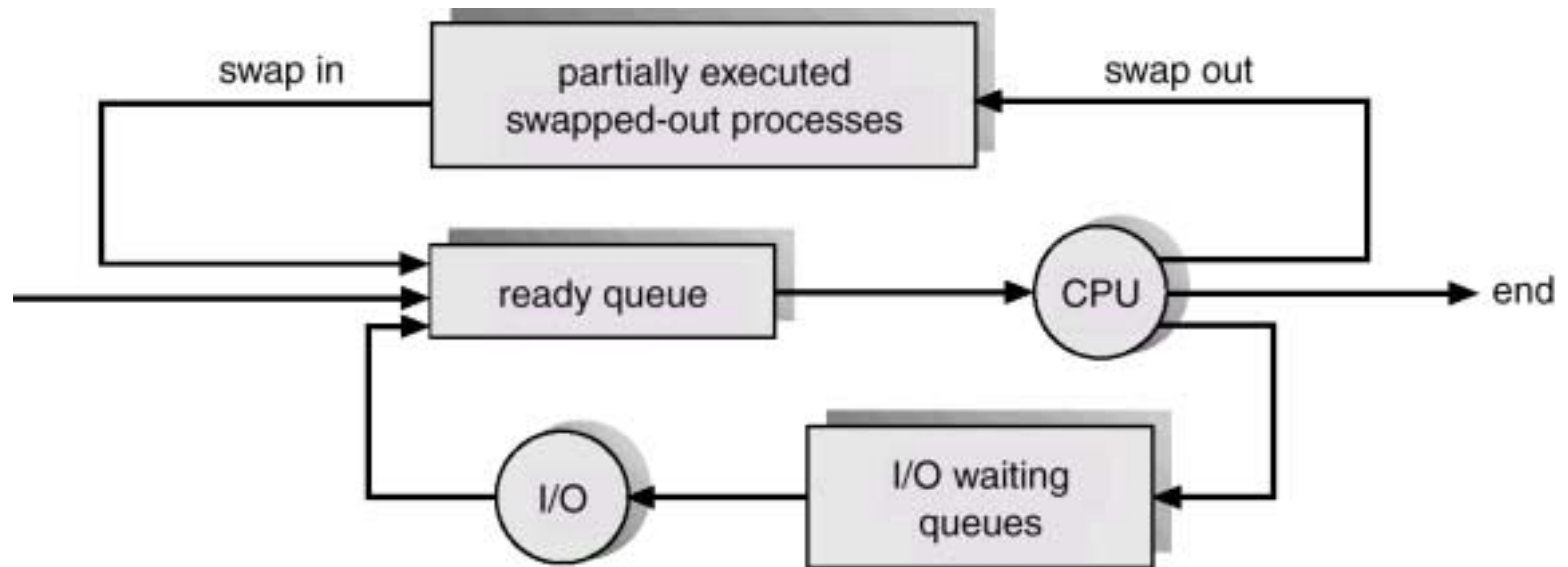
Schedulers

- 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 (Always)

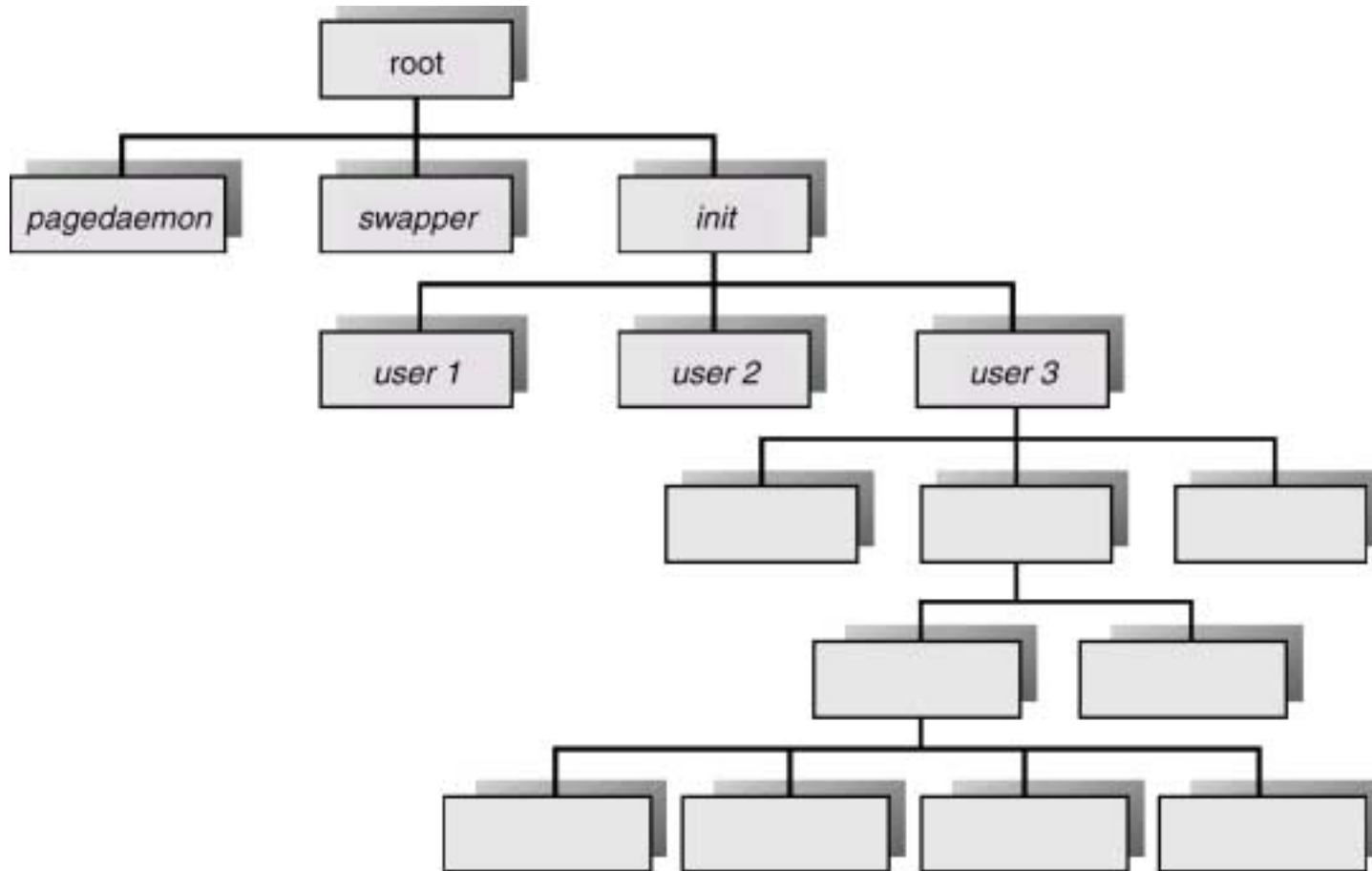
How does process know to continue?

