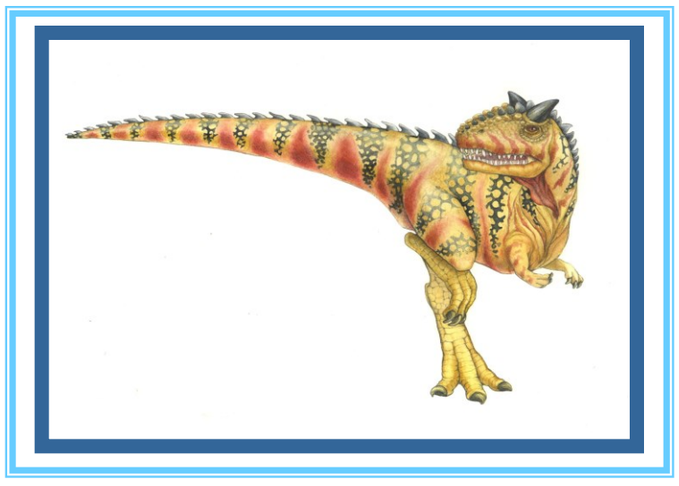
Chapter 3: Processes



Silberschatz, Galvin and Gagne ©2013



Chapter 3: Processes

- Process Concept
- Process Scheduling
- Operations on Processes
- Interprocess Communication
- Examples of IPC Systems
- Communication in Client-Server Systems





Objectives

- 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 explore interprocess communication using shared memory and message passing
- To describe communication in client-server systems





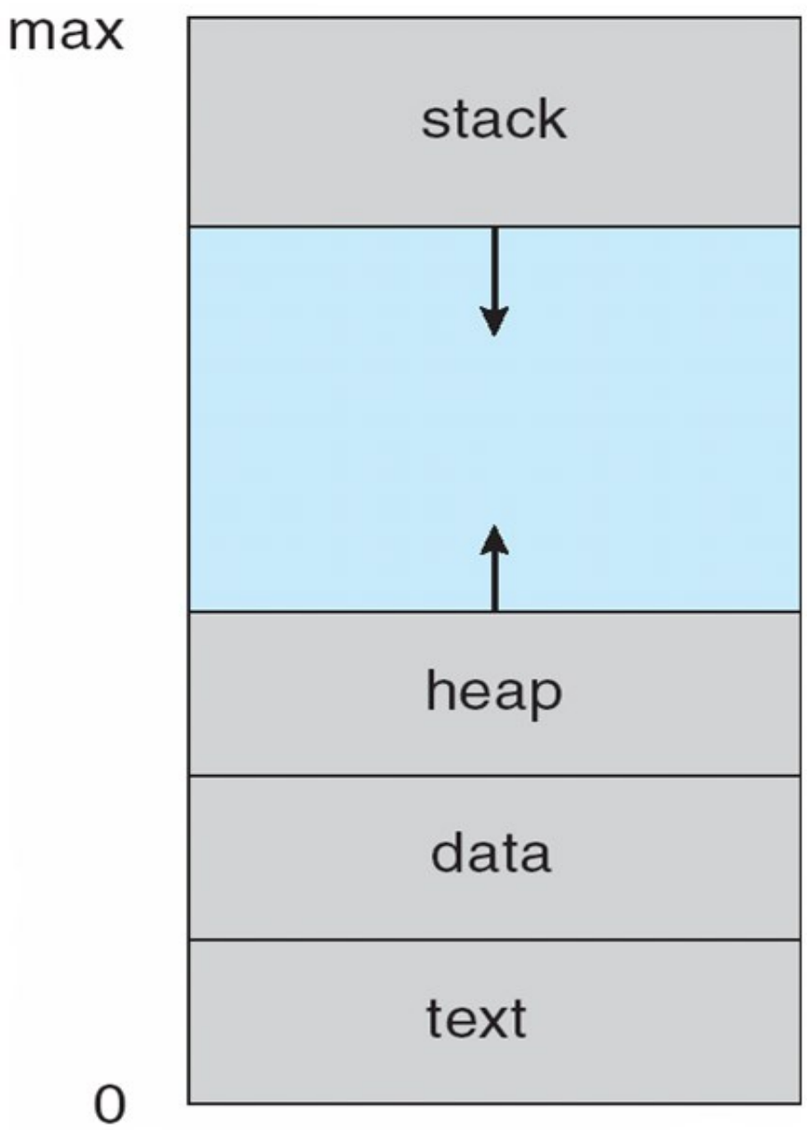
Process Concept

- An operating system executes a variety of programs:
  - Batch system – **jobs**
  - Time-shared systems – **user programs** or **tasks or Active program**
- Textbook uses the terms **job** and ***process*** almost interchangeably
- **Process** – a program in execution; process execution must progress in sequential fashion
- Multiple parts
  - The program code, also called **text section**
  - Current activity including **program counter**, processor registers
  - **Stack** containing temporary data
    - Function parameters, return addresses, local variables
  - **Data section** containing global variables
  - **Heap** containing memory dynamically allocated during run time
- Program is ***passive*** entity stored on disk (**executable file**), process is ***active***
  - Program becomes process when executable file loaded into memory {Multi}
- Execution of program started via GUI mouse clicks, command line entry of its name, etc
- One program can be several processes {how example}
  - Consider multiple users executing the same program





