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# Chapter 3: Processes

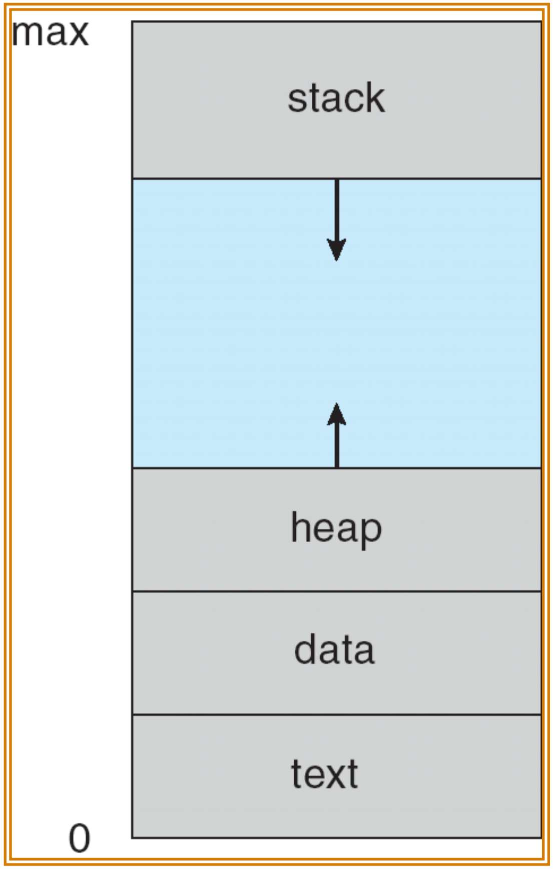
# Process Concept

- 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

# Typical Elements of a Process Image

- **Text section** (user program code)
- **Data section** (global variables)
- **Stack**
  - User Stack (temporary data such as function parameters, return addresses, local variables)
  - Kernel Stack (register values, parameters and calling addresses for system calls)
- **Heap** (memory that is dynamically allocated during process run time)
- **Process Control Block** (PCB)