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.

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*;

$nextc := buffer[out]$;

$out := out + 1 \bmod n$;

 ...

 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
 - Links 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.

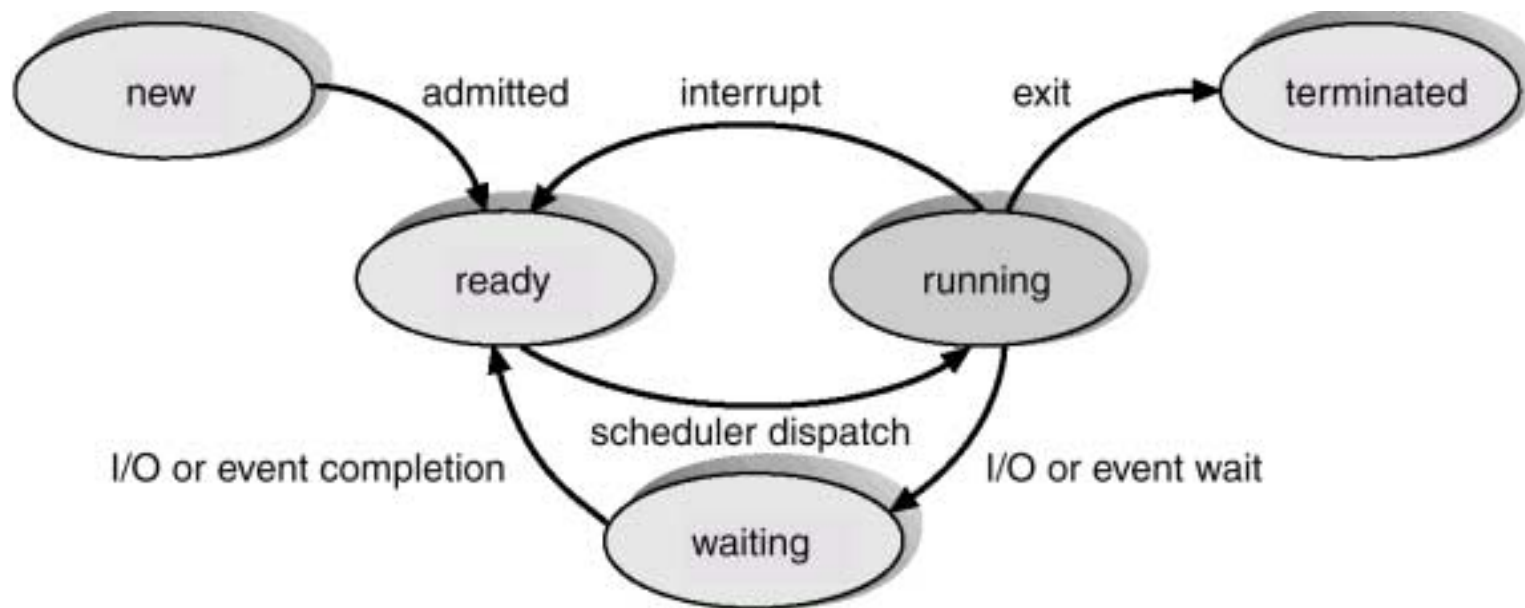
Buffering

- 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