Process in Memory







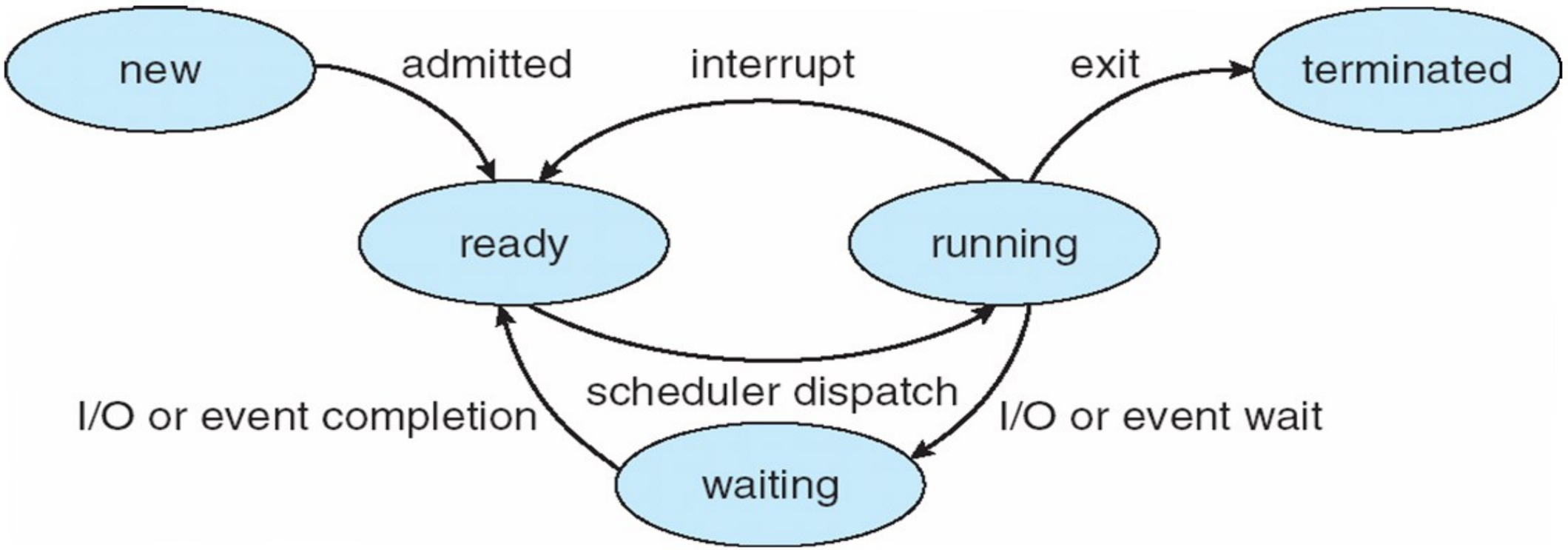
Process State

- 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 processor {Memory}
  - **terminated**: The process has finished execution (Passive/program}





Diagram of Process State





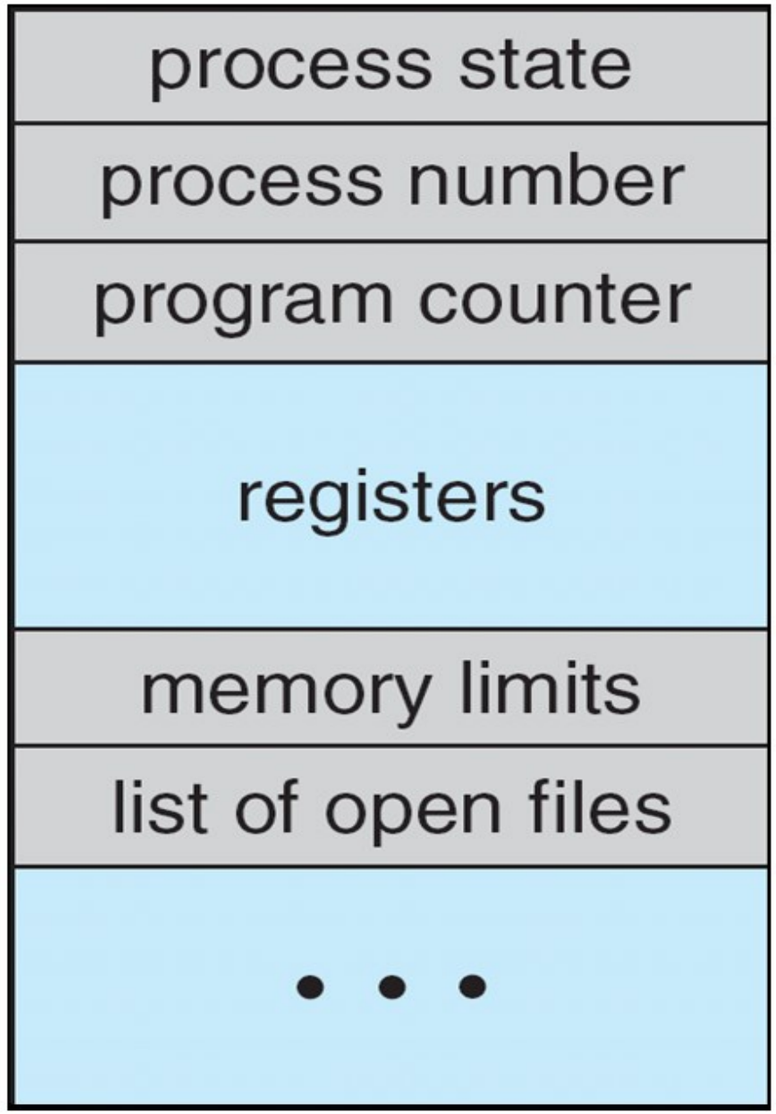


Process Control Block (PCB)

