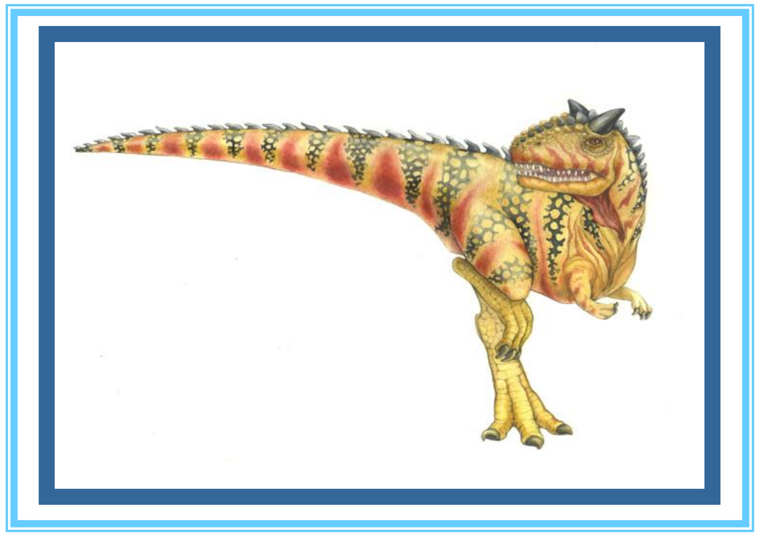
Processes



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Processes

- Process Concept
- Process Scheduling
- Operations on Processes
- Inter-process 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 describe communication in **client-server** systems