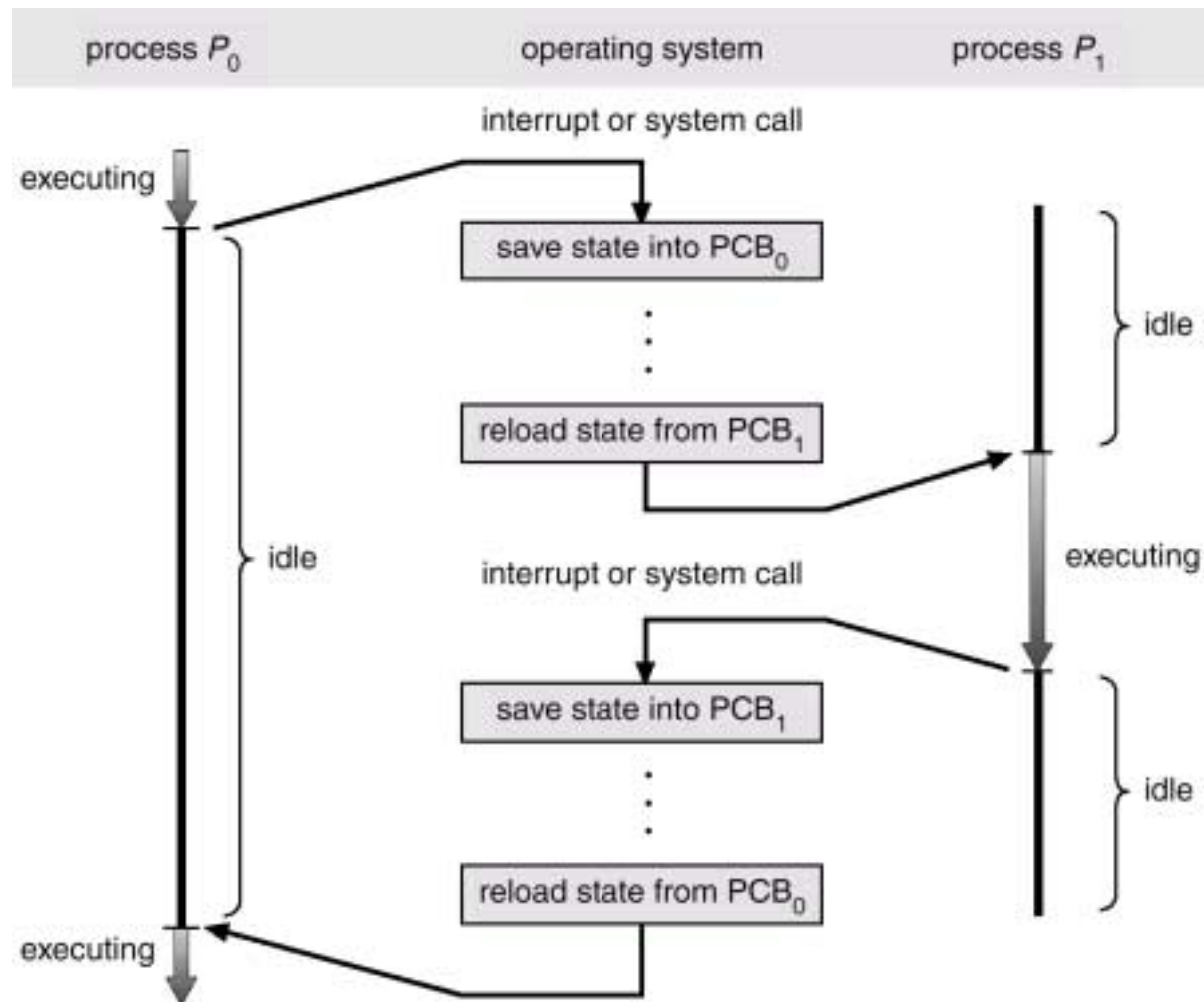
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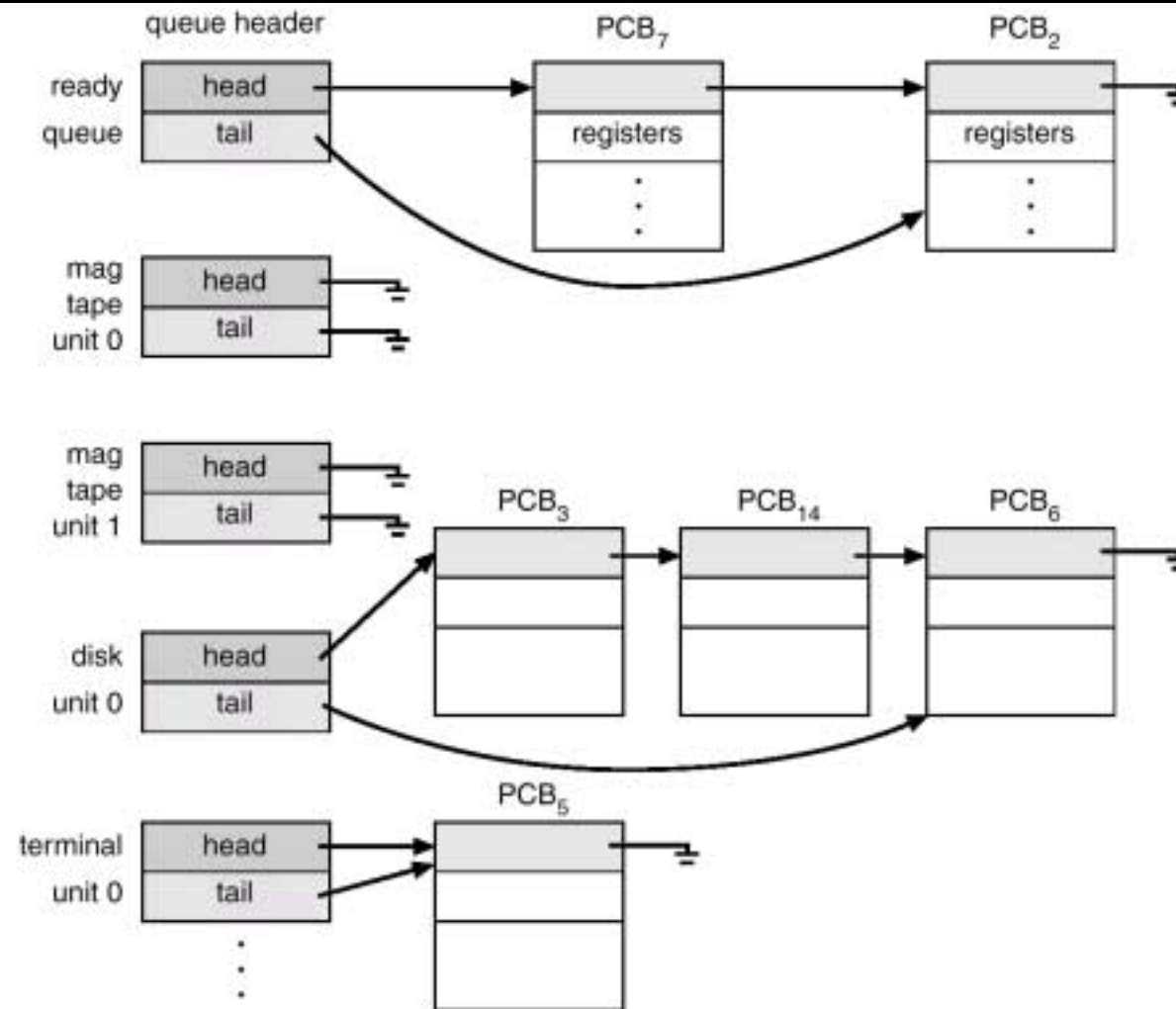
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| | |