Information associated with each process

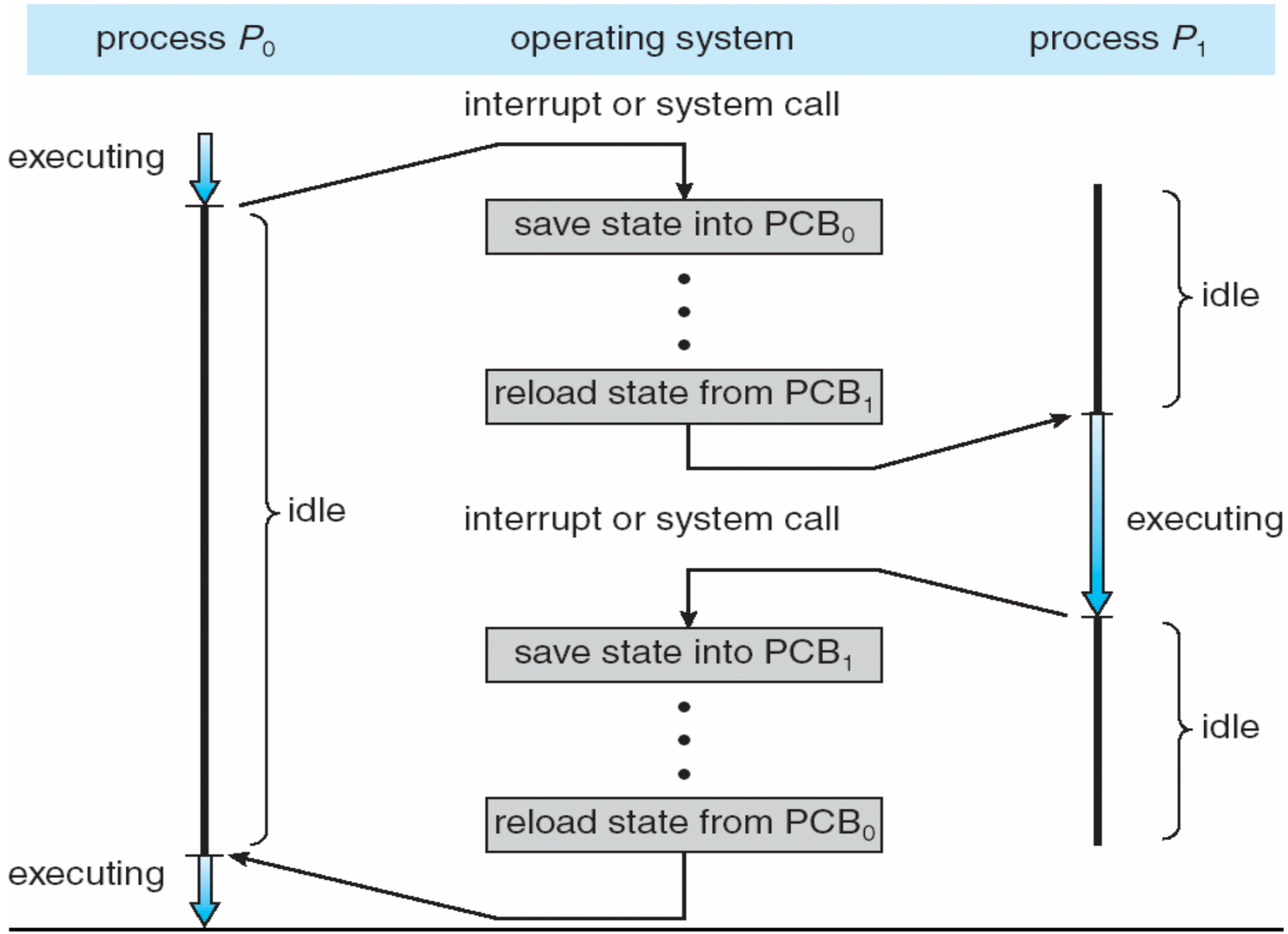
(also called **task control block**)

- Process state – running, waiting, etc
- Program counter – location of instruction to next execute
- CPU registers – contents of all process-centric registers
- CPU scheduling information- priorities, scheduling queue pointers
- Memory-management information – memory allocated to the process
- Accounting information – CPU used, clock time elapsed since start, time limits
- I/O status information – I/O devices allocated to process, list of open files





CPU Switch From Process to Process



States Q



Threads

- So far, process has a single thread of execution
- Consider having multiple program counters per process
  - Multiple locations can execute at once
    - Multiple threads of control -> **threads**
- Must then have storage for thread details, multiple program counters in PCB
- See next chapter