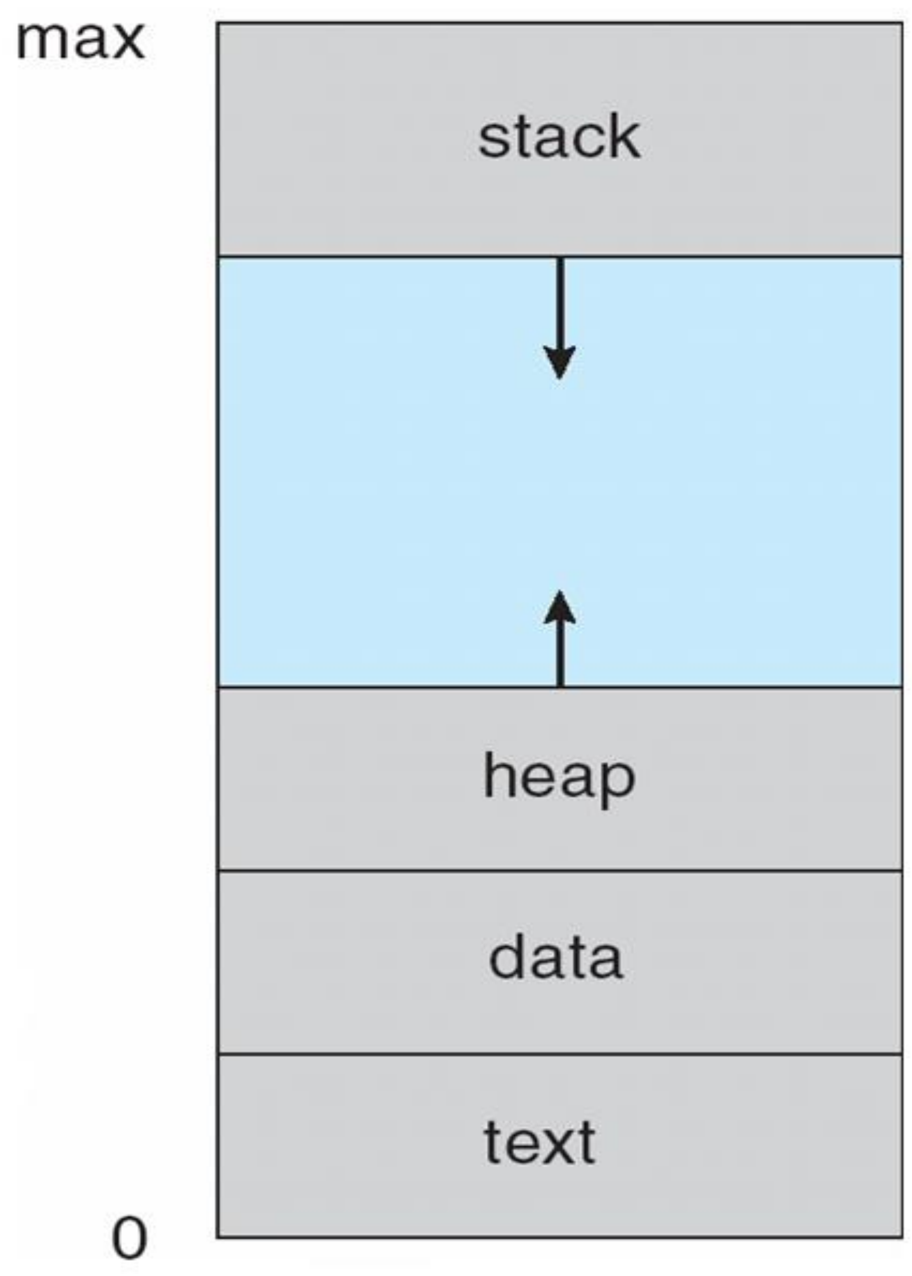
Process Concept

- An operating system executes a variety of programs:
  - Batch system – jobs
  - Time-shared systems – user programs or tasks
- 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 [data + heap]

Process vs. Program

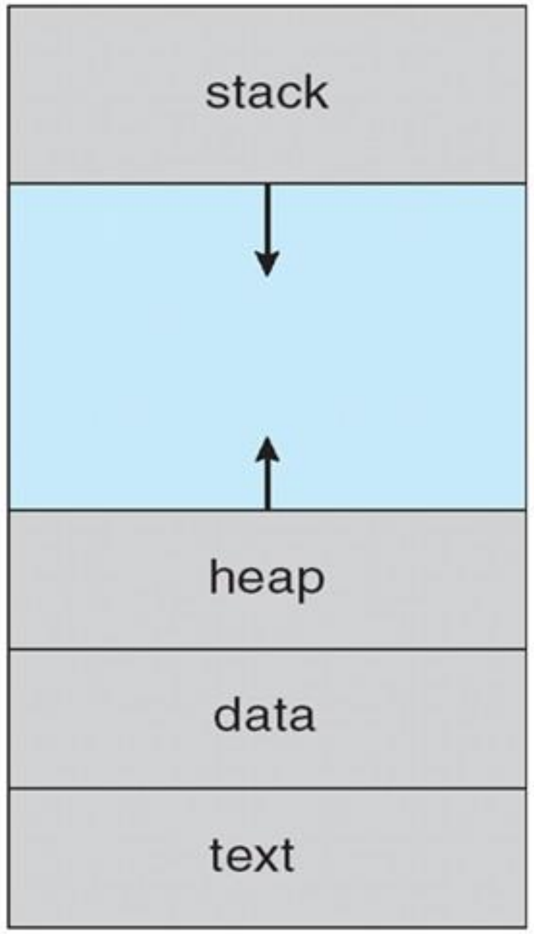
- Program is a **passive** entity
  - It usually found on hard drives or magnetic disks
- Process is an **active** entity
  - The action starts when a program file **loaded into memory**
- Execution of program started via
  - **GUI** event (GUI = Graphic User Interfaces)
  - **Command line** entry of its name (cmd.exe, xterm, putty, …)
  - **Exec system calls** (exec*(), CreateProcess, …)
- One program can start many processes
  - Consider 10 instances of FireFox process (10 tabs)
  - Consider multiple users executing the same program

Process in Memory



The Process

- **Text section (machine code!!)**
- **program counter**, **processor registers**
- **Data section**
  - Consists of global and static variables that are initialized by the programmer (like C++ const/global declarations, Java Final…)
  - Does not change at run-time
- **Heap**
  - Dynamic memory, allocated during run time
  - data is freed with delete, delete[], or free()
  - (this is where memory leaks happen …)
- **Stack** containing temporary data
  - Function arguments
  - Return values (usually pointers to structures on the heap)
  - local variables (C uses the stack to store local variables)