|--------------------|------------------|
| pointer | process state |
| process number | |
| program counter | |
| registers | |
| memory limits | |
| list of open files | |
| ⋮ | |

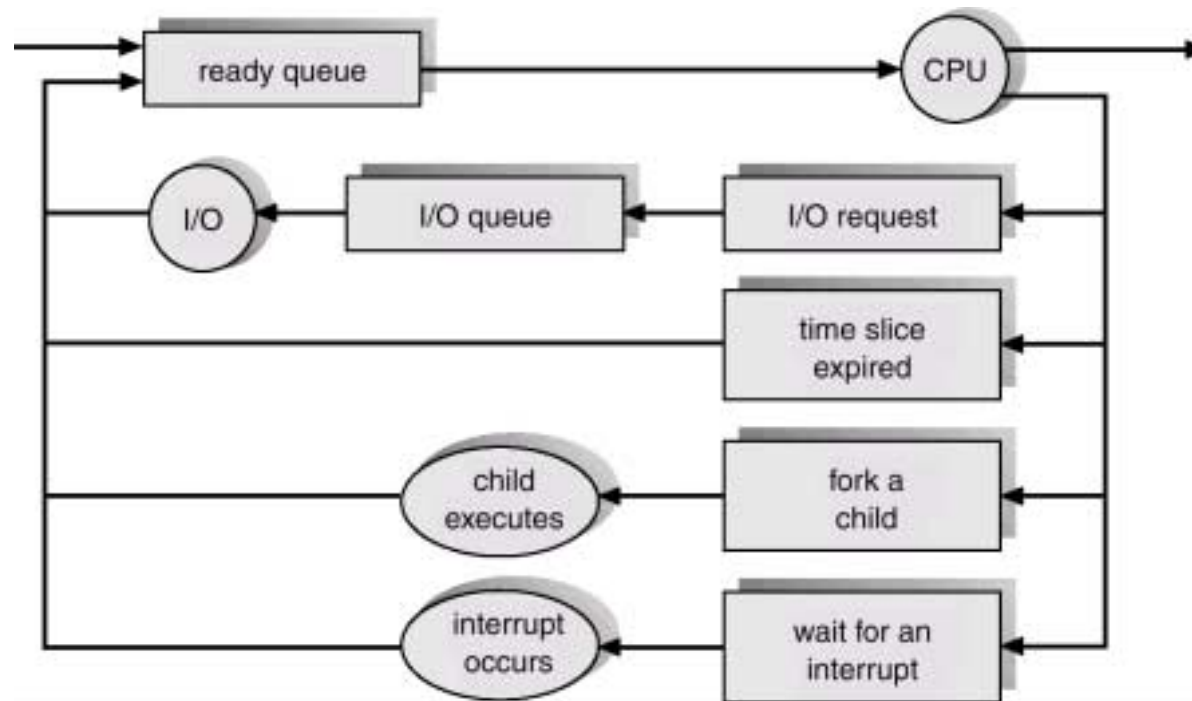
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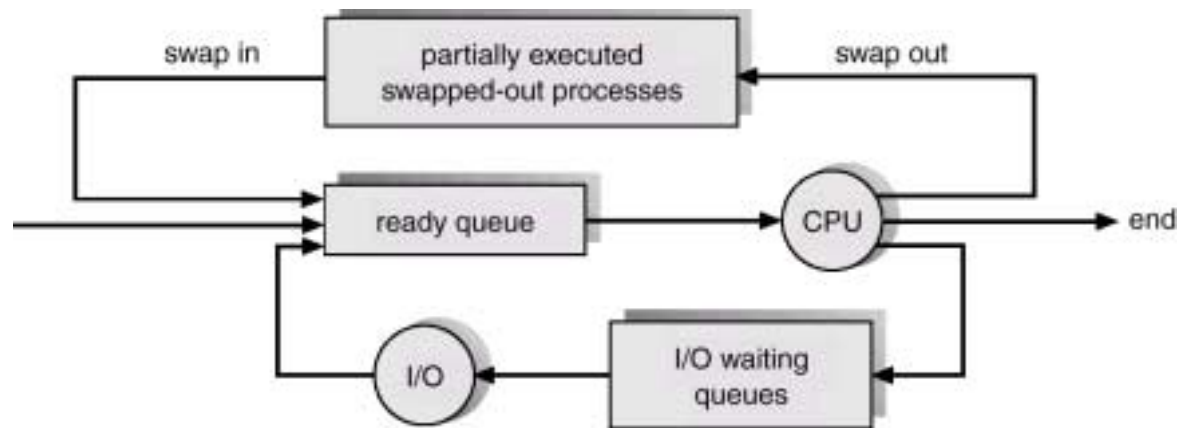
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