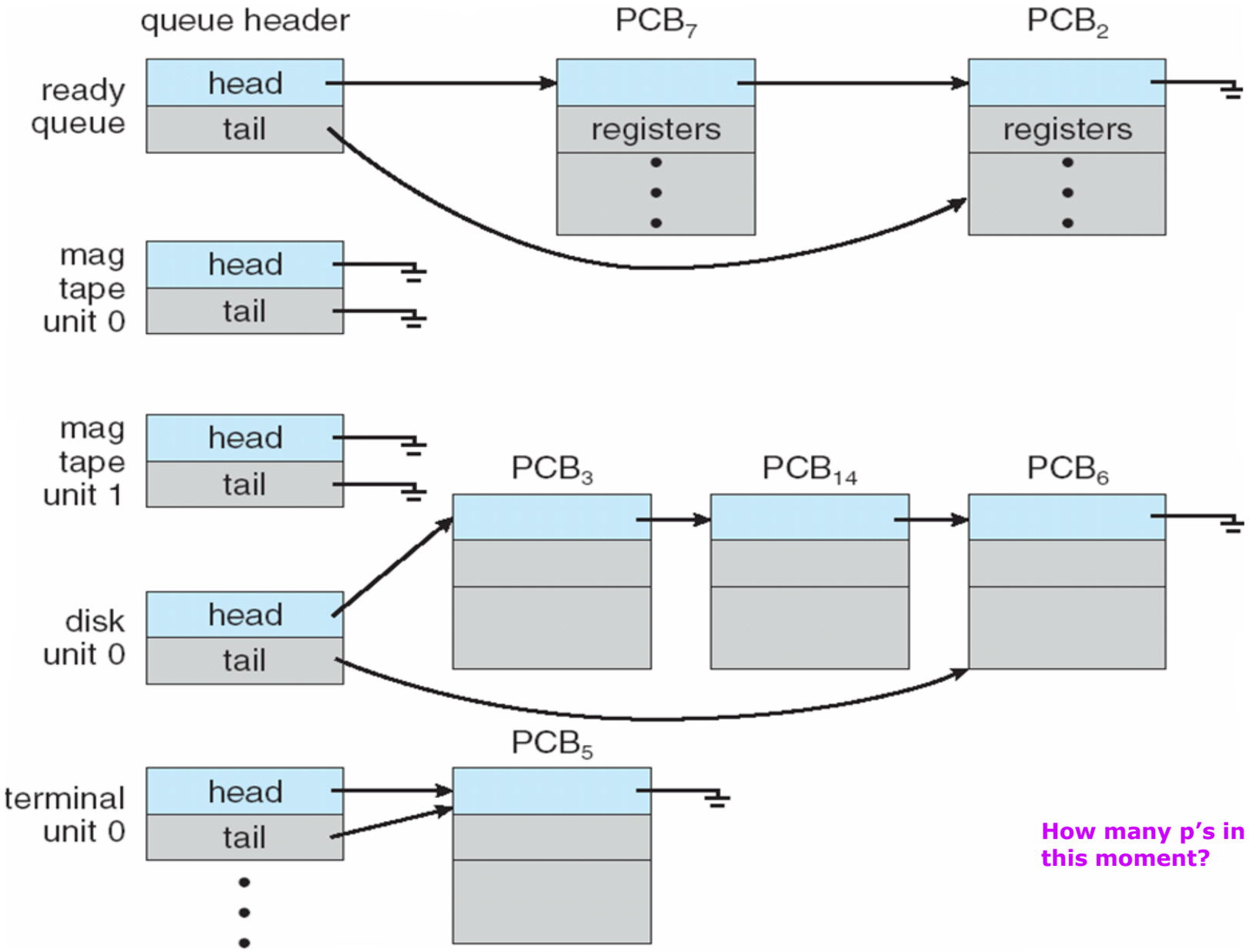
Process Scheduling

- Maximize CPU use, quickly switch processes onto CPU for time sharing
- **Process scheduler (S/W):** selects among available processes for next execution on CPU
- Maintains **scheduling queues** of processes
  - **Job queue** – set of all processes in the system
  - **Ready queue** – set of all processes residing in main memory, ready and waiting to execute // {belong to}
  - **Device queues** – set of processes waiting for an I/O device
  - Processes migrate among the various queues // (State diagram /Process life cycle)





Ready Queue And Various I/O Device Queues



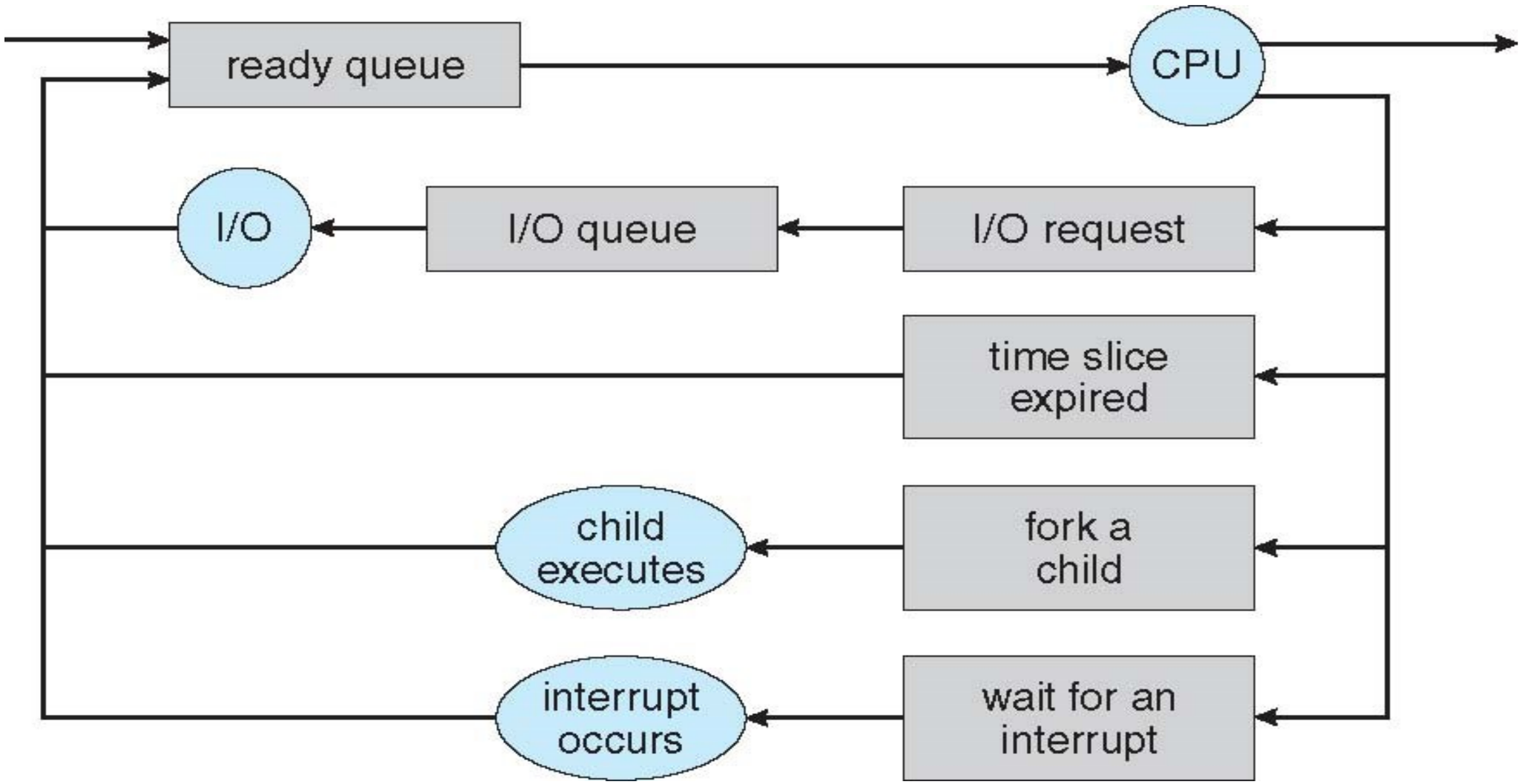
How many p's in the system this moment?