Example

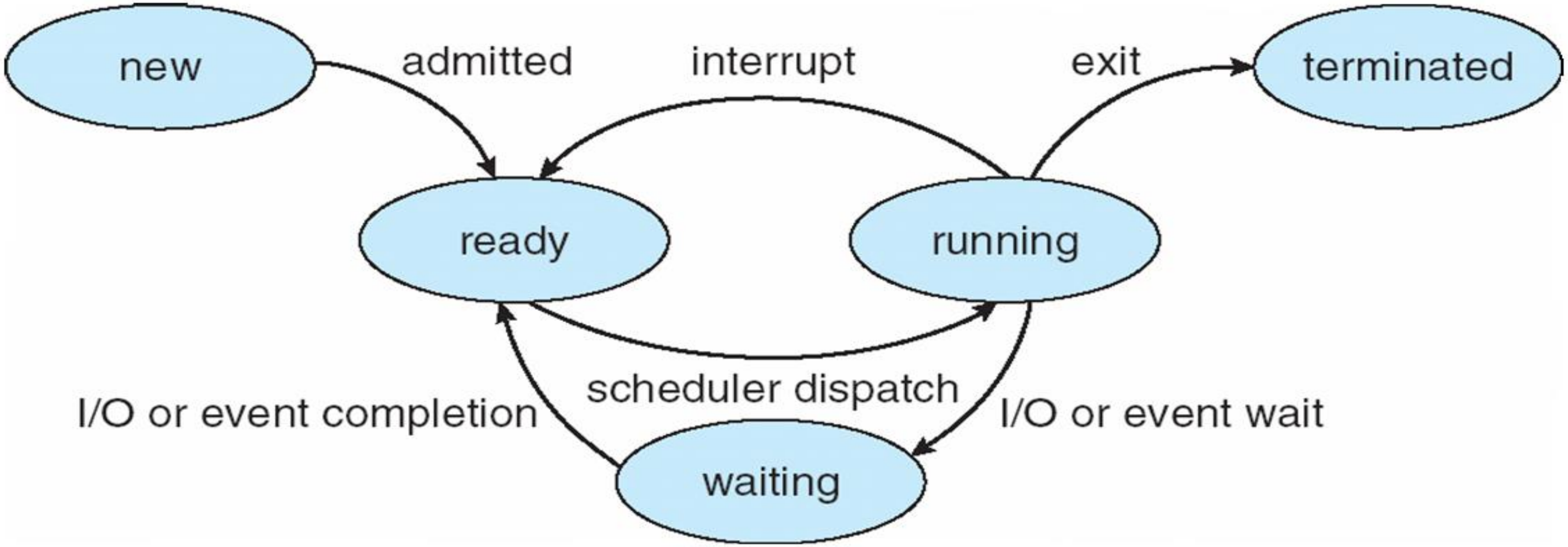
```
double PI = 3.14159   // data or text?
unsigned int u = 27   // data section
char * str = "No changes allowed"; // data section

int foo()
{
  char *pBuffer; // nothing allocated yet (excluding the pointer itself,
                 // which is allocated here on the stack).
  bool b = true; // Allocated on the stack
  if(b)
  {
    long int x, y, z ;       // Create 3 longs on the stack! (local vars)
    char buffer[500];        // Create 500 bytes on the stack! (local var)
    pBuffer = new char[500]; // Create 500 bytes on the heap!  (array of char objects)

   } // buffer is deallocated here, pBuffer is not!
}    // oops there's a memory leak, should have called:
     // delete[] pBuffer;
```

Process State

During its lifetime, process changes *states:*

- **New** The process is being created
  The process has been launched and is loaded to memory
- **Ready** The process is waiting to be assigned to a processor
  It is in memory and ready to run (scheduling)
- **Running** Instructions are being executed
  CPU control was given to the process and it now the CPU master
- **Waiting** The process is waiting for some event to occur
  wait for data write, data read, network response, child process to finish work, …
- **Terminated** The process has finished execution

