Distributed Operating Systems

Process Management

Processes Management

- Process Concept
- Operations on Processes
- Inter-process Communication
- Examples of IPC Systems

Process Concept

- Process – a program in execution; process execution must progress in sequential fashion
- A process includes:
  - program counter
  - stack
  - data section

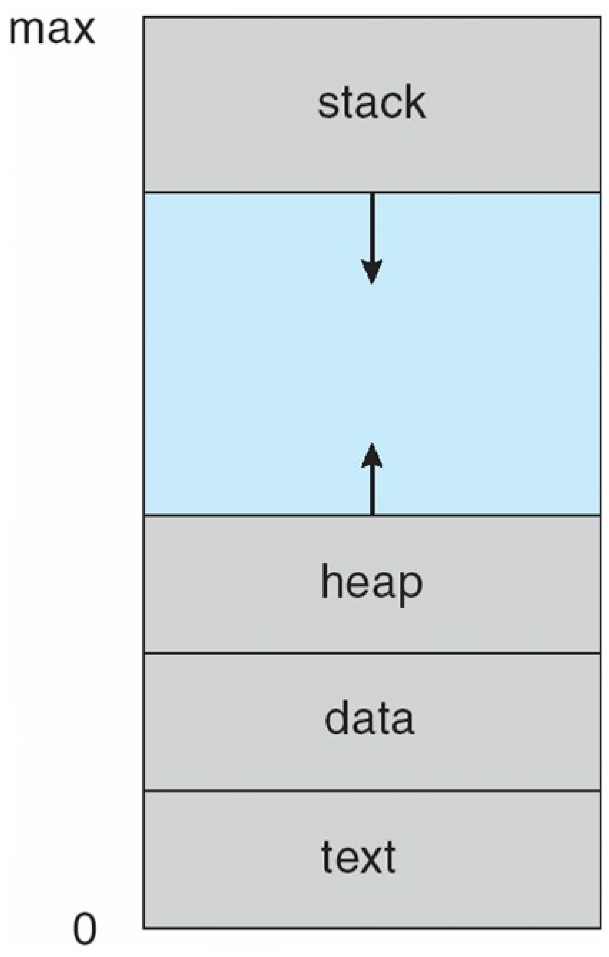
The Process

- Program is passive entity, process is active
  - Program becomes process when executable file loaded into memory
- Execution of program started via GUI mouse clicks, command line entry of its name, etc
- One program can be several processes
  - Consider multiple users executing the same program