Representation of Process Scheduling

- **Queueing diagram** represents queues, resources, flows







Schedulers

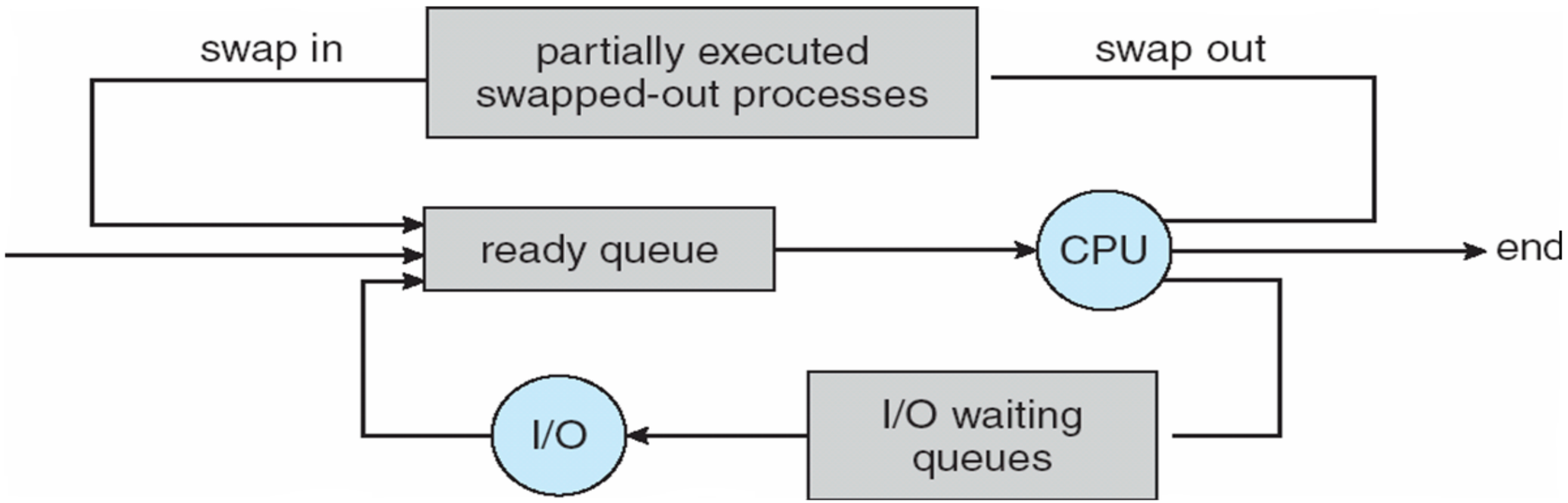
- **Long-term scheduler** (or **job scheduler**) – selects which processes should be brought into the ready queue
- **Short-term scheduler** (or **CPU scheduler**) – selects which process should be executed next and allocates CPU
  - Sometimes the only scheduler in a system
- Short-term scheduler is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





Addition of Medium Term Scheduling

- **Medium-term scheduler** can be added if degree of multiple programming needs to decrease
  - Remove process from memory, store on disk, bring back in from disk to continue execution: **swapping**



Merge F13& F15 in one single Figure





Multitasking in Mobile Systems

- Some systems / early systems allow only one process to run, others suspended
- Due to screen real estate, user interface limits iOS provides for a
  - Single **foreground** process- controlled via user interface { refers back to page 37}
  - Multiple **background** processes– in memory, running, but not on the display, and with limits
  - Limits include single, short task, receiving notification of events, specific long-running tasks like audio playback.

- Android runs foreground and background, with fewer limits
  - Background process uses a **service** to perform tasks
  - Service can keep running even if background process is suspended
  - Service has no user interface, small memory use

Two operating systems currently dominate mobile computing: Apple iOS and Google Android. iOS was designed to run on Apple iPhone and iPad mobile devices. Android powers smartphones and tablet computers available from many manufacturers. We examine these two mobile operating systems in further detail in Chapter 2.





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 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
  - The more complex the OS and the PCB -> longer the context switch
- Time dependent on hardware support





Operations on Processes

- **System must provide mechanisms for process creation, termination, and so on as detailed next.**

- **Process Creation : 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**)