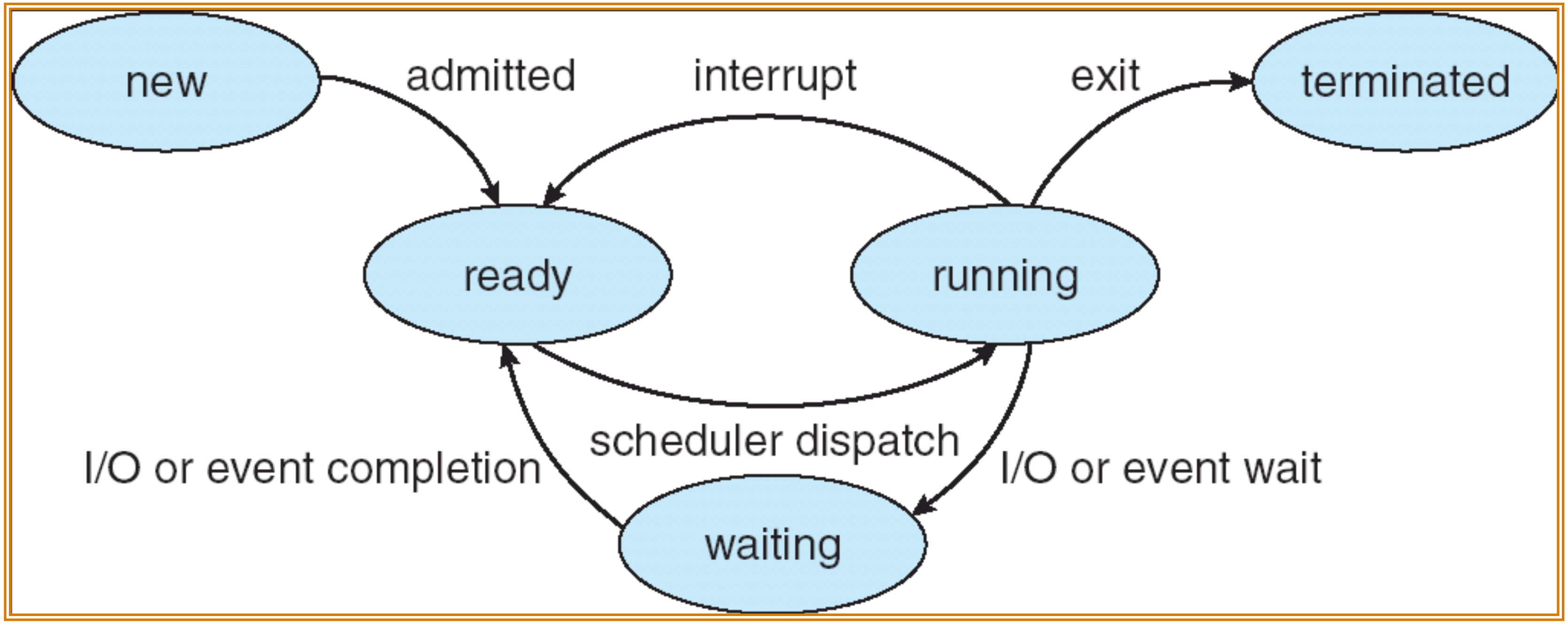
# Process in Memory



# 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

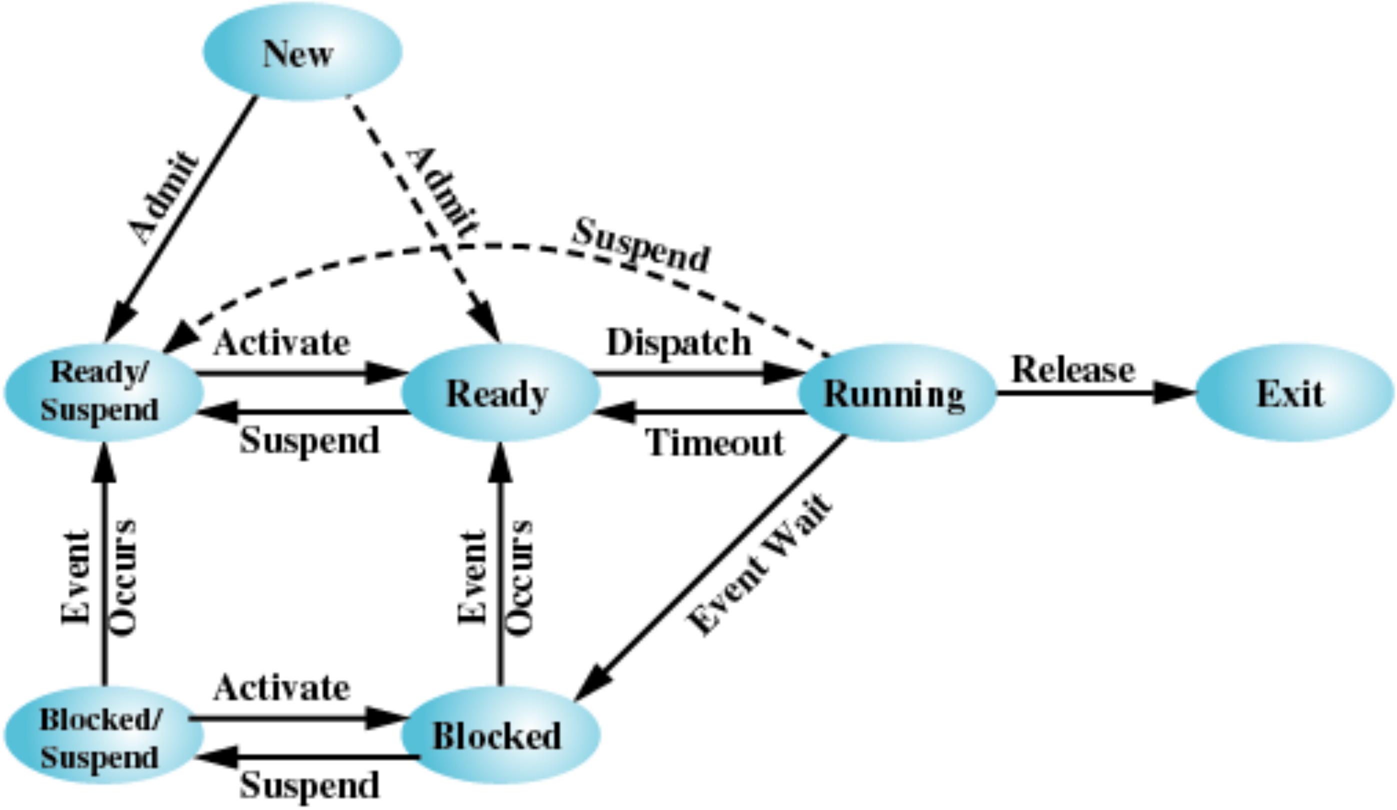


# Need for Swapping

- Processor is faster than I/O; so all processes could be waiting for I/O
- Even with multiprogramming, a processor could be idle most of the time.
- Swapping: moving part or all of a process from main memory to disk (to free up more memory)
  - blocked state becomes suspend state when swapped to disk
  - suspended queue : a queue of existing processes that have been temporarily kicked out of main memory, or suspended.