Parts of a Process

- 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

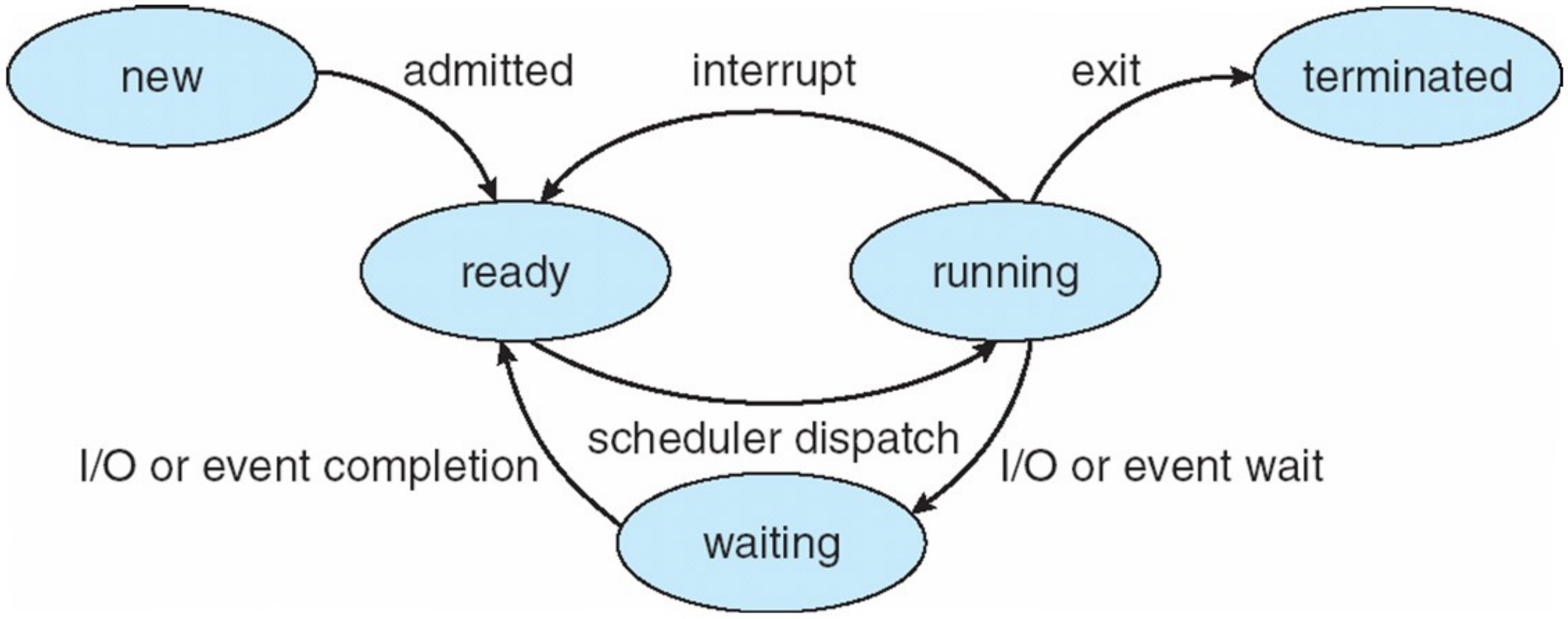
Process in Memory



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
  - **terminated**: The process has finished execution

Diagram of Process State

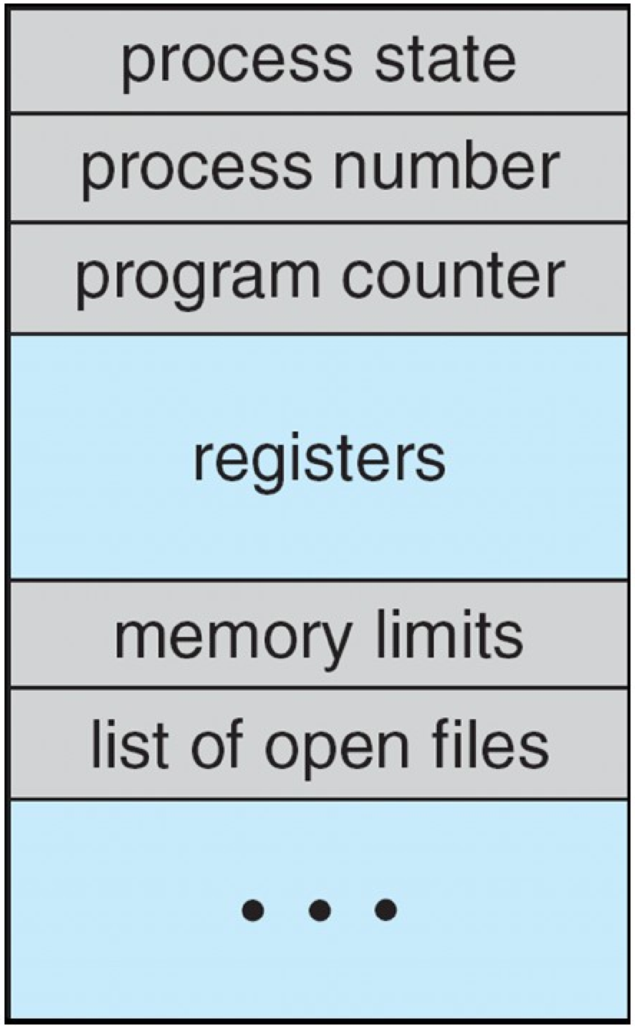


Process Control Block (PCB)

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)