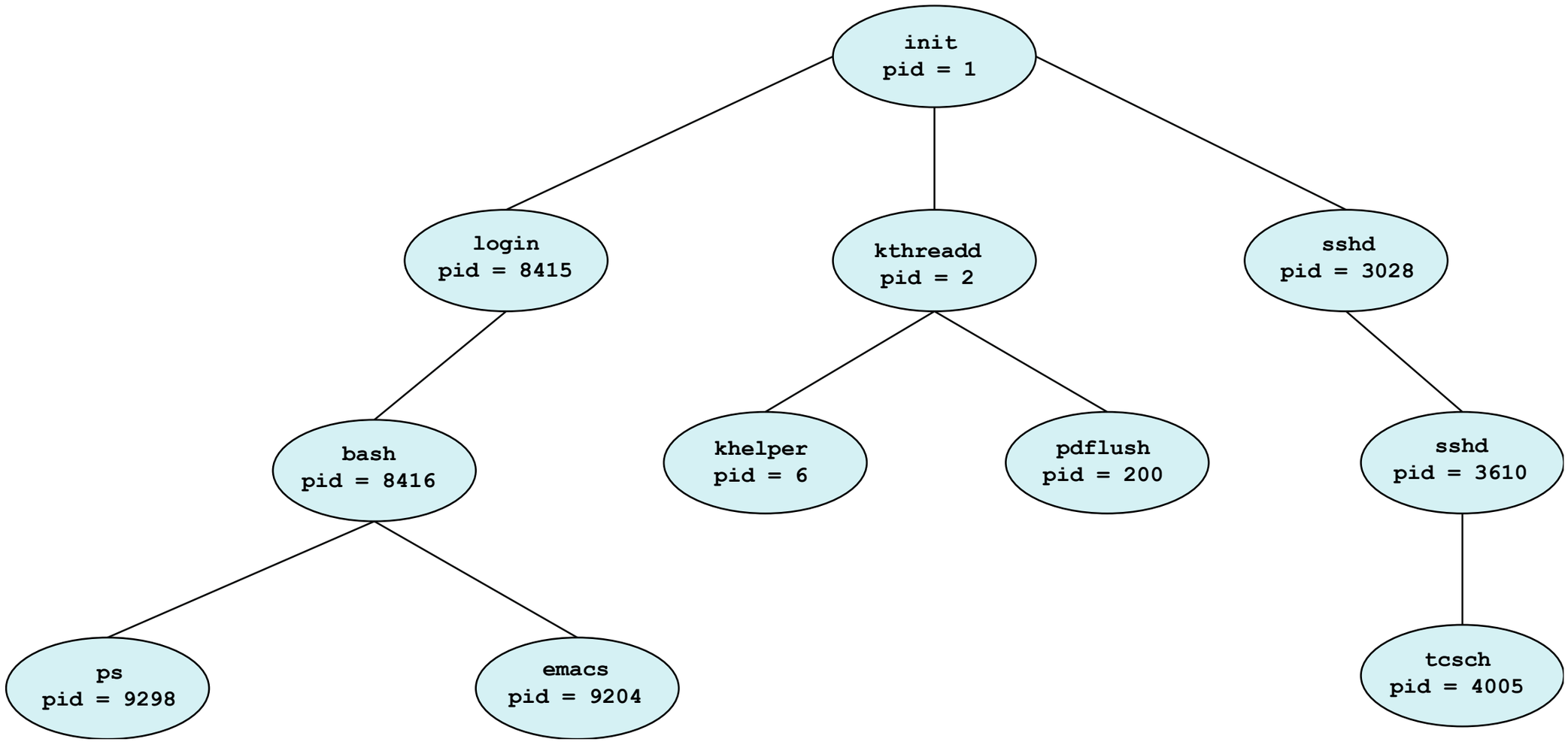
- Resource sharing options
  - Parent and children share all resources
  - Children share subset of parent's resources
  - Parent and child share no resources

- Execution options
  - Parent and children execute concurrently
  - Parent waits until children terminate





A Tree of Processes in Linux

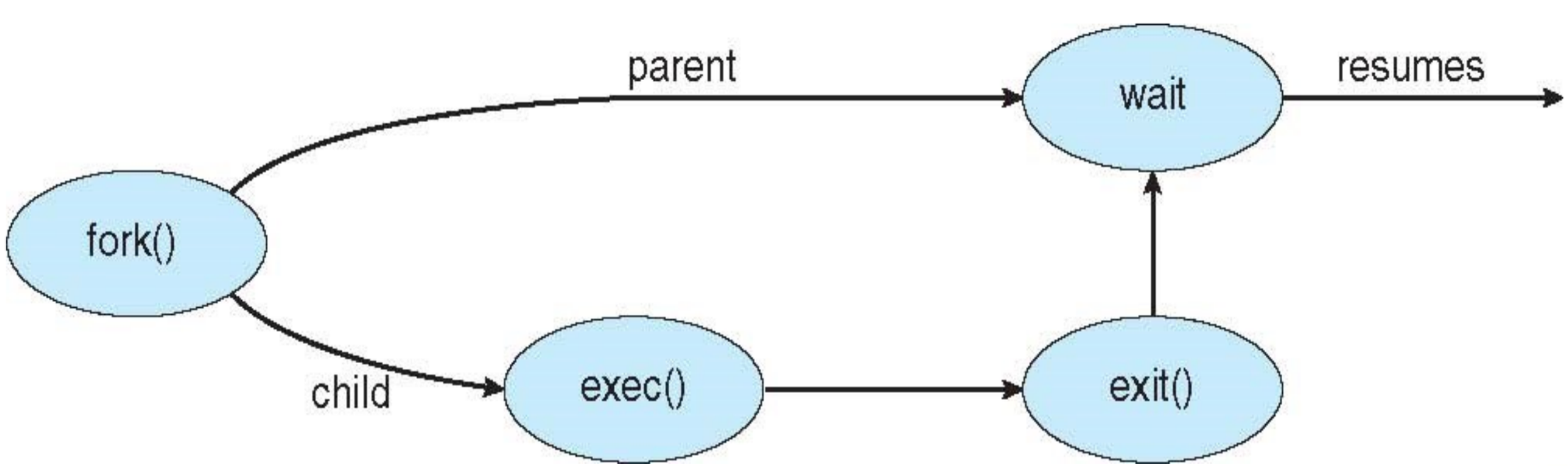




Process Creation (Cont.)

- Address space
  - Child duplicate of parent
  - Child has a program loaded into it

- UNIX examples
  - `fork()` system call creates new process{ what is fork and in which os is found}
  - `exec()` system call used after a `fork()` to replace the process' memory space with a new program





C Program Forking Separate Process

```
#include <sys/types.h>
#include <stdio.h>
#include <unistd.h>

int main()
{
pid_t pid;

    /* fork a child process */
    pid = fork();

    if (pid < 0) { /* error occurred */
       fprintf(stderr, "Fork Failed");
       return 1;
    }
    else if (pid == 0) { /* child process */
       execlp("/bin/ls","ls",NULL);
    }
    else { /* parent process */
       /* parent will wait for the child to complete */
       wait(NULL);
       printf("Child Complete");
    }

    return 0;
}
```