** **two new states**: ready-suspended & blocked-suspended

# Two Suspend States

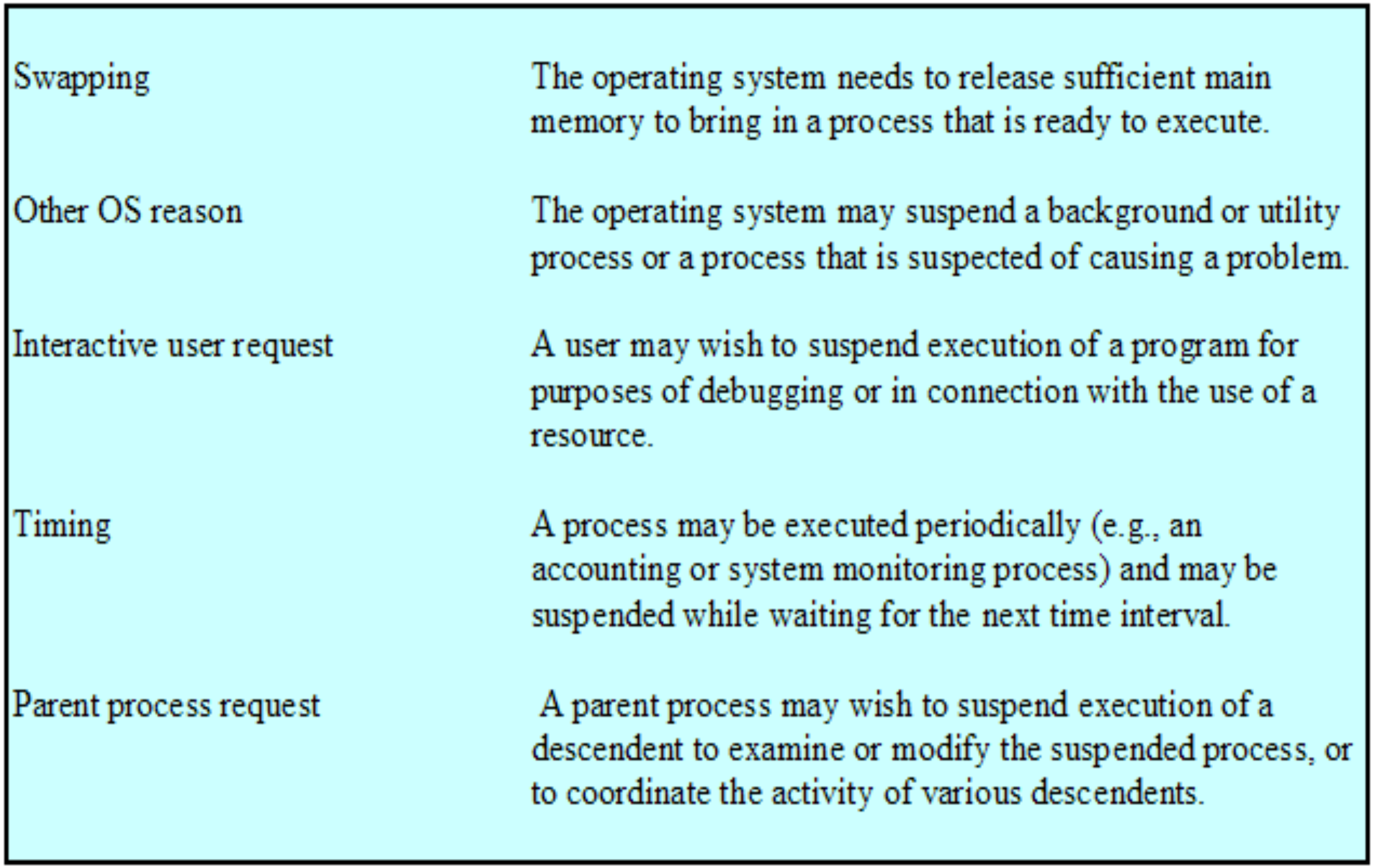


(b) With Two Suspend States

*Blocked state = Waiting state in the previous diagram*

*** *Operating Systems: Internals and Design Principles, William Stallings*

# Reasons for Process Suspension

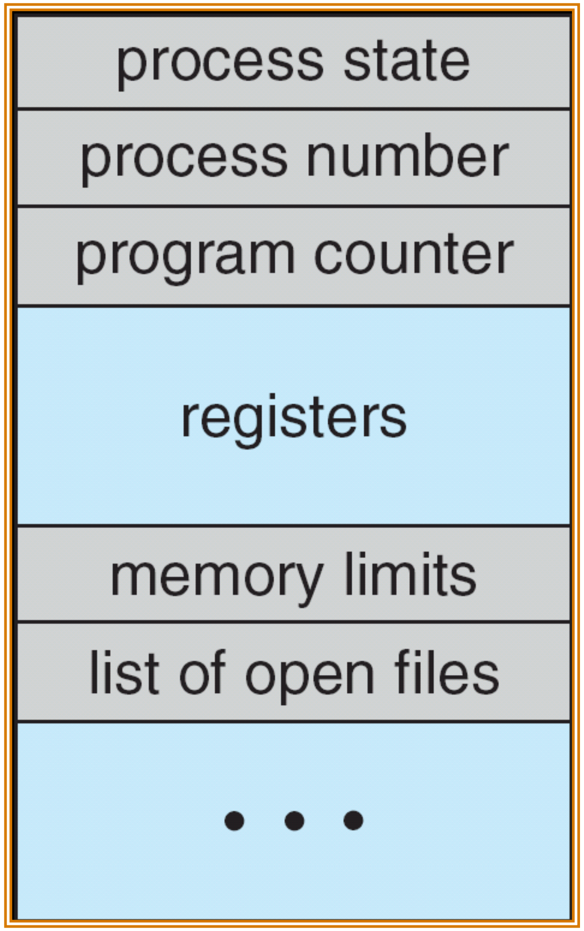


| | |
|---|---|
| Swapping | The operating system needs to release sufficient main memory to bring in a process that is ready to execute. |
| Other OS reason | The operating system may suspend a background or utility process or a process that is suspected of causing a problem. |
| Interactive user request | A user may wish to suspend execution of a program for purposes of debugging or in connection with the use of a resource. |
| Timing | A process may be executed periodically (e.g., an accounting or system monitoring process) and may be suspended while waiting for the next time interval. |
| Parent process request | A parent process may wish to suspend execution of a descendent to examine or modify the suspended process, or to coordinate the activity of various descendents. |

# 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)



process state

process number

program counter

registers

memory limits

list of open files

• • •

# Process Control Block

- Information is classified into three categories:
  a. Process identification,
  b. Processor state information
  c. Process control information

## a. Process identification

- Numeric identifiers that may be stored with the process control block include
  - Identifier of this process
  - Identifier of the process that created this process (parent process)
  - User identifier

# b. Processor State Information

- User-Visible Registers
  - A user-visible register is one that may be referenced by means of the machine language that the processor executes while in user mode.
- Control and Status Registers
  - *Program counter:* Contains the address of the next instruction to be fetched
  - *Condition codes:* Result of the most recent arithmetic or logical operation (e.g., sign, zero, carry, equal, overflow)
  - *Status information:* Includes interrupt enabled / disabled flags, execution mode
- Stack Pointers

# c. Process Control Information

- Scheduling and State Information
  - *Process state*
  - *Priority:* One or more fields may be used to describe the scheduling priority of the process.
  - *Scheduling-related information:* This will depend on the scheduling algorithm used.
  - *Event:* Identity of event the process is awaiting before it can be resumed
- Data Structuring
  - A process may be linked to other process in a queue, ring, or some other structure.
  - all processes in a waiting state for a particular priority level may be linked in a queue.