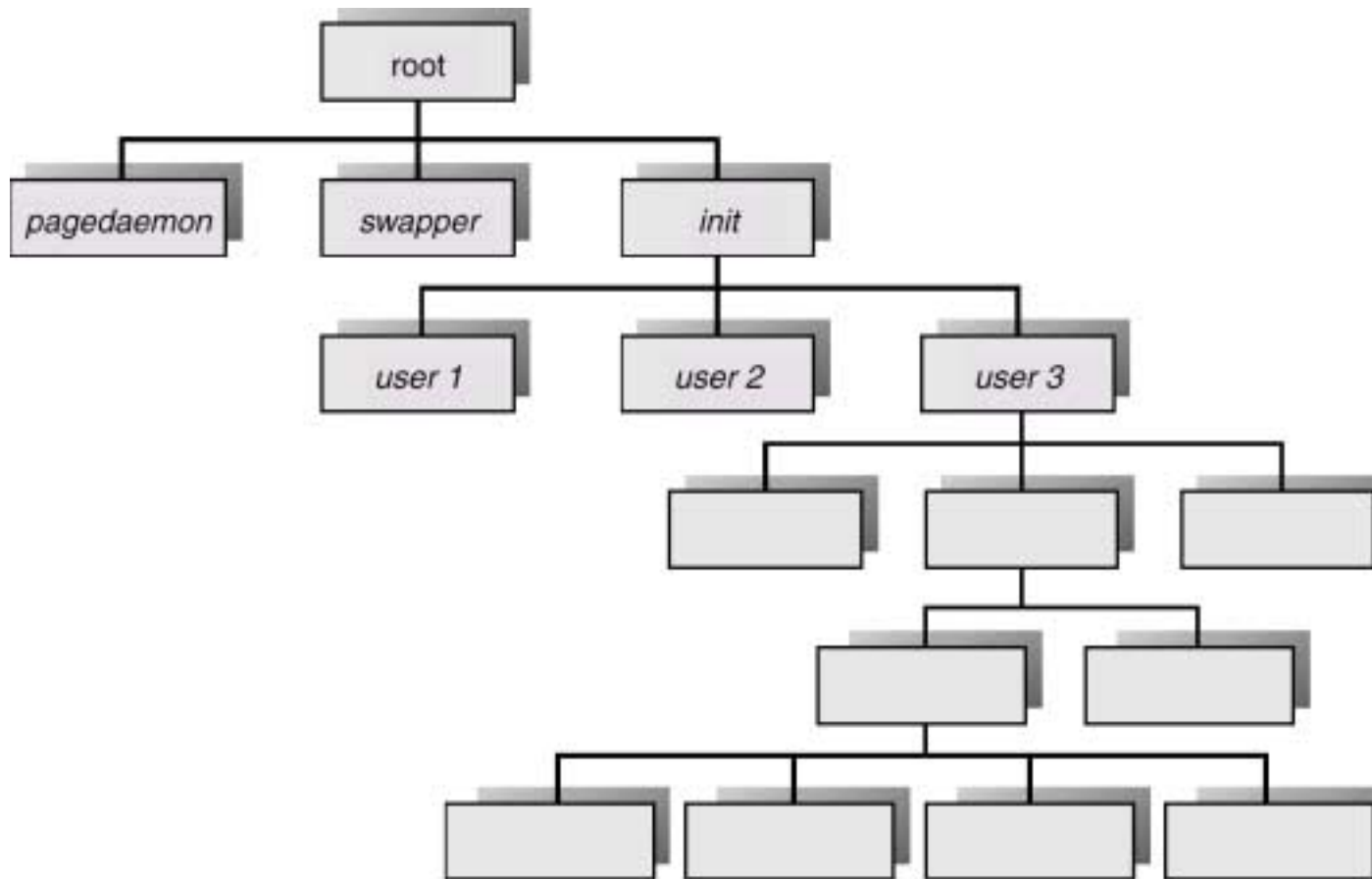
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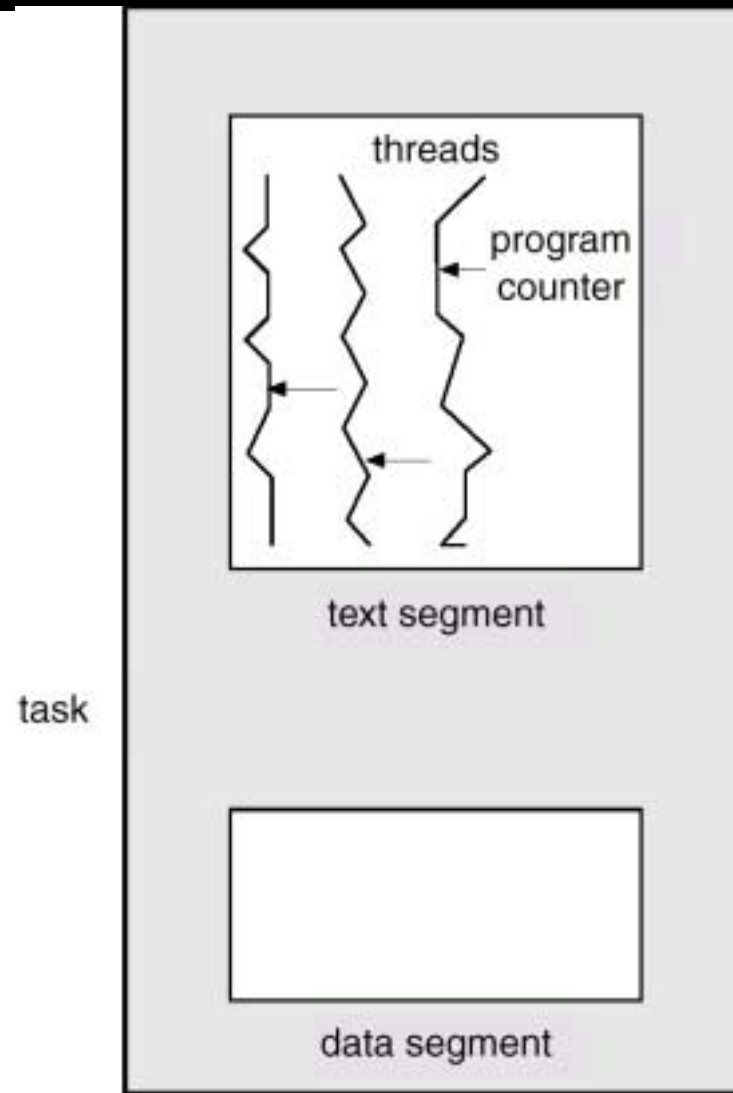
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