Creating a Separate Process via Windows API

```
#include <stdio.h>
#include <windows.h>

int main(VOID)
{
STARTUPINFO si;
PROCESS_INFORMATION pi;

    /* allocate memory */
    ZeroMemory(&si, sizeof(si));
    si.cb = sizeof(si);
    ZeroMemory(&pi, sizeof(pi));

    /* create child process */
    if (!CreateProcess(NULL, /* use command line */
     "C:\\WINDOWS\\system32\\mspaint.exe", /* command */
     NULL, /* don't inherit process handle */
     NULL, /* don't inherit thread handle */
     FALSE, /* disable handle inheritance */
     0, /* no creation flags */
     NULL, /* use parent's environment block */
     NULL, /* use parent's existing directory */
     &si,
     &pi))
    {
       fprintf(stderr, "Create Process Failed");
       return -1;
    }
    /* parent will wait for the child to complete */
    WaitForSingleObject(pi.hProcess, INFINITE);
    printf("Child Complete");

    /* close handles */
    CloseHandle(pi.hProcess);
    CloseHandle(pi.hThread);
}
```





Process Termination

- Process executes last statement and asks the operating system to delete it (`exit()`) what is the commend?
  - Output data from child to parent (via `wait()`)
  - Process' resources are deallocated by operating system

- Parent may terminate execution of children processes (`abort()`) when the abort command happened by parent?
  - Child has exceeded allocated resources
  - Task assigned to child is no longer required
  - If parent is exiting
    - Some operating systems do not allow child to continue if its parent terminates
      - All children terminated - **cascading termination**

- Wait for termination, returning the pid:

```
pid t_pid; int status;
pid = wait(&status);
```

- If no parent waiting, then terminated process is a **zombie***
- If parent terminated, processes are **orphans** **page 121**

* A process that has terminated, but whose parent has not yet called wait(), is known as a **zombie** process.

* Now consider what would happen if a parent did not invoke wait() and instead terminated, thereby leaving its child processes as **orphans**.





Multiprocess Architecture – Chrome Browser

- Many web browsers ran as single process (some still do)
  - If one web site causes trouble, entire browser can hang or crash
- Google Chrome Browser is multiprocess with 3 categories
  - **Browser** process manages user interface, disk and network I/O
  - **Renderer** process renders web pages, deals with HTML, Javascript, new one for each website opened
    - Renderer process runs in **sandbox** restricting disk and network I/O, minimizing effect of security exploits
  - **Plug-in** process for each type of plug-in page 123