Diagram of Process State

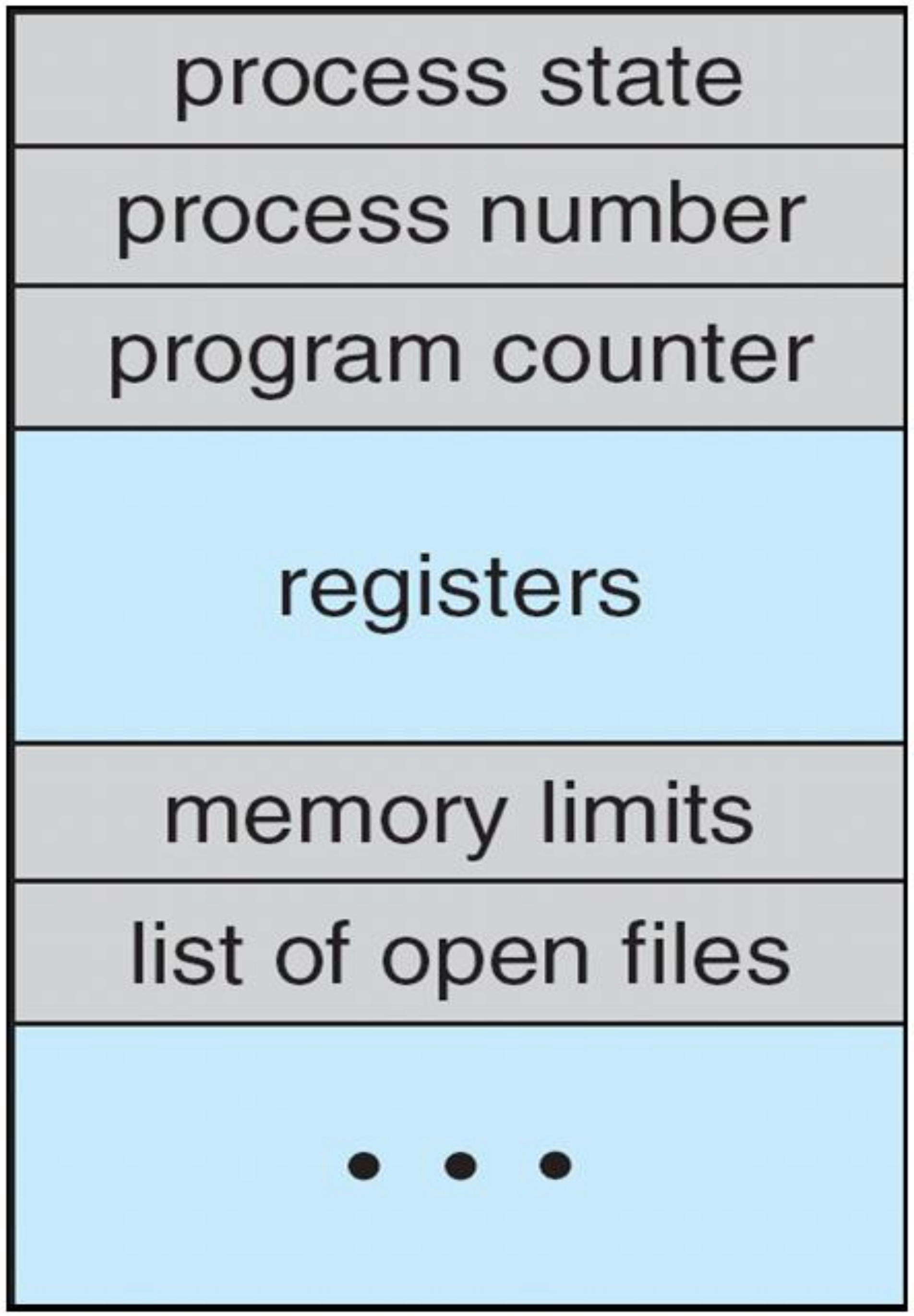


Process Control Block (PCB)