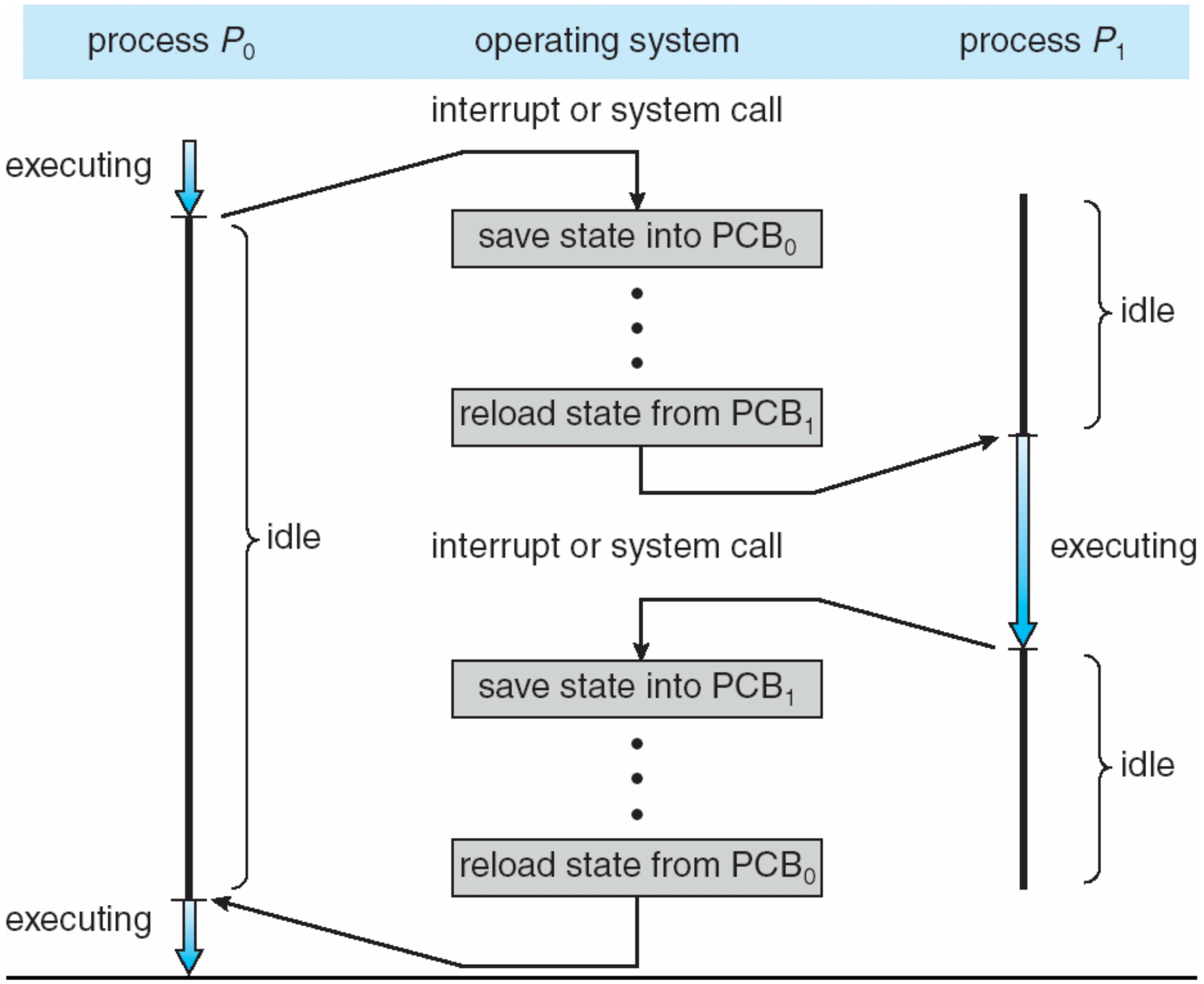
Multiprogramming

- A number of processes share the CPU time for improving system efficiency.
- The number of user processes is called degree of multiprogramming.
- CPU is revoked from a process if it needs to wait for some resource (I/O operation for instance).
- CPU is revoked also at the end of a pre-defined period called ***time slice***

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
  - Some hardware provides multiple sets of registers per CPU -> multiple contexts loaded at once