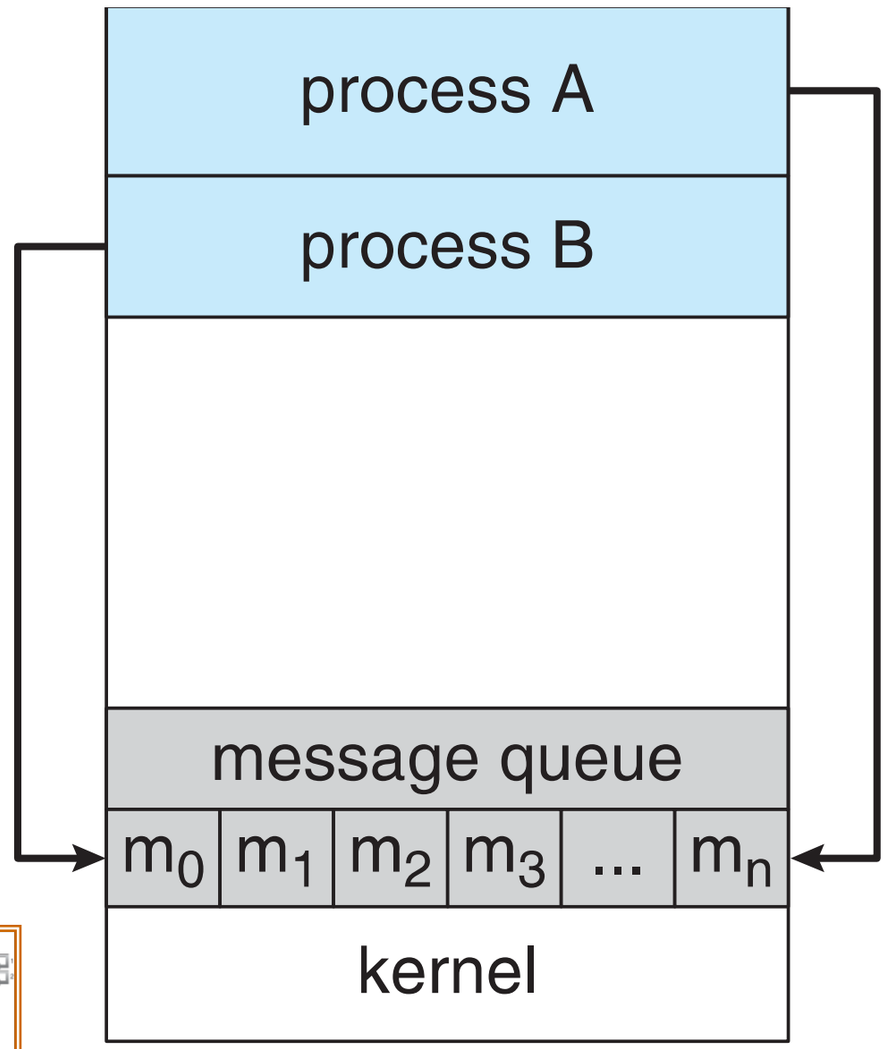


Interprocess Communication

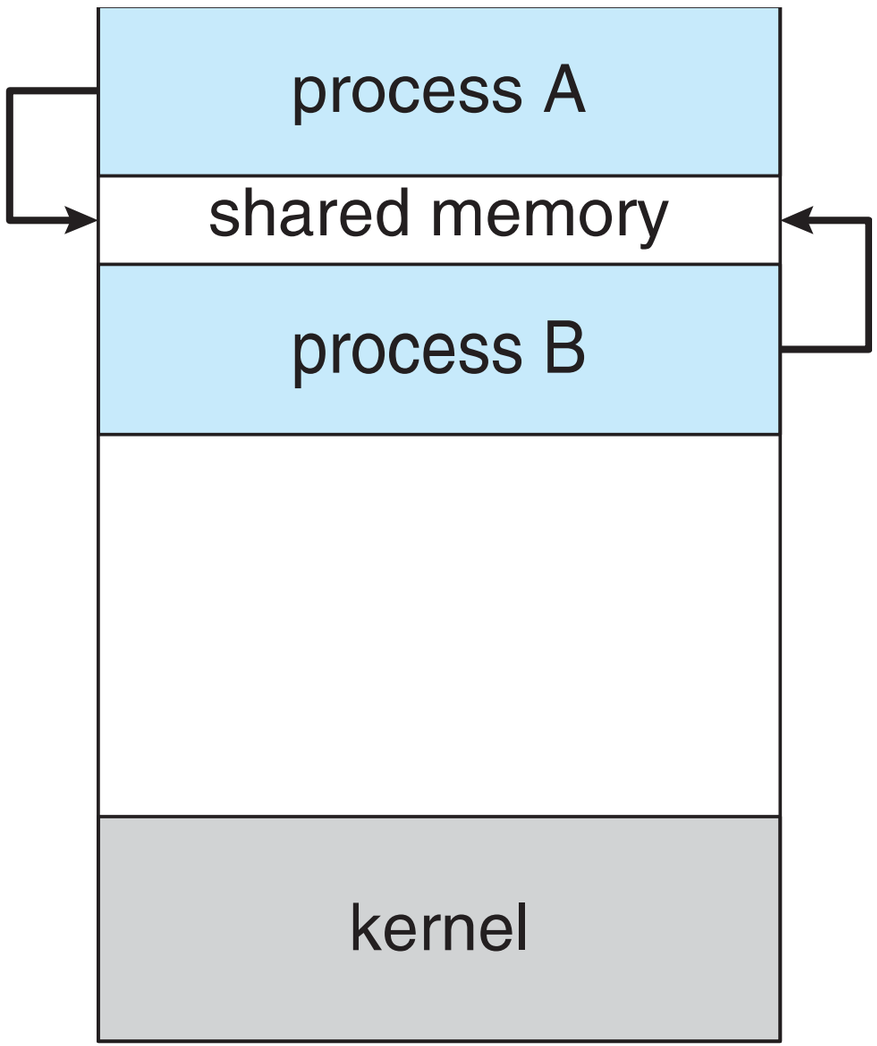
- Processes within a system may be ***independent*** or ***cooperating***
- Cooperating process can affect or be affected by other processes, including sharing data
- Reasons for cooperating processes:
  - Information sharing
  - Computation speedup
  - Modularity
  - Convenience
- Cooperating processes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



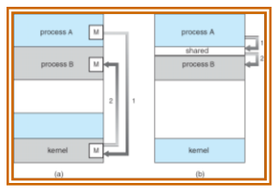
Communications Models



(a)



(b)





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

Q. Explain the function of the following segment

- Shared data

```
#define BUFFER_SIZE 10

typedef struct {
  . . .
} item;

item buffer[BUFFER_SIZE];

int in = 0;

int out = 0;
```

- Solution is correct, but can only use BUFFER_SIZE-1 elements





Bounded-Buffer – Producer

Q. Explain the function of the following segment?

```
item next_produced;
while (true) {
    /* produce an item in next produced */
    while (((in + 1) % BUFFER_SIZE) == out)
        ; /* do nothing */
    buffer[in] = next_produced;
    in = (in + 1) % BUFFER_SIZE;
}
```





Bounded Buffer – Consumer

```
item next_consumed;

while (true) {
     while (in == out)
          ; /* do nothing */
     next_consumed = buffer[out];
     out = (out + 1) % BUFFER_SIZE;

     /* consume the item in next consumed */
}
```





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., direct or indirect, synchronous or asynchronous, automatic or explicit buffering)





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
  - 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





Indirect Communication

- Operations
  - create a new mailbox
  - send and receive messages through mailbox
  - destroy a mailbox

- Primitives are defined as:

  `send`(*A, message*) – send a message to mailbox A

  `receive`(*A, message*) – receive a message from mailbox A





Indirect Communication

- 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.





Synchronization

- 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

}



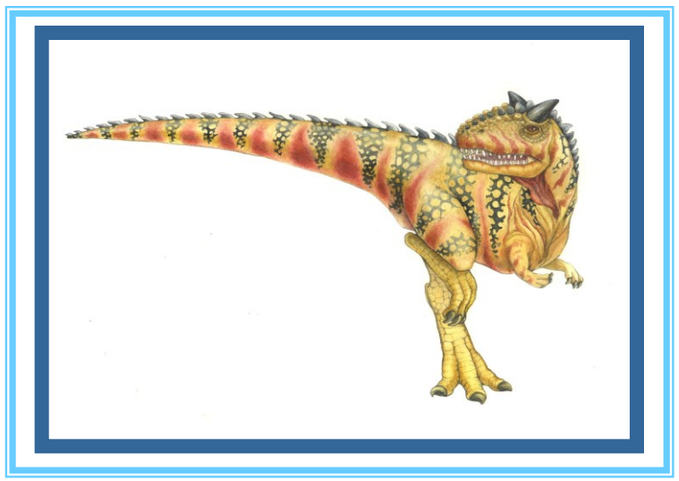


Examples of IPC Systems – Windows

- Message-passing centric via **advanced local procedure call (LPC)** facility
  - Only works between processes on the same system
  - Uses ports (like mailboxes) to establish and maintain communication channels
  - Communication works as follows:
    - The client opens a handle to the subsystem's **connection port** object.
    - The client sends a connection request.
    - The server creates two private **communication ports** and returns the handle to one of them to the client.
    - The client and server use the corresponding port handle to send messages or callbacks and to listen for replies.



End of Chapter 3



Silberschatz, Galvin and Gagne ©2013