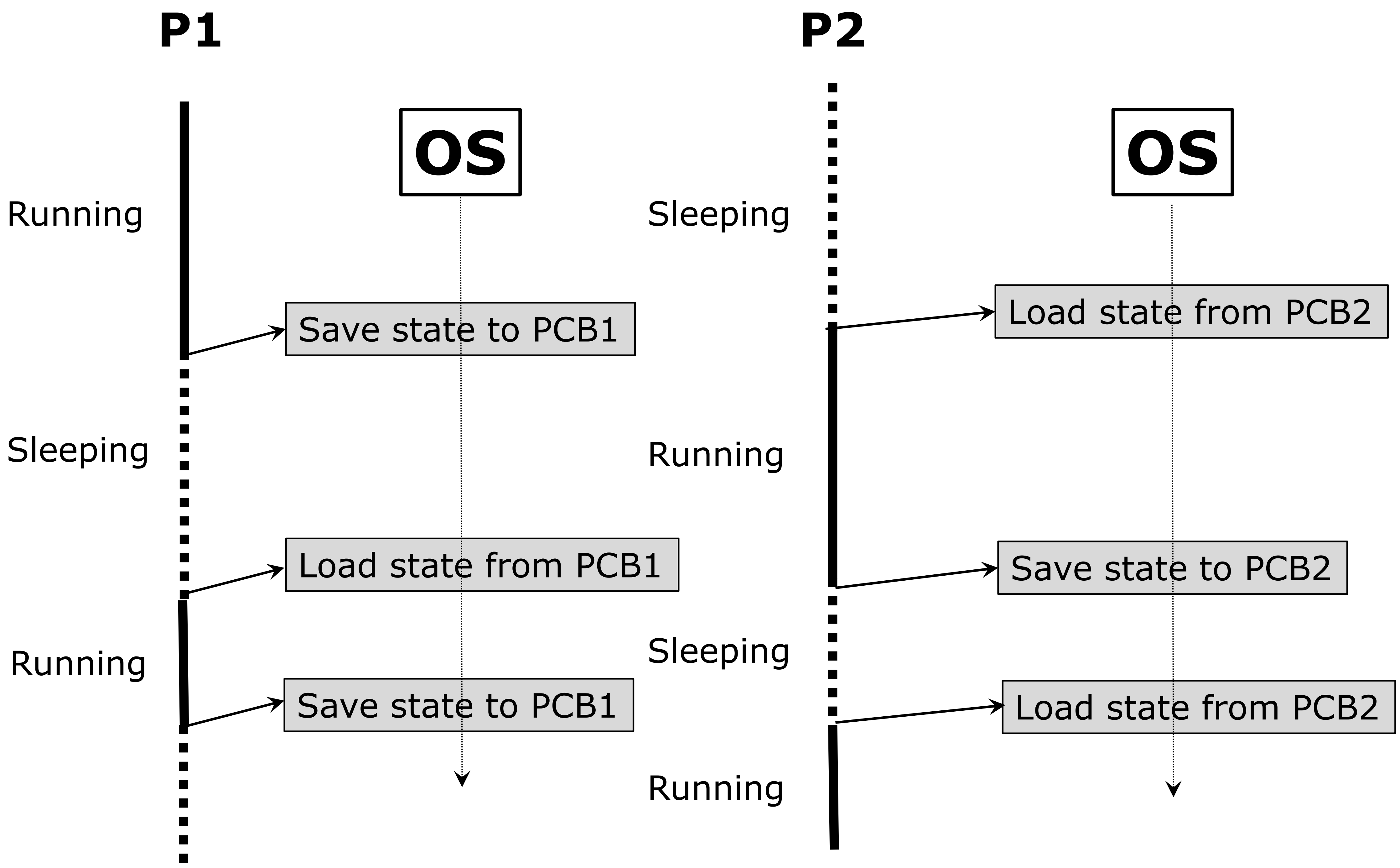
Data structure holding process information

- **Process state** (ready, waiting, running, …)
- **Program counter**
- **CPU registers**
- **CPU scheduling information** (priority, queues)
- **Memory-management information** (base, limit)
- **Accounting information** (run times, reads, writes, …)
- **I/O status information** (open files tables)

Process Control Block (PCB)