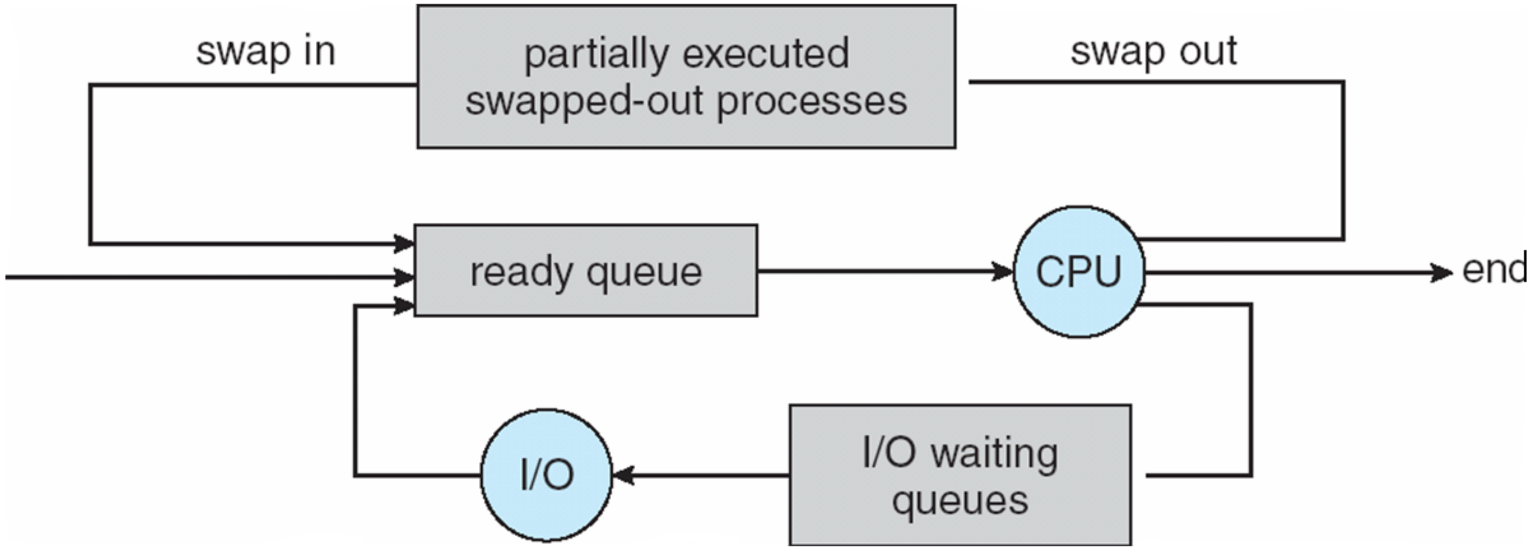
CPU Switch From Process to Process



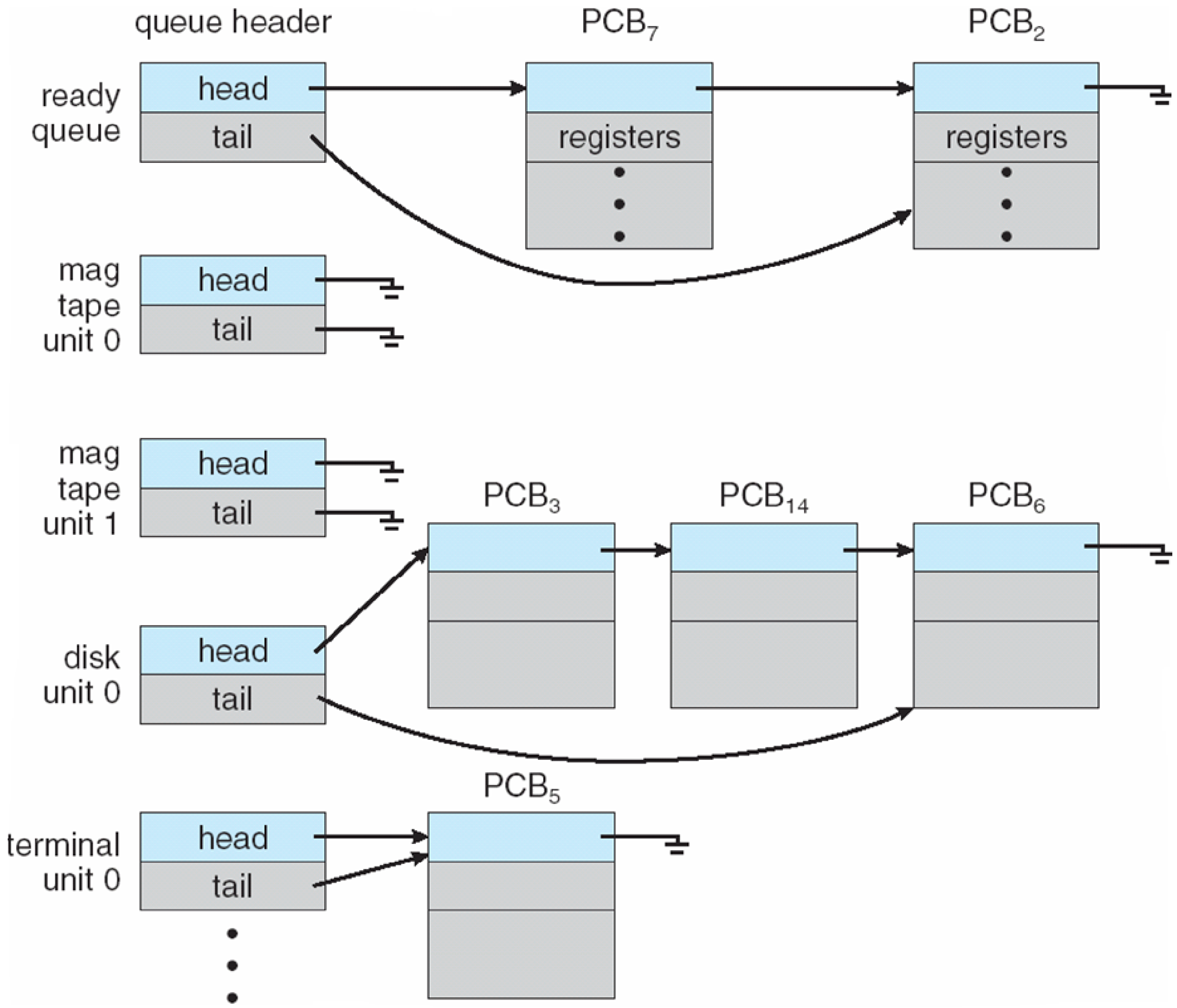
Process Scheduling

- Maximize CPU use, quickly switch processes onto CPU for time sharing
- **Process scheduler** 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
  - **Device queues** – set of processes waiting for an I/O device
  - Processes migrate among the various queues