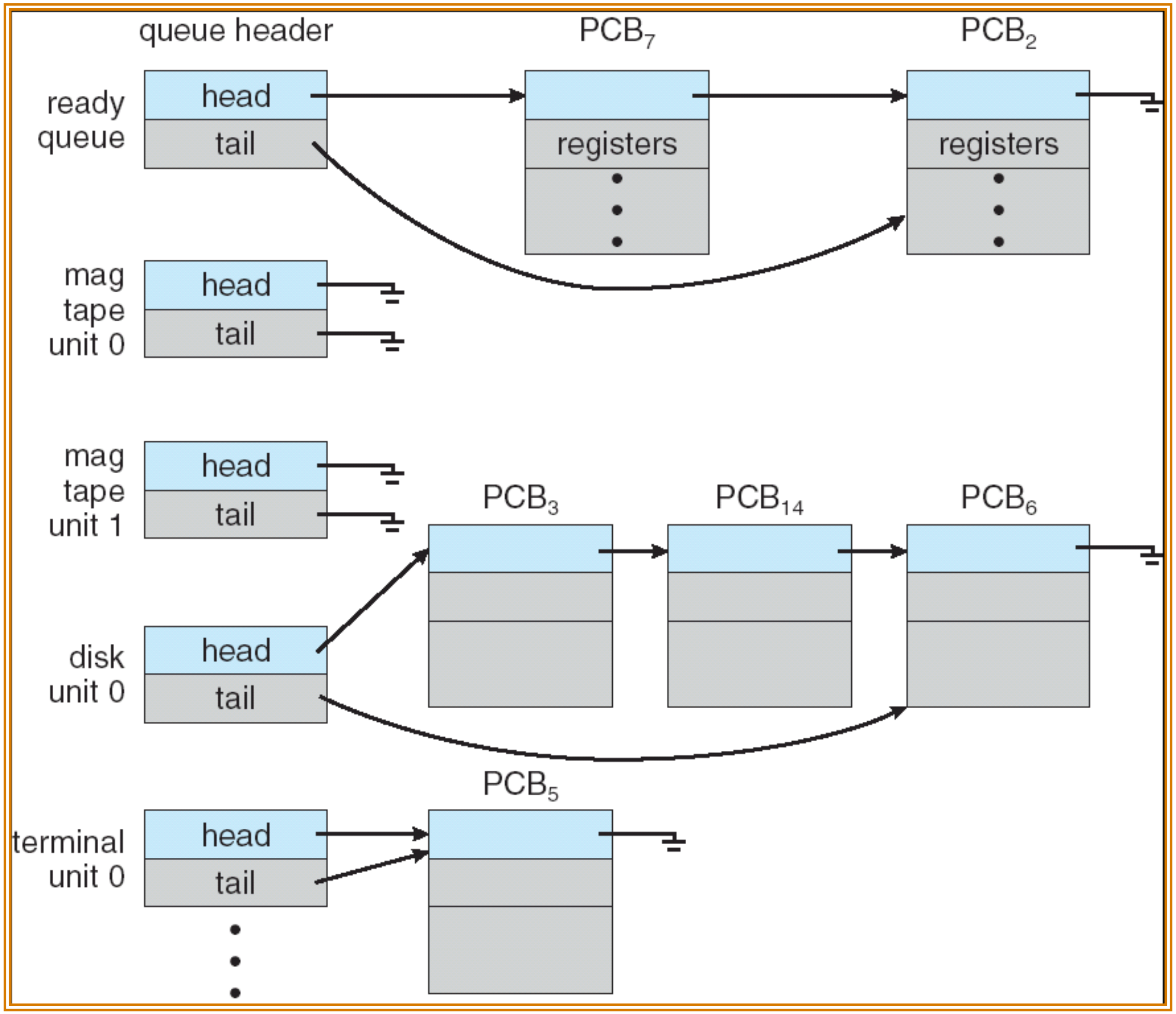
# c. Process Control Information (cont.)

- Interprocess Communication
- Process Privileges
- Memory Management
  - This section may include pointers to segment and/or page tables that describe the virtual memory assigned to this process.
- Resource Ownership and Utilization
  - Resources controlled by the process may be indicated, such as opened files. A history of utilization of the processor or other resources may also be included.