CPU Switch From Process to Process



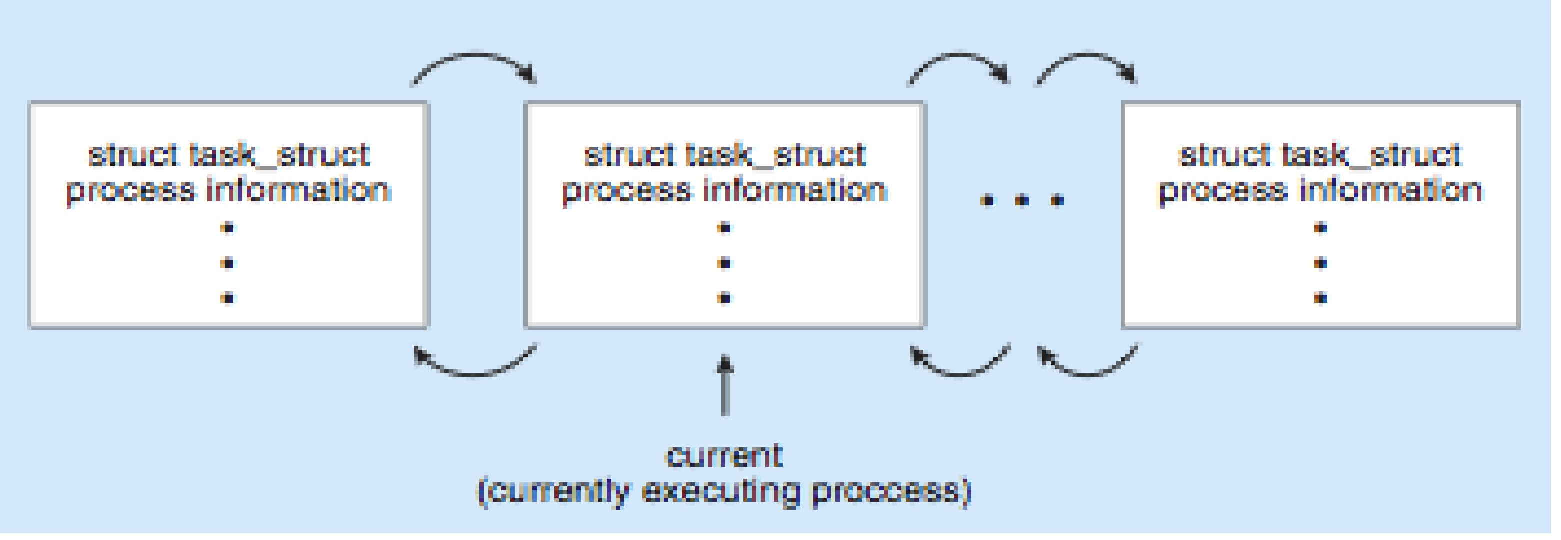
Process Scheduling

- Maximize CPU usage
- Optimize process time sharing by quick switches
- **Process scheduler** role is to decide 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 (per device)
- Processes migrate among the various queues

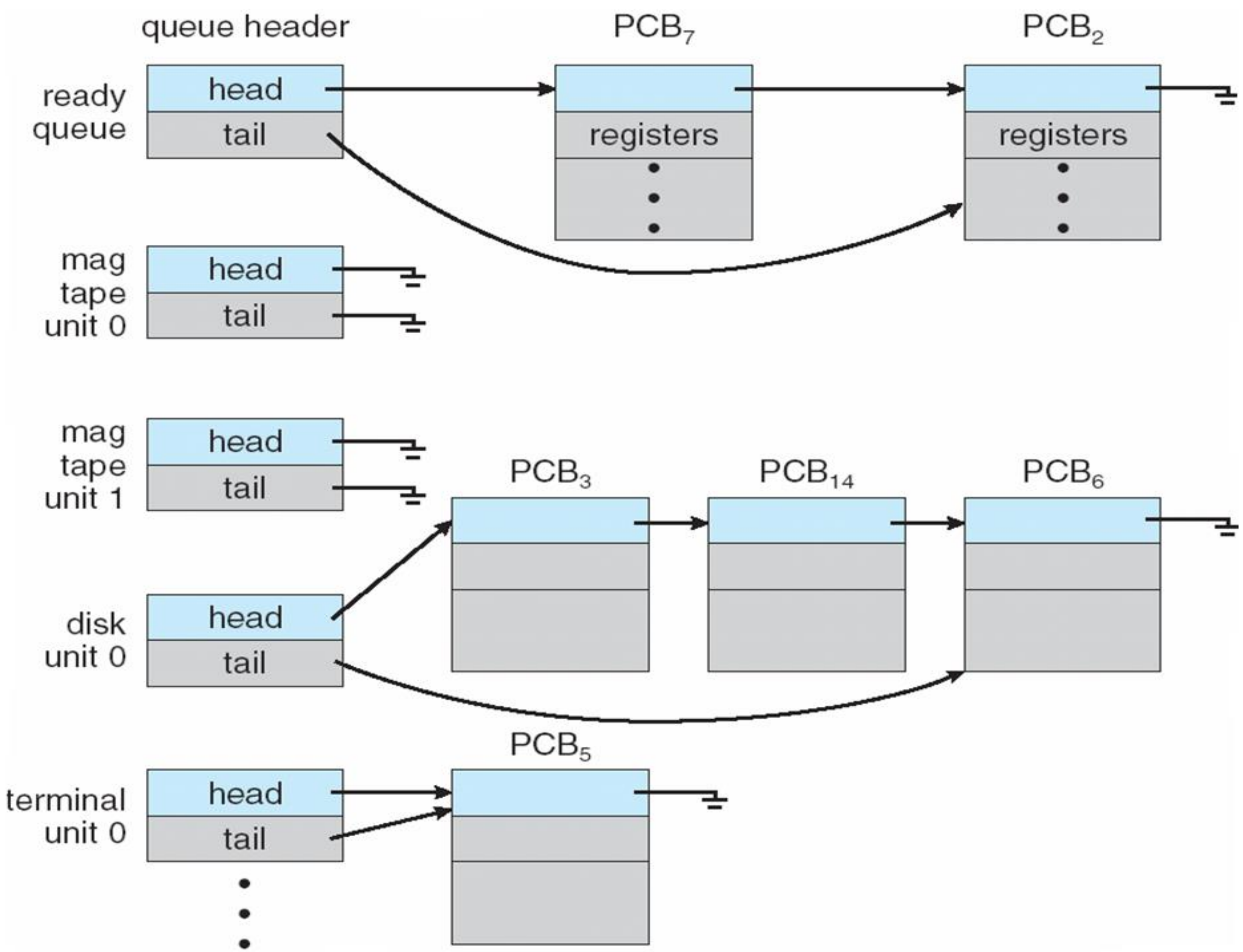
Process Representation in Linux

- Represented by the C structure **`task_struct`**

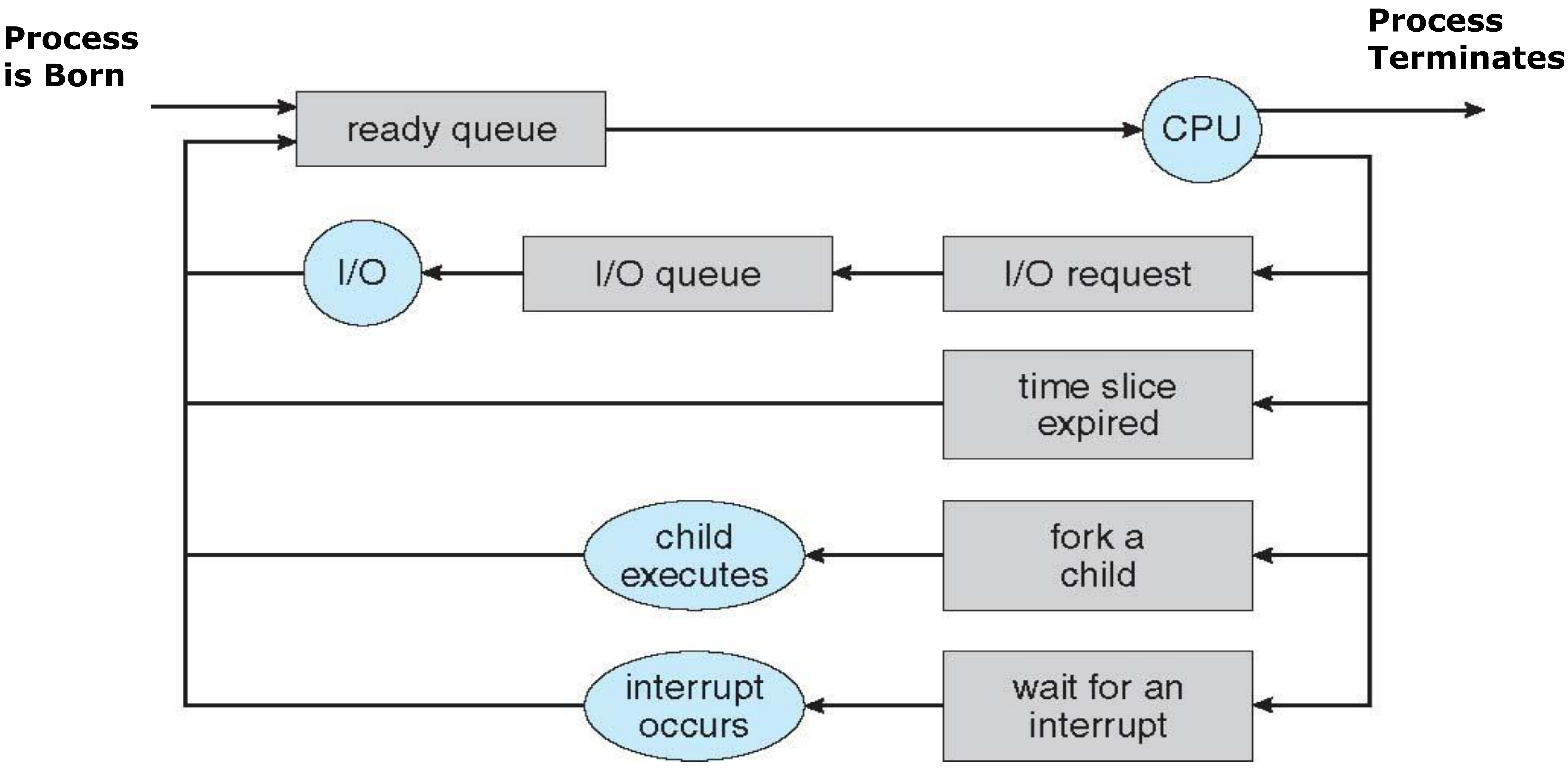
```
pid_t pid;                    /* process identifier */
long state;                   /* state of the process */
unsigned int time_slice       /* scheduling information */
struct task_struct *parent; /* this process's parent */
struct list_head children;  /* this process's children */
struct files_struct *files; /* list of open files */
struct mm_struct *mm;         /* memory management info */
struct task_struct *p_opptr, *p_pptr, *p_cptr, *p_ysptr, *p_osptr;
/* op=original parent, p=parent, c=youngest child, ys=youngest siebling,
   os=older siebling */
```