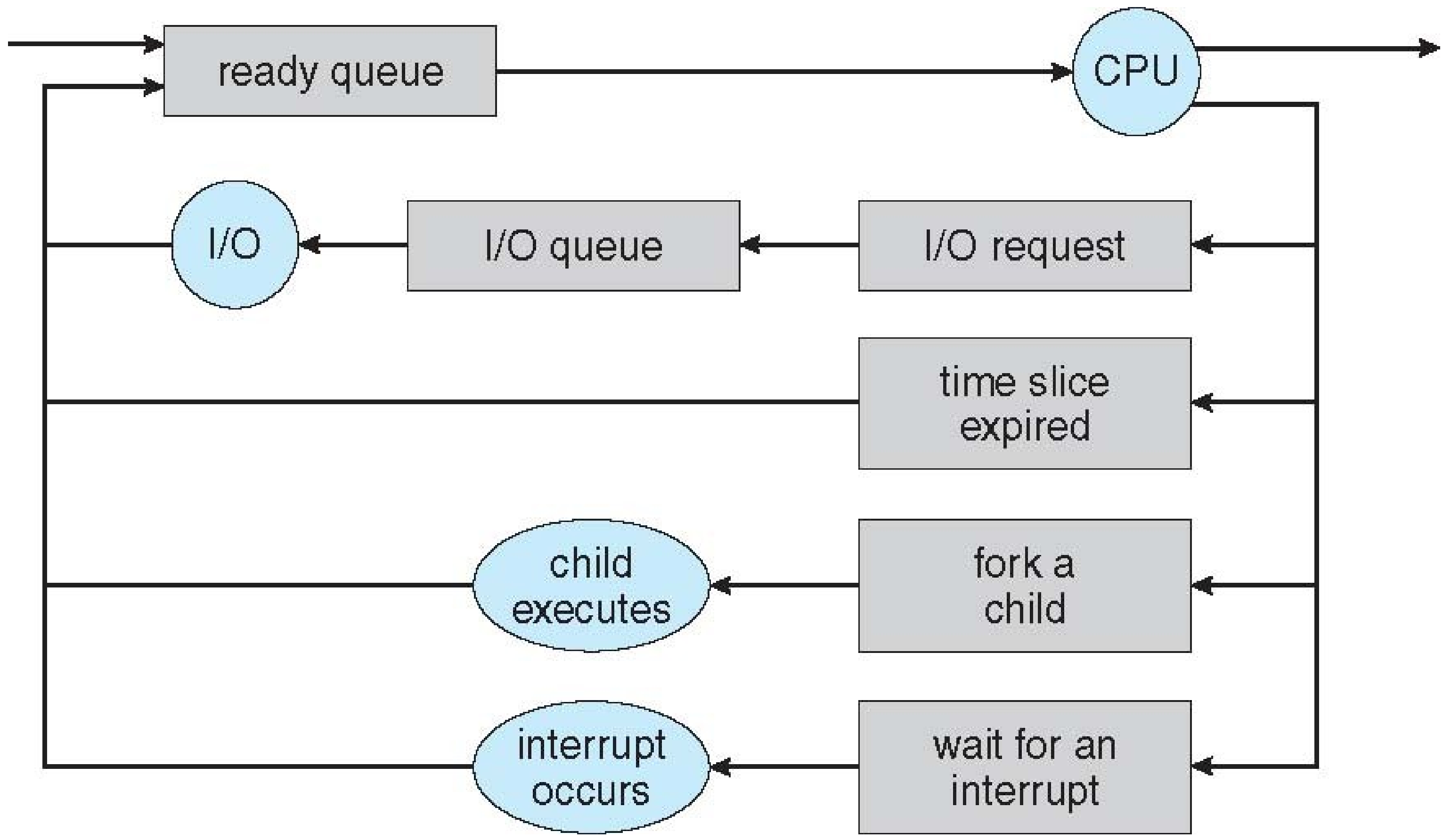
Scheduling


swap in
partially executed swapped-out processes
swap out
ready queue
CPU
end
I/O
I/O waiting 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
  - Sometimes the only scheduler in a system