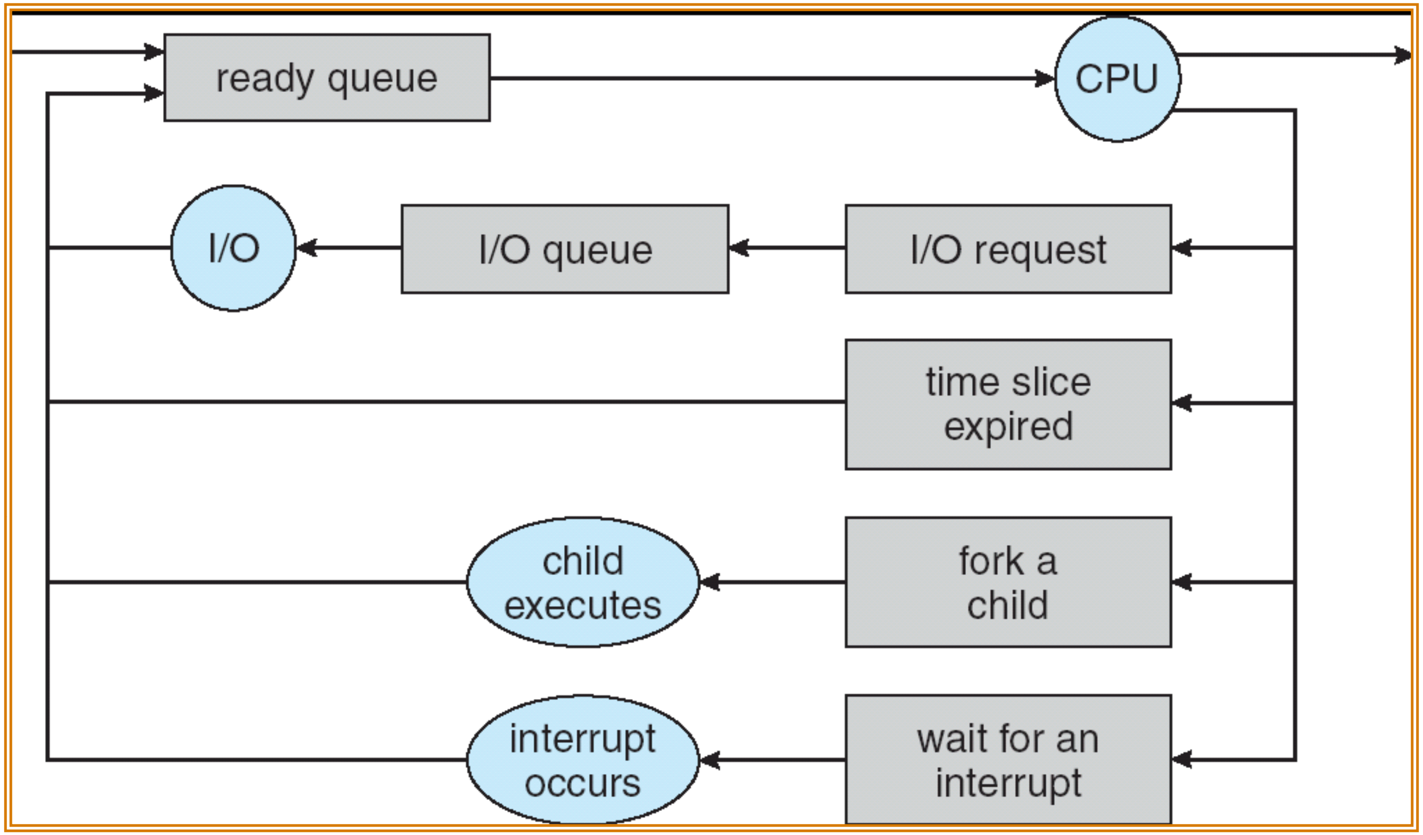
# Process Scheduling Queues

- **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
- Processes migrate among 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 from the pool (typically a disk) into the ready queue
  - Does not exist in Linux or Windows.
- **Short-term scheduler** (or CPU scheduler) – selects which process should be executed next and allocates CPU

# Schedulers (Cont.)

- Short-term scheduler is invoked very frequently (milliseconds) (must be fast)
- Long-term scheduler is invoked  less  frequently (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

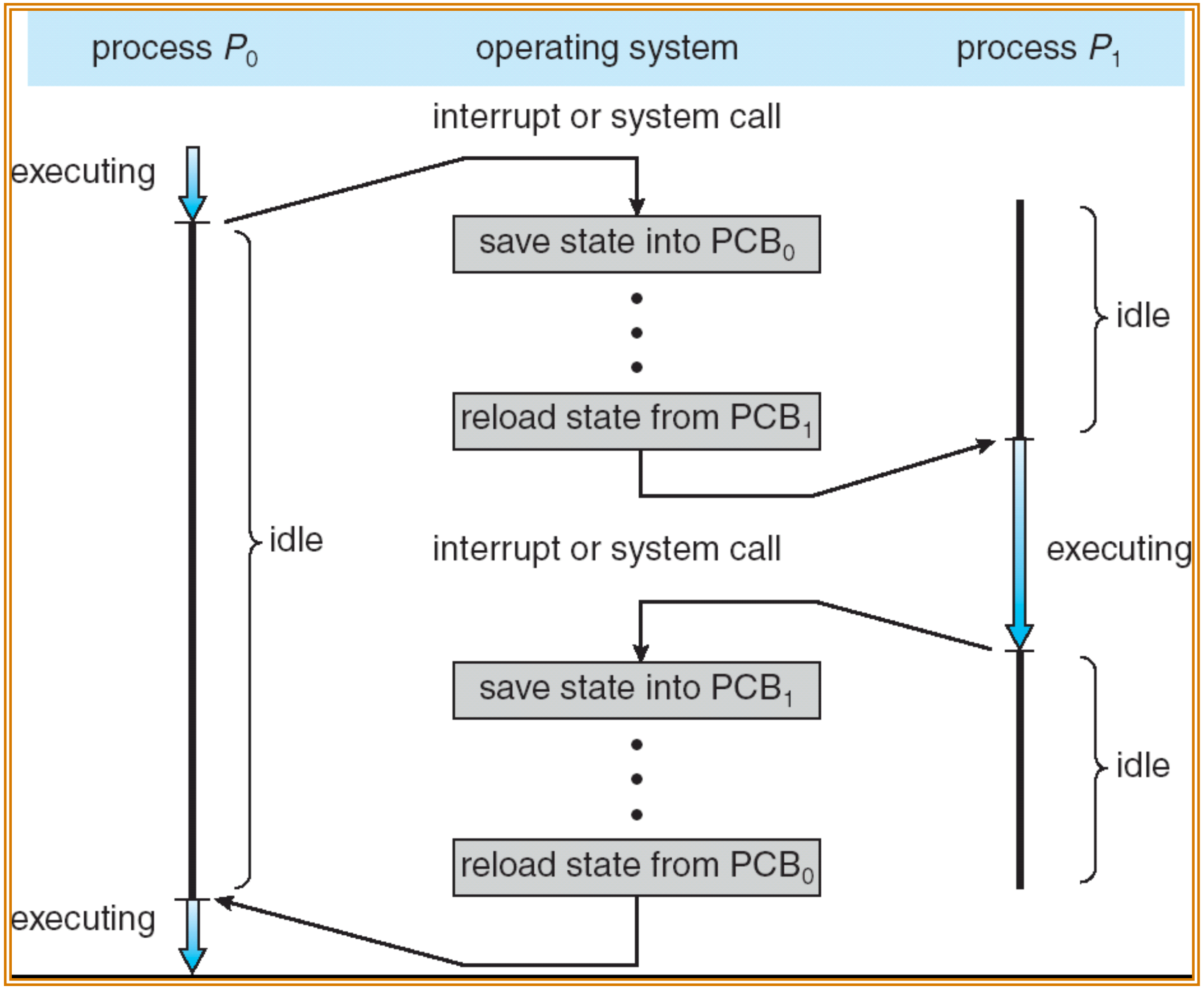
- When CPU switches to another process, the system must save the state of the old process and load the saved state for the new process
- Context-switch time is overhead; the system does no useful work while switching
- Time dependent on hardware support

# Steps in a Process Switch

- Save context of processor including PC and other registers
- Update the process control block of the process that is currently in the running state
  - (changing the state of the process)
- Move process control block to appropriate queue
  - (ready; blocked; ready/suspend)
- Select another process for execution
- Update the process control block of the process selected (change state to running)
- Update memory-management data structures
- Restore the context of the processor