Ready Queue And Various I/O Device Queues



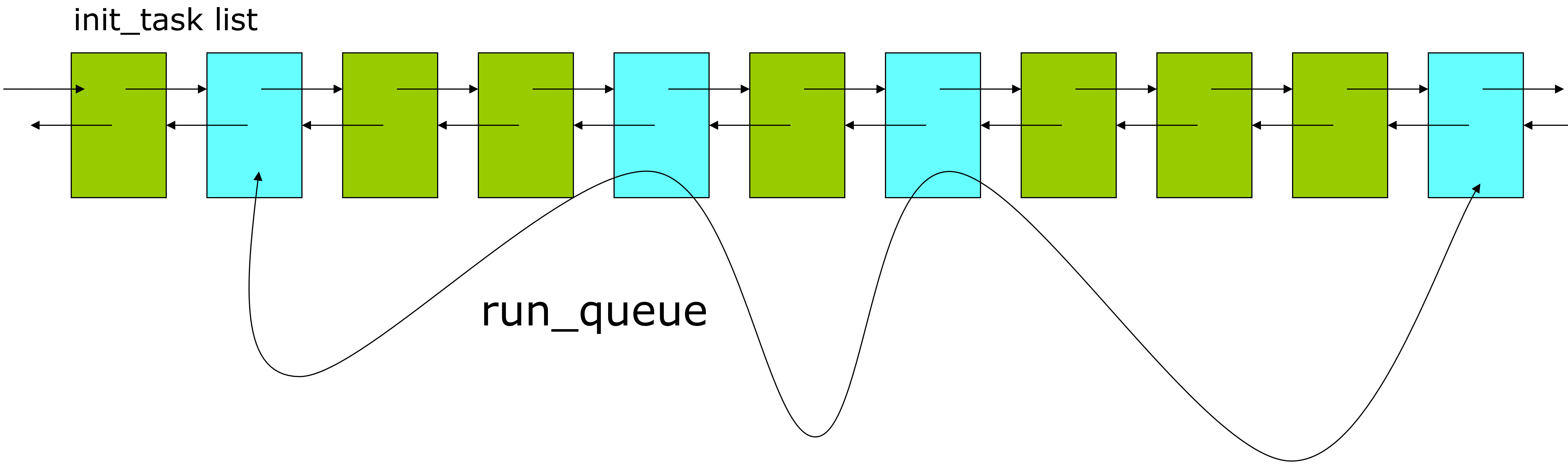
Representation of Process Scheduling



Schedulers

- **Long-term scheduler** (or job scheduler)
  - Selects which processes should be brought into the ready queue
  - Selects which processes be swapped to disk
- **Short-term scheduler** (or CPU scheduler)
  - selects which process will run next
  - Sometimes the only scheduler in a system

Some tasks are 'ready-to-run'



Those tasks that are ready-to-run comprise a sub-list of all the tasks, and they are arranged on a queue known as the 'run-queue'

Those tasks that are blocked while awaiting a specific event to occur are put on alternative sub-lists, called 'wait queues', associated with the particular event(s) that will allow a blocked task to be unblocked

Schedulers (Cont.)

- Short-term scheduler is invoked very frequently
  - Typically 15-60 milliseconds
  - Must be fast!
- Long-term scheduler is invoked very infrequently
  - Seconds, minutes, or hours
  - Could be slow (disk swap is very slow …)
- Processes that run for days, or even sleep for days but hold large memory segments. The long-term scheduler may swap them to disk
- Processes can be described as either:
  - **I/O-bound process** – spends more time doing I/O than computations, many short CPU bursts and long I/O bursts
  - **CPU-bound process** – spends more time doing computations; few very long CPU bursts