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

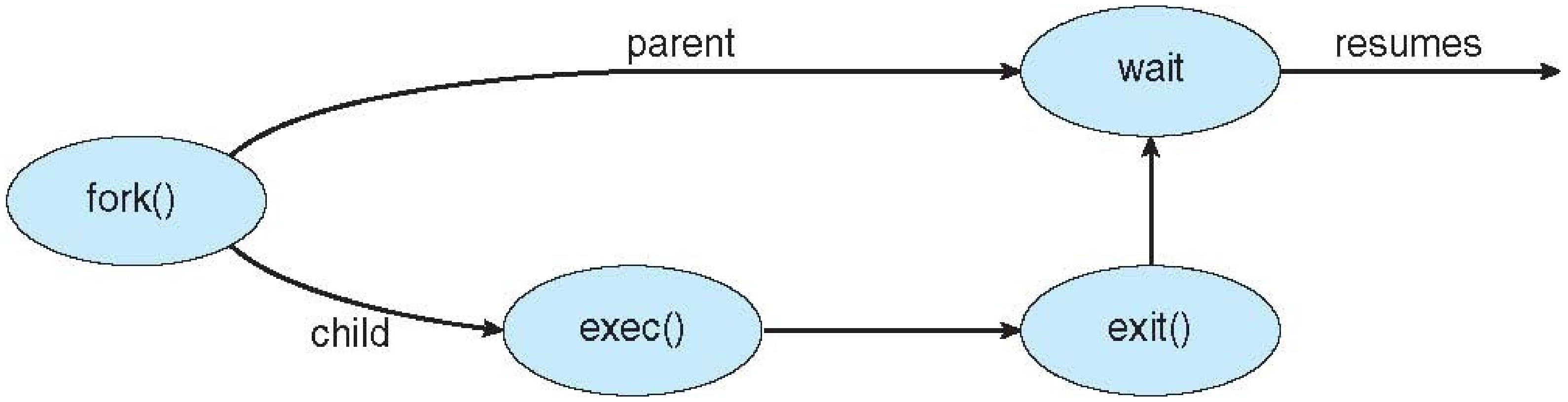
Process Creation

- **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
  - 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 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