** with the selected process when it was last switched out

# Context Switch



# Process Creation

- Parent process create 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

# Process Creation (Cont.)

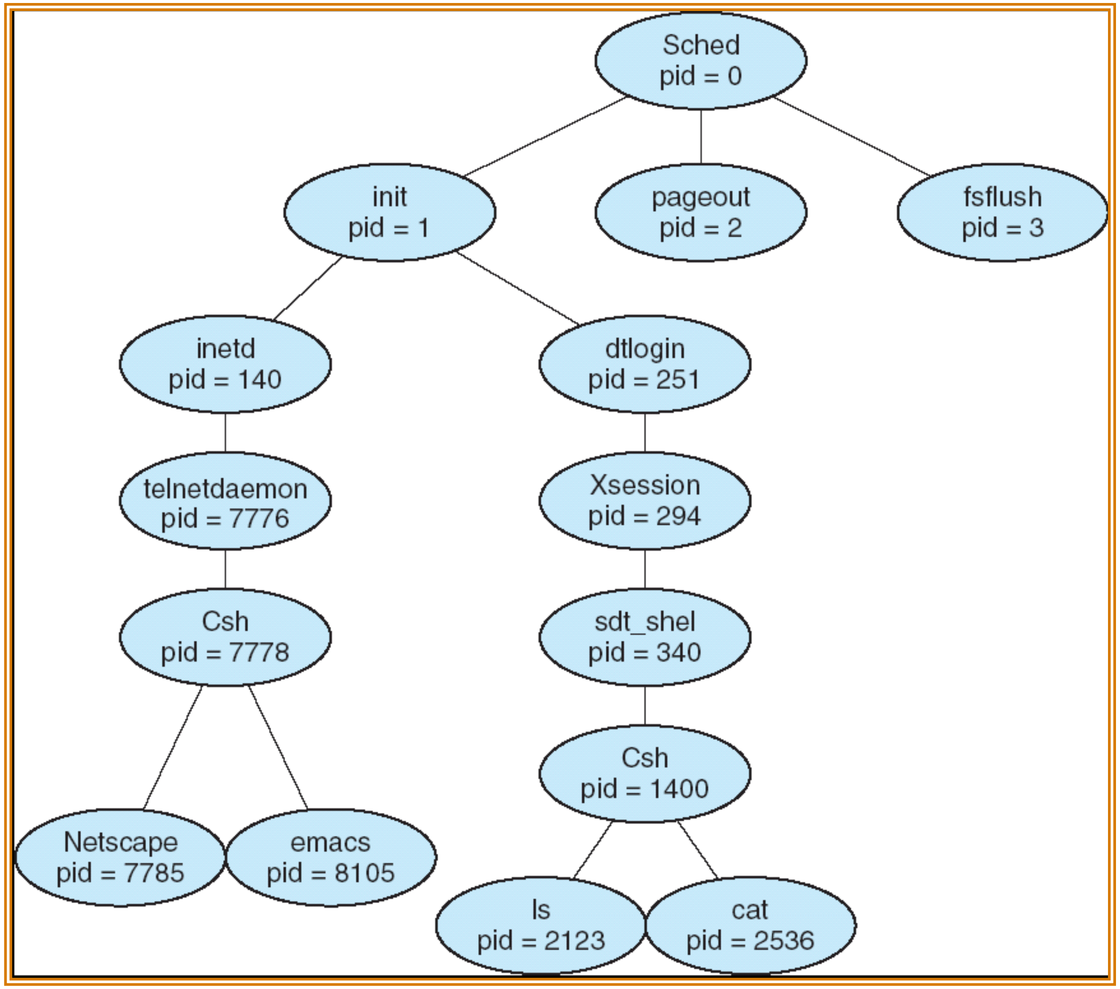
- Address space
  - Child duplicates the address space of the parent.
  - Child has a program loaded into it.
- UNIX examples
  - **fork** system call creates new process.
  - **exec** system call used after a **fork** to replace the process' memory space with a new program.

# Steps of  Process Creation

- Assign a unique process identifier
  - A new entry is added to the primary process table
- Allocate space for the process
- Initialize process control block
- Set up appropriate linkages
  - add new process to linked list  for scheduling queue

    ***  put in  ready  list  or  ready/suspend list
- Create or expand other data structures
  - Ex: maintain an accounting file

# A tree of processes on a typical Solaris



# Process Termination

- Process executes last statement and asks the operating system to delete it (**exit** system call)
  - Output data (return status) from child to parent (**wait** system call)
  - Process' resources are deallocated by operating system
- Parent may terminate execution of children processes
  - Child has exceeded allocated resources
  - Task assigned to child is no longer required
  - parent is exiting and OS not allow child to continue if its parent terminates
    - If parent terminates, all children are terminated by OS (*cascading termination)*