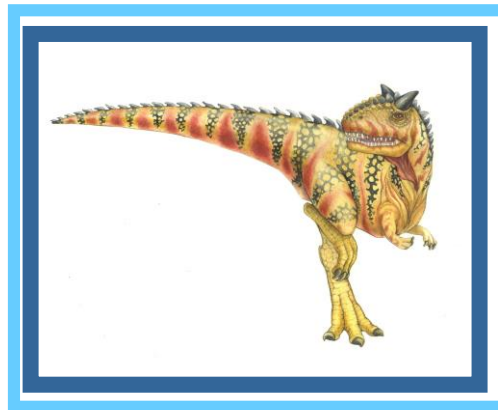
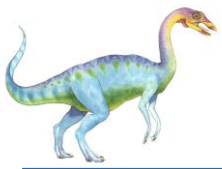


# Chapter 3: Processes

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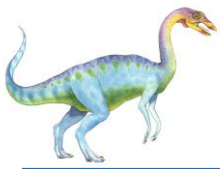


# Chapter 3: Processes

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- Process Concept
- Process Scheduling
- Operations on Processes
- Interprocess Communication
- Threads
- Multithreading



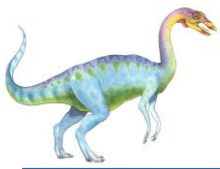


# Objectives

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- To introduce the notion of a process -- a program in execution, which forms the basis of all computation
- To describe the various features of processes, including scheduling, creation and termination, and communication
- To describe communication in client-server systems



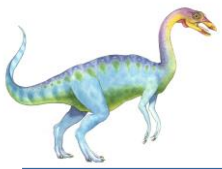


# Process Concept

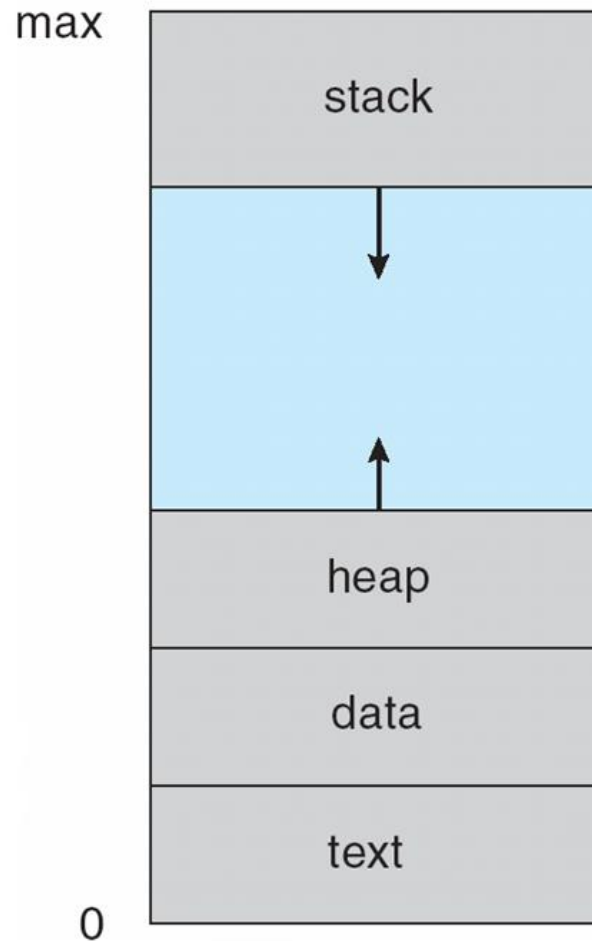
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- An operating system executes a variety of programs:
  - Batch system – jobs
  - Time-shared systems – user programs or tasks
- Textbook uses the terms *job* and *process* almost interchangeably
- Process – a program in execution; process execution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





# Process in Memory



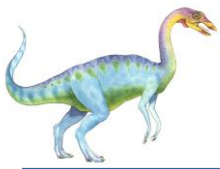


# Process State

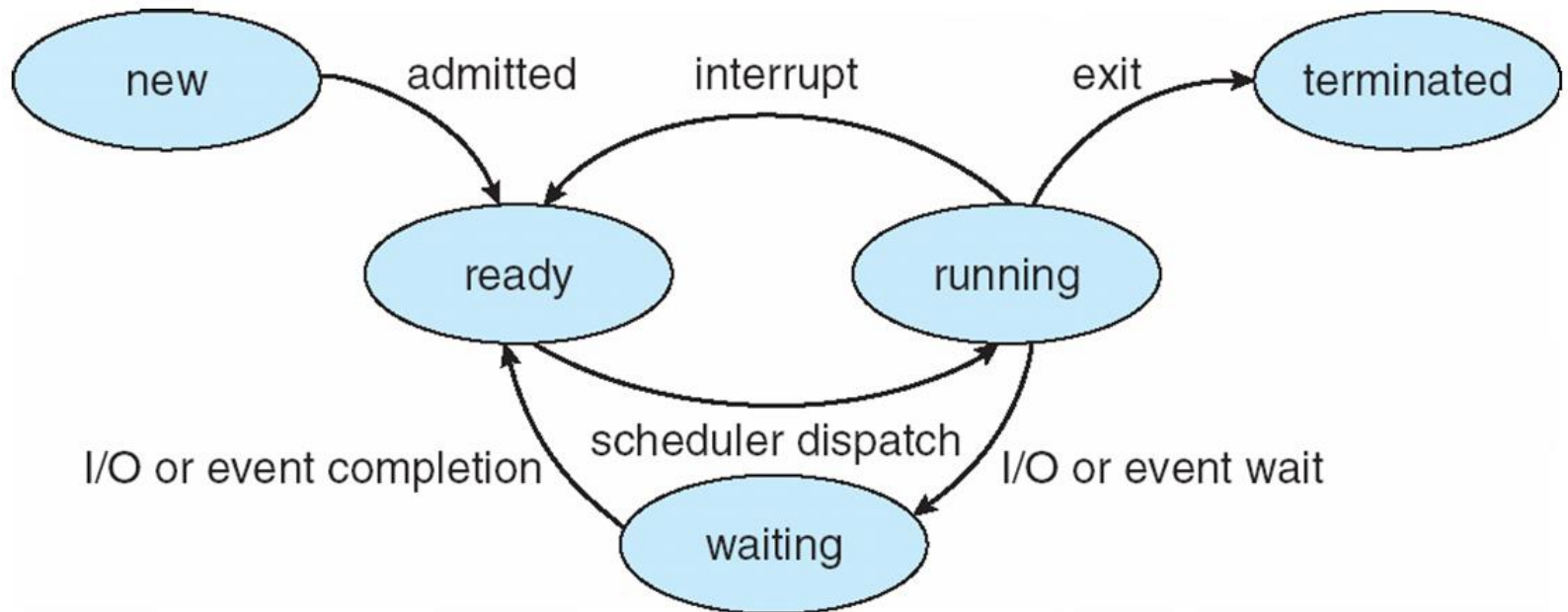
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- As a process executes, it changes *state*
  - **new**: The process is being created
  - **running**: Instructions are being executed
  - **waiting**: The process is waiting for some event to occur
  - **ready**: The process is waiting to be assigned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





# Diagram of Process State





# Process Control Block (PCB)

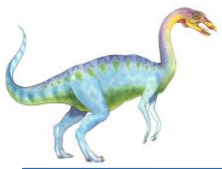
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information associated with each process

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

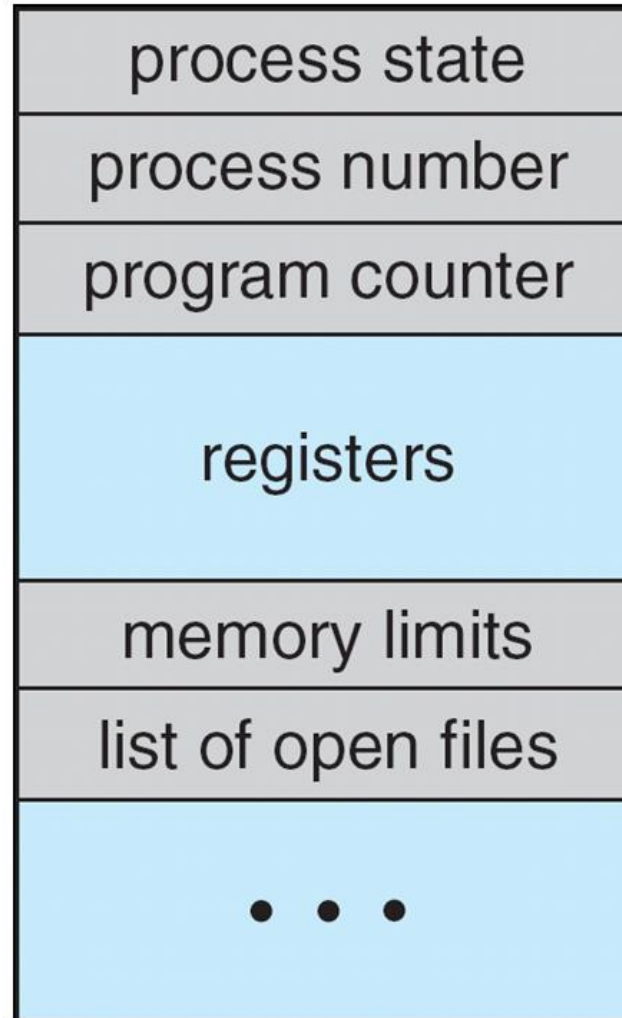






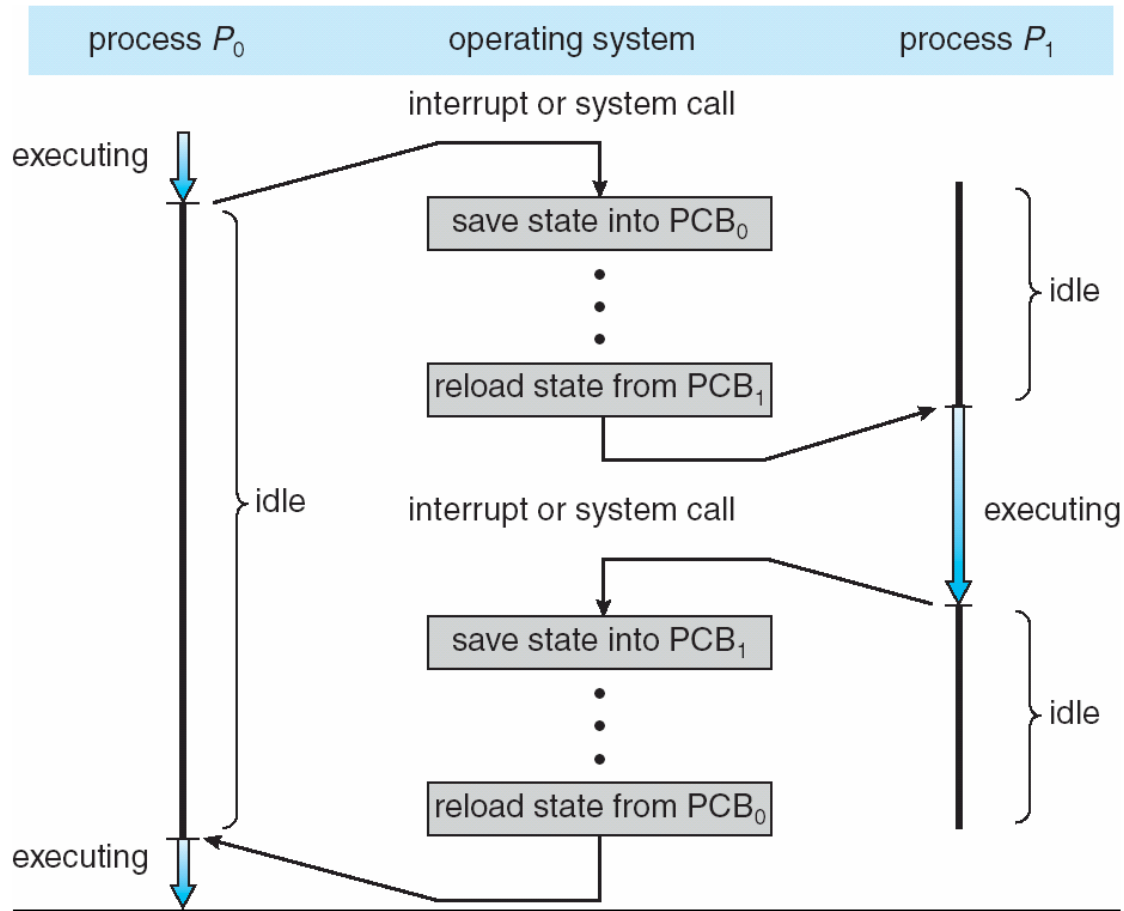
# Process Control Block (PCB)

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# CPU Switch From Process to Process



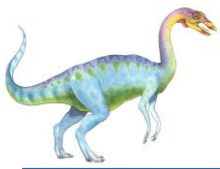


# Scheduling

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The objective of multiprogramming is to have some process running at all times, so as to maximize CPU utilization. The objective of time-sharing is to switch the CPU among processes so frequently that users can interact with each program while it is running. A uniprocessor system can have only one running process. If more processes exist, the rest must wait until the CPU is free and can be rescheduled.



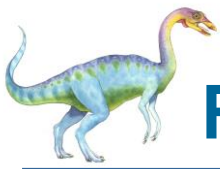


# Process Scheduling Queues

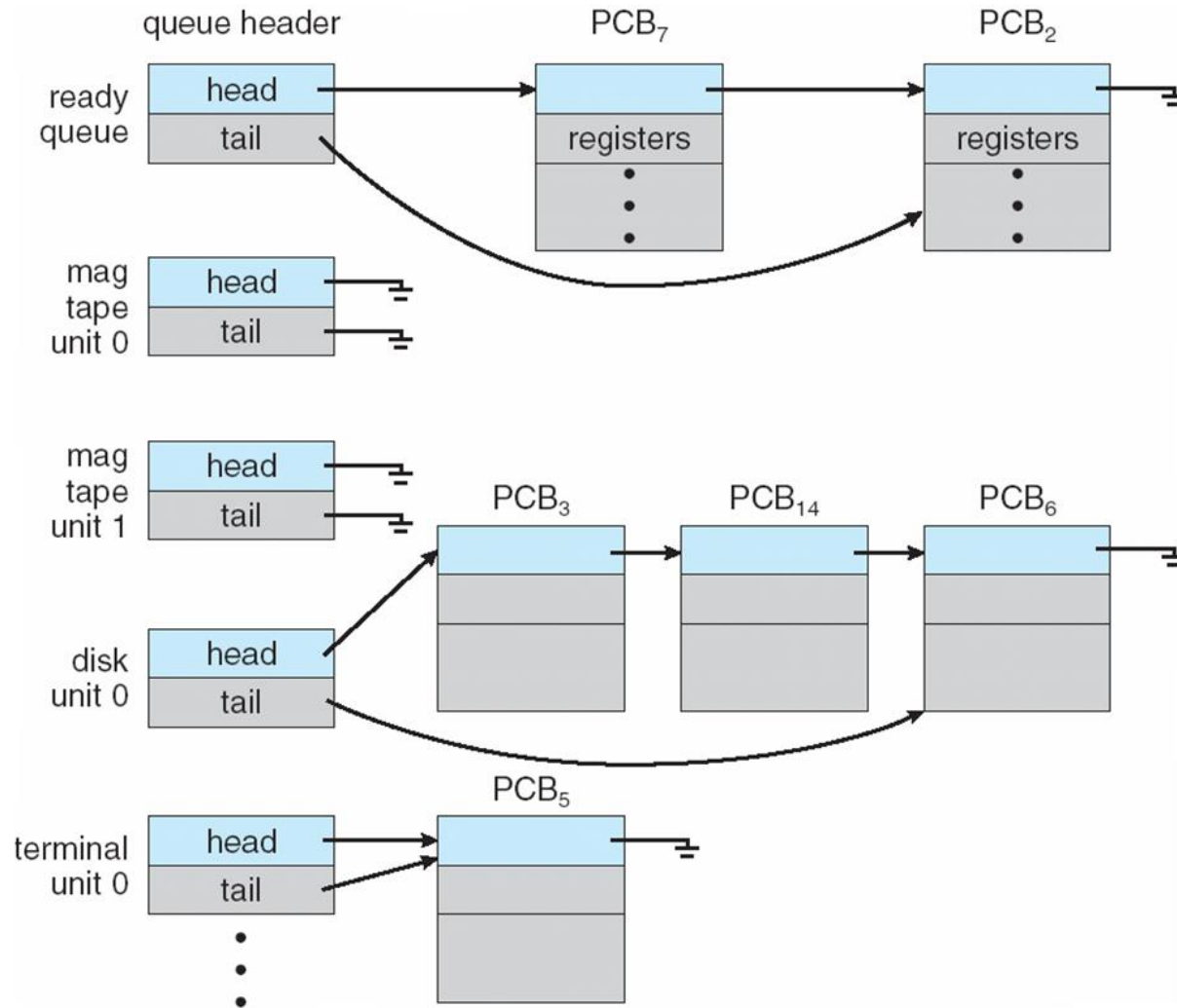
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- **Job queue** – set of all processes in the system
- **Ready queue** – set of all processes residing in main memory, ready and waiting to execute
- **Device queues** – set of processes waiting for an I/O device
- Processes migrate among the various queues



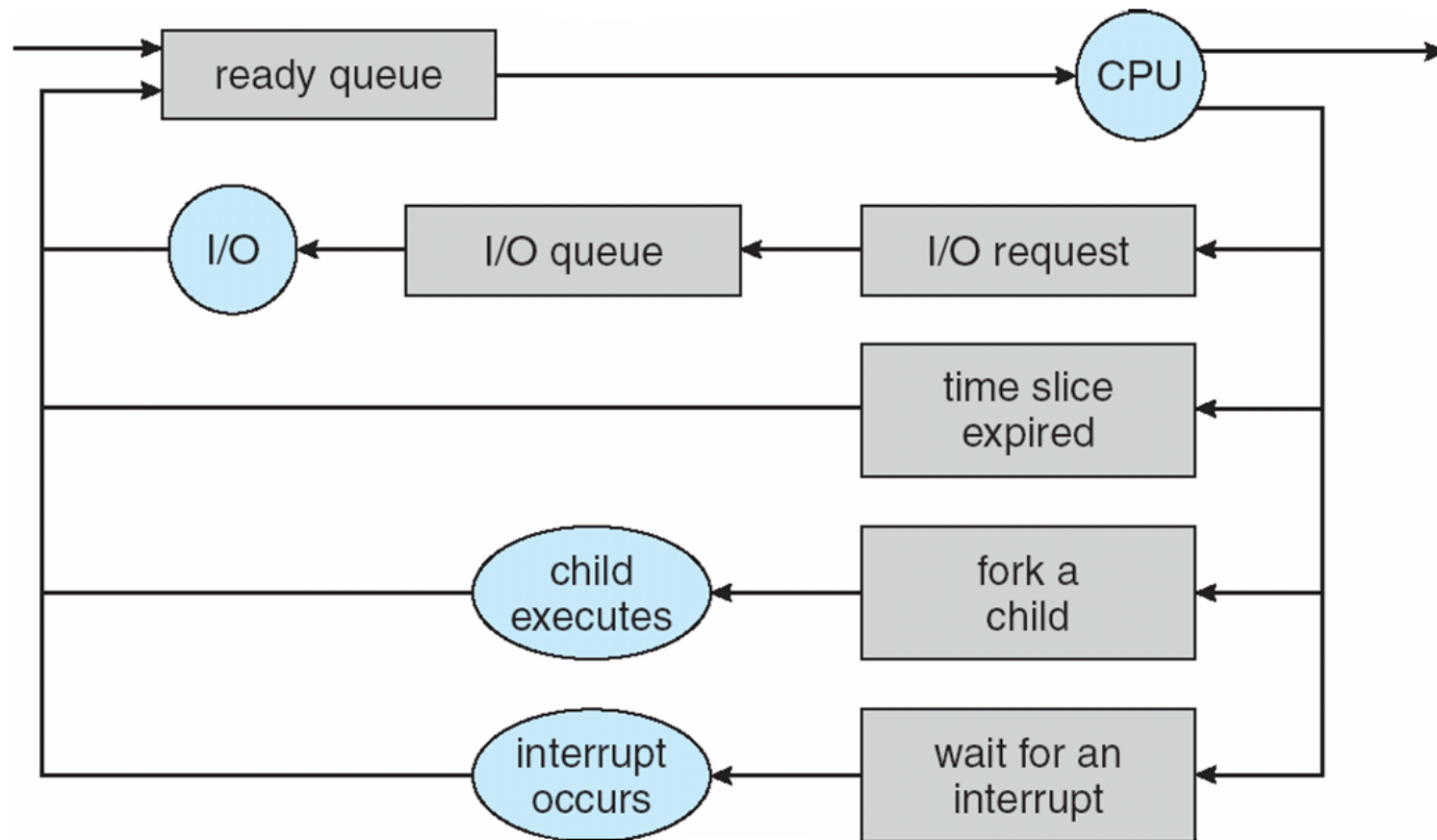


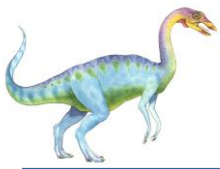
# Ready Queue And Various I/O Device Queues





# Representation of Process Scheduling





# Several events during execution

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- 1) The process could issue an I/O request, and then be placed in an I/O queue.
- 2) The process could create a new subprocess and wait for its termination.
- 3) The process could be removed forcibly from the CPU, as a result of an interrupt, and be put back in the ready queue.





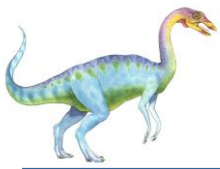
# Schedulers

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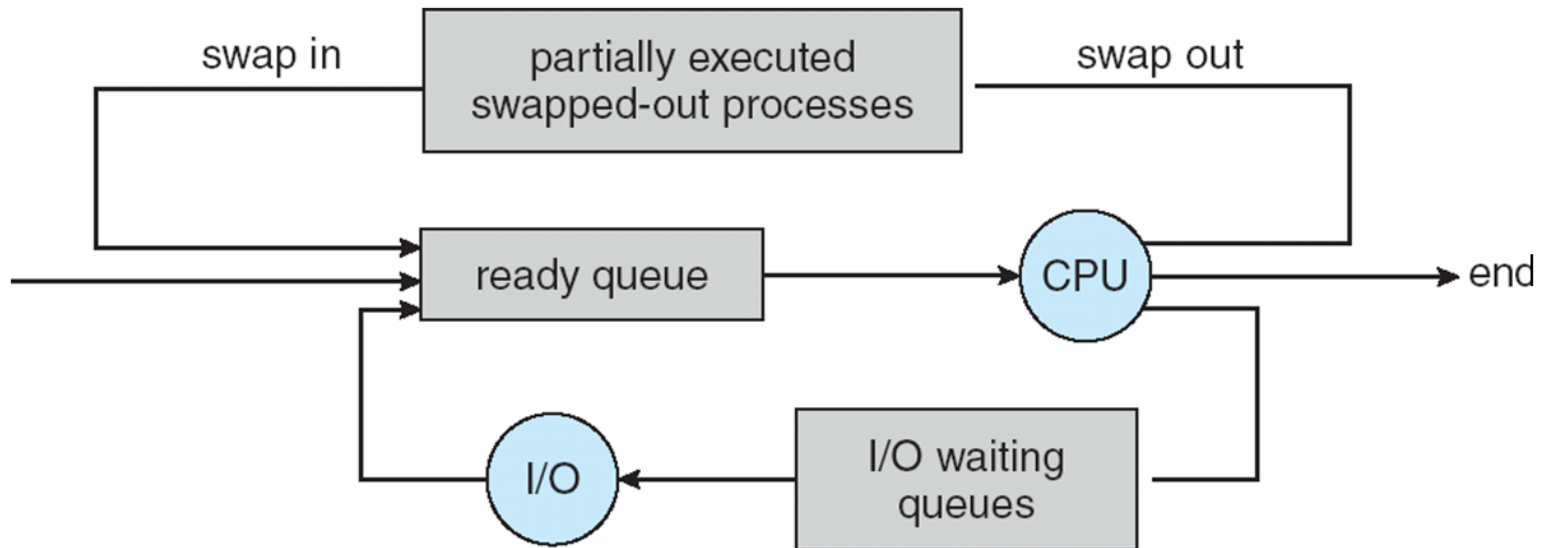
- **Long-term scheduler** (or job scheduler) – selects which processes should be brought into the ready queue
- **Short-term scheduler** (or CPU scheduler) – selects which process should be executed next and allocates CPU







# Addition of Medium Term Scheduling





# Schedulers (Cont)

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- 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



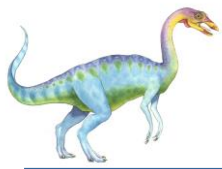


# Context Switch

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- 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 via a **context switch**
- **Context** of a process represented in the PCB
- Context-switch time is overhead; the system does no useful work while switching
- Time dependent on hardware support



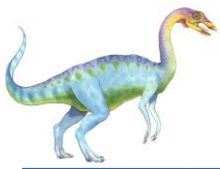


# Process Creation

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- **Parent** process create **children** processes, which, in turn create other processes, forming a tree of processes
- Generally, process identified and managed via a **process identifier (pid)**
- 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



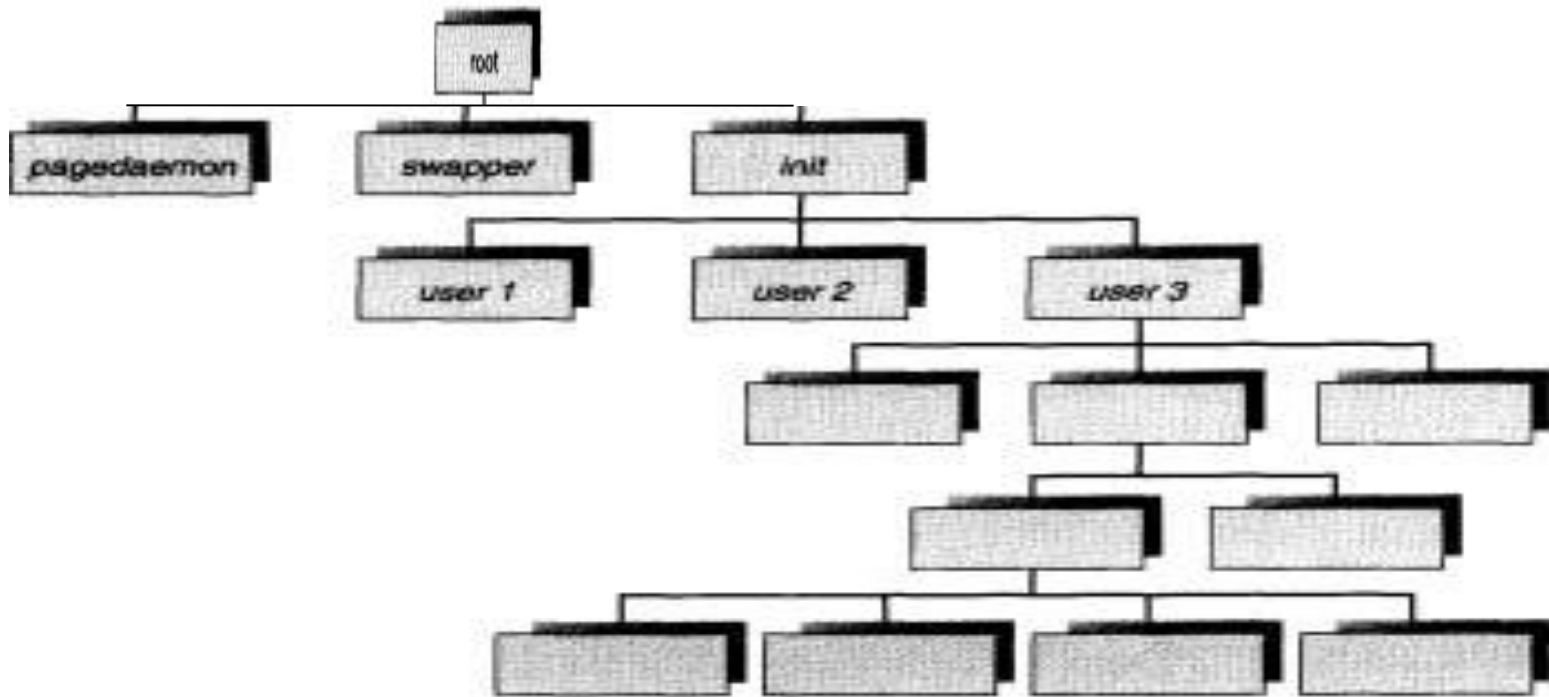
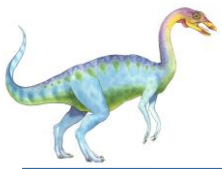


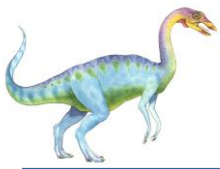
# Process Creation (Cont)

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- Address space
  - Child duplicate of 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







# Process Termination

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- Process executes last statement and asks the operating system to delete 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
  - If parent is exiting
    - ▶ Some operating system do not allow child to continue if its parent terminates
      - All children terminated - **cascading termination**





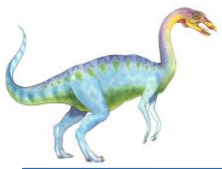
# Interprocess Communication

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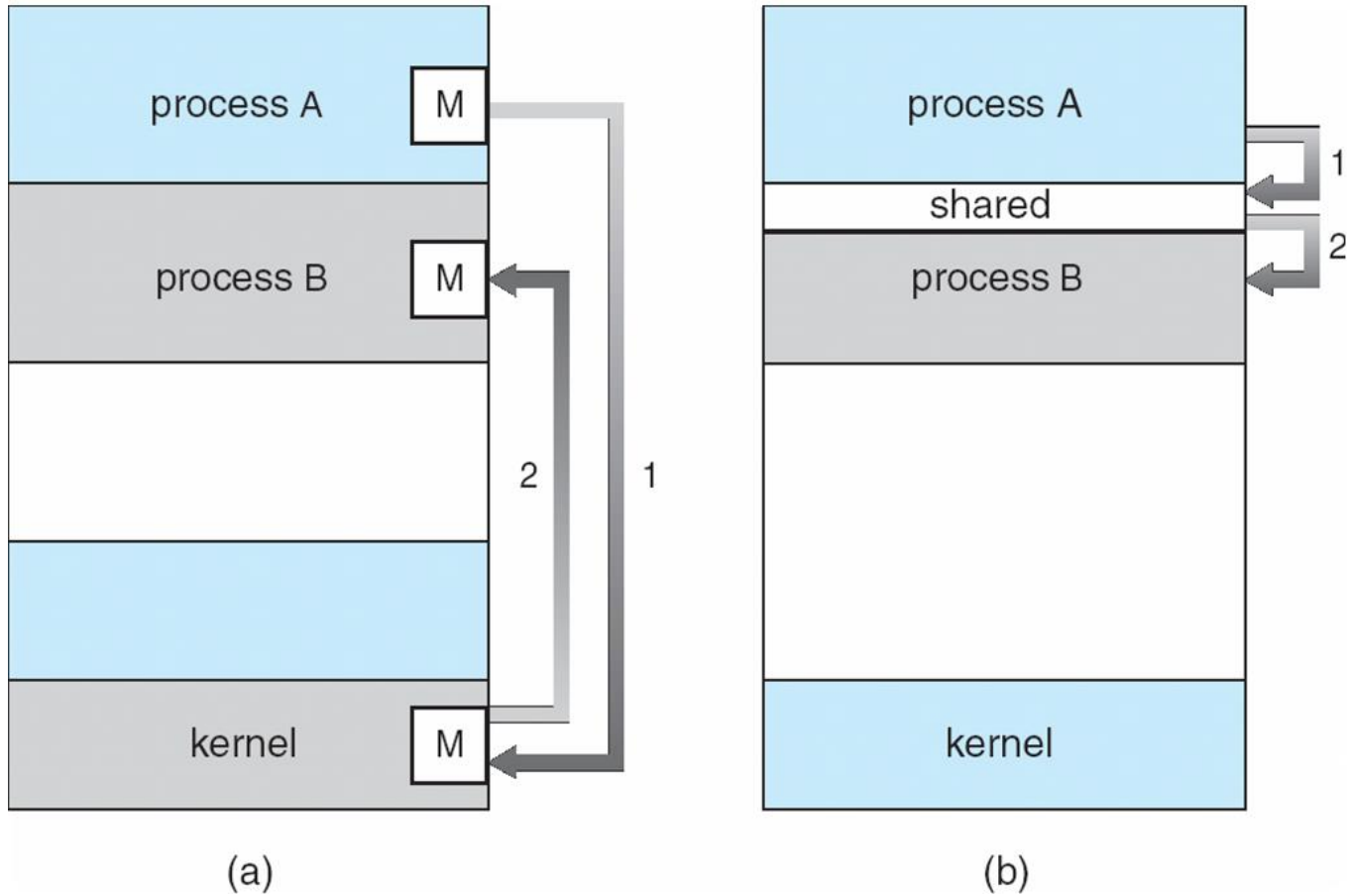
- Processes within a system may be **independent** or **cooperating**
- Cooperating process can affect or be affected by other processes, including sharing data
- Reasons for cooperating processes:
  - Information sharing
  - Computation speedup
  - Modularity
  - Convenience
- Cooperating processes need **interprocess communication (IPC)**
- Two models of IPC
  - Shared memory
  - Message passing

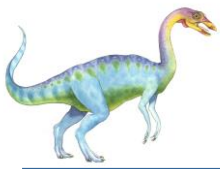






# Communications Models

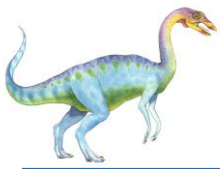




# Interprocess Communication – Message Passing

- 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)



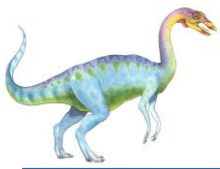


# Direct Communication

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- 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

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- 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
  - `send(A,message)`
  - `receive(A,message)`
- 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





# Synchronization

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- Message passing may be either blocking or non-blocking
- **Blocking** is considered **synchronous**
  - **Blocking send** has the sender block until the message is received
  - **Blocking receive** has the receiver block until a message is available
- **Non-blocking** is considered **asynchronous**
  - **Non-blocking send** has the sender send the message and continue
  - **Non-blocking receive** has the receiver receive a valid message or null





# Buffering

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- 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



# End of Chapter 3

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