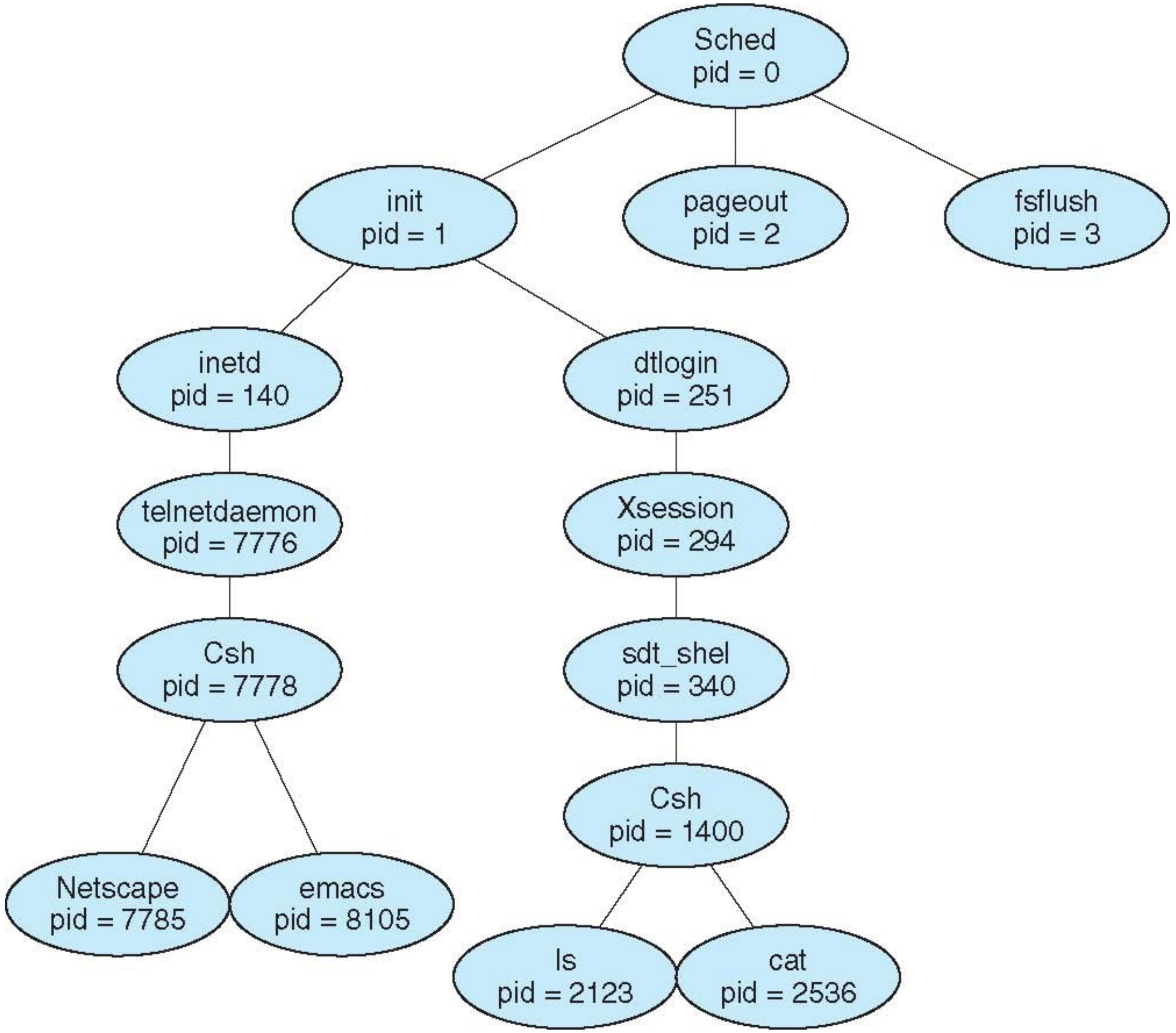
Process Creation



C Program Forking Separate Process

```
#include <sys/types.h>
#include <studio.h>
#include <unistd.h>
int main()
{
pid_t  pid;
     /* fork another 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 */
             wait (NULL);
             printf ("Child Complete");
     }
     return 0;
}
```

A Tree of Processes on Solaris



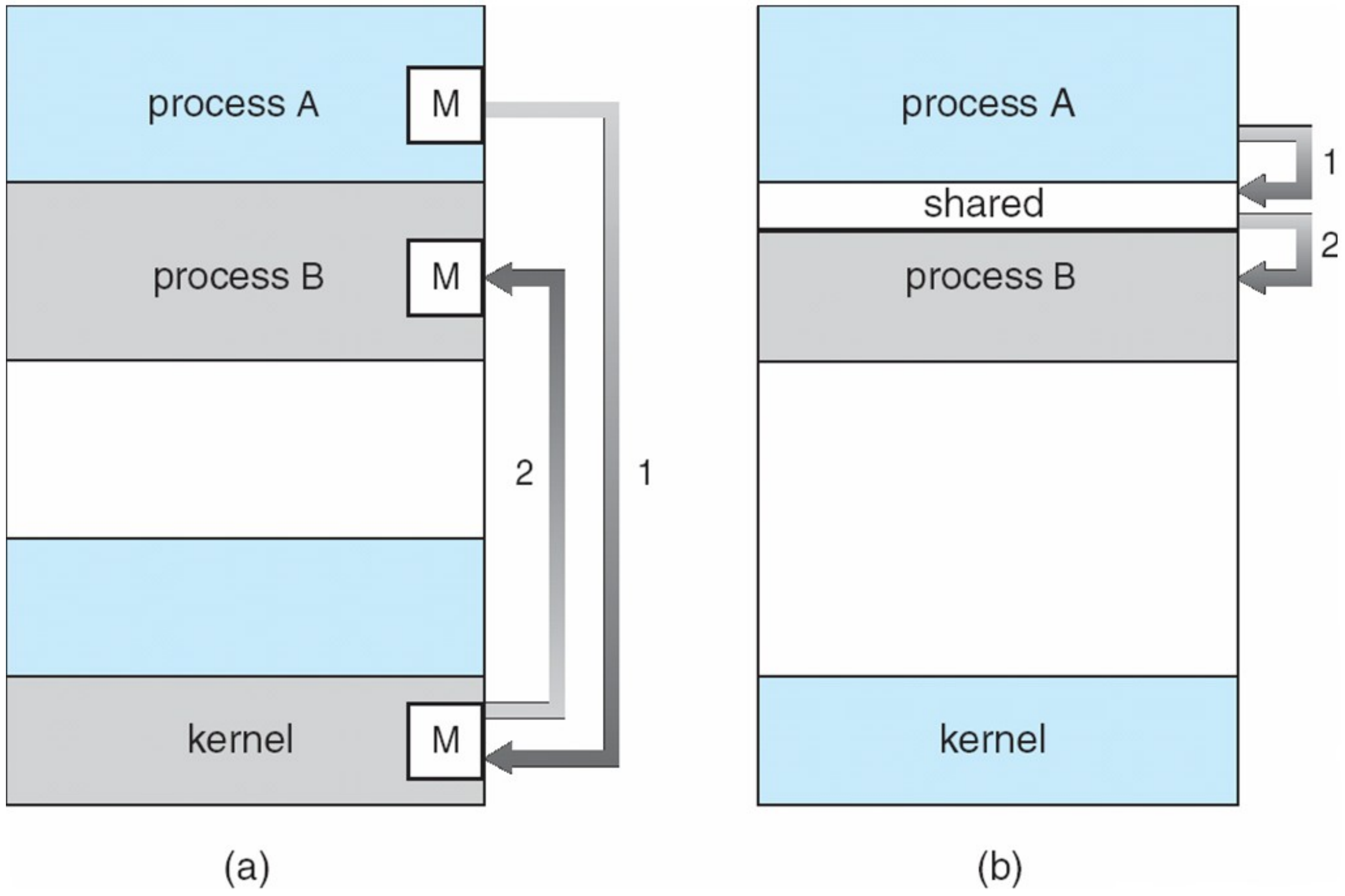
Process Termination

- 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 systems do not allow child to continue if its parent terminates
      - All children terminated - **cascading termination**

Inter-process 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 **inter-process communication** (**IPC**)
- Two models of IPC
  - Shared memory
  - Message passing

Communications Models



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

```
#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

```
while (true) {
  /* Produce an item */
   while (( (in + 1) % BUFFER_SIZE)  == out)
    ;   /* do nothing -- no free buffers */
   buffer[in] = item;
   in = (in + 1) % BUFFER_SIZE;
 }
```

Bounded Buffer – Consumer

```
while (true) {
     while ( in == out )
            ; // do nothing -- nothing to consume

    // remove an item from the buffer
    item = buffer[out];
    out = (out + 1) % BUFFER SIZE;
return item;
 }
```

Inter-process 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)

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

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

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

Examples of IPC Systems - POSIX

- POSIX Shared Memory
  - Process first creates shared memory segment

```
segment id = shmget(IPC PRIVATE, size, S
  IRUSR | S IWUSR);
```

  - Process wanting access to that shared memory must attach to it

```
shared memory = (char *) shmat(id, NULL,
  0);
```

  - Now the process could write to the shared memory

```
sprintf(shared memory, "Writing to shared
  memory");
```

  - When done a process can detach the shared memory from its address space

```
shmdt(shared memory);
```

Pipes

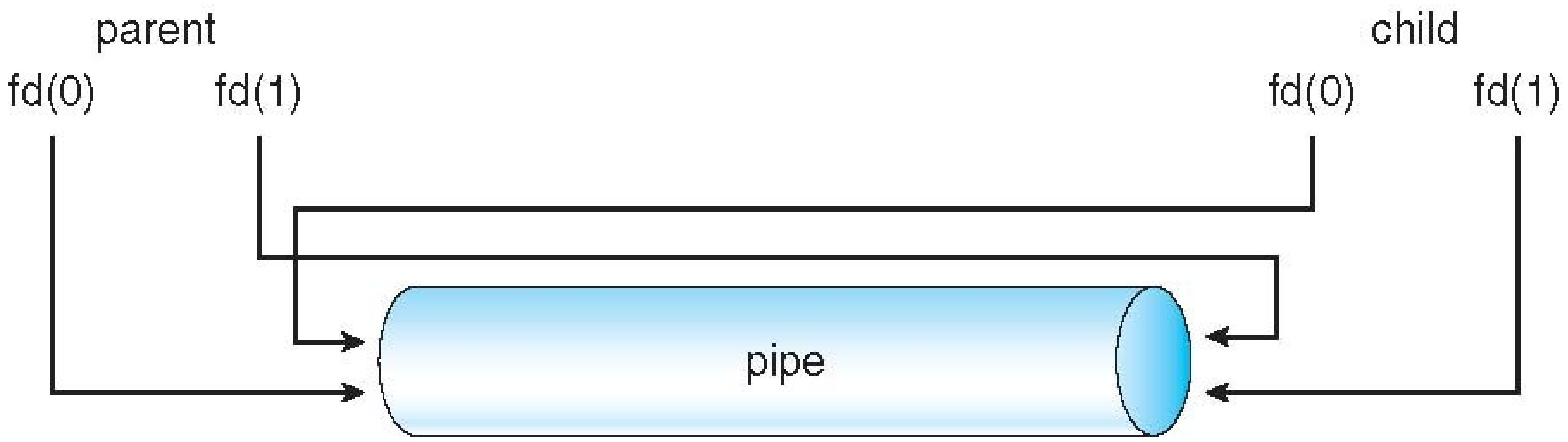
- Acts as a conduit allowing two processes to communicate

- **Issues**
  - Is communication unidirectional or bidirectional?
  - In the case of two-way communication, is it half or full-duplex?
  - Must there exist a relationship (i.e. parent-child) between the communicating processes?
  - Can the pipes be used over a network?

Ordinary Pipes

- **Ordinary Pipes** allow communication in standard producer-consumer style
- Producer writes to one end (the *write-end* of the pipe)
- Consumer reads from the other end (the *read-end* of the pipe)
- Ordinary pipes are therefore unidirectional
- Require parent-child relationship between communicating processes

Ordinary Pipes



Named Pipes

- Named Pipes are more powerful than ordinary pipes
- Communication is bidirectional
- No parent-child relationship is necessary between the communicating processes
- Several processes can use the named pipe for communication
- Provided on both UNIX and Windows systems

Problems with Inter-Process Communication

- Simultaneous access to a shred resource (shared memory location) can produce invalid results.
- Access to the shared memory locations when a process updates the values should be controlled.

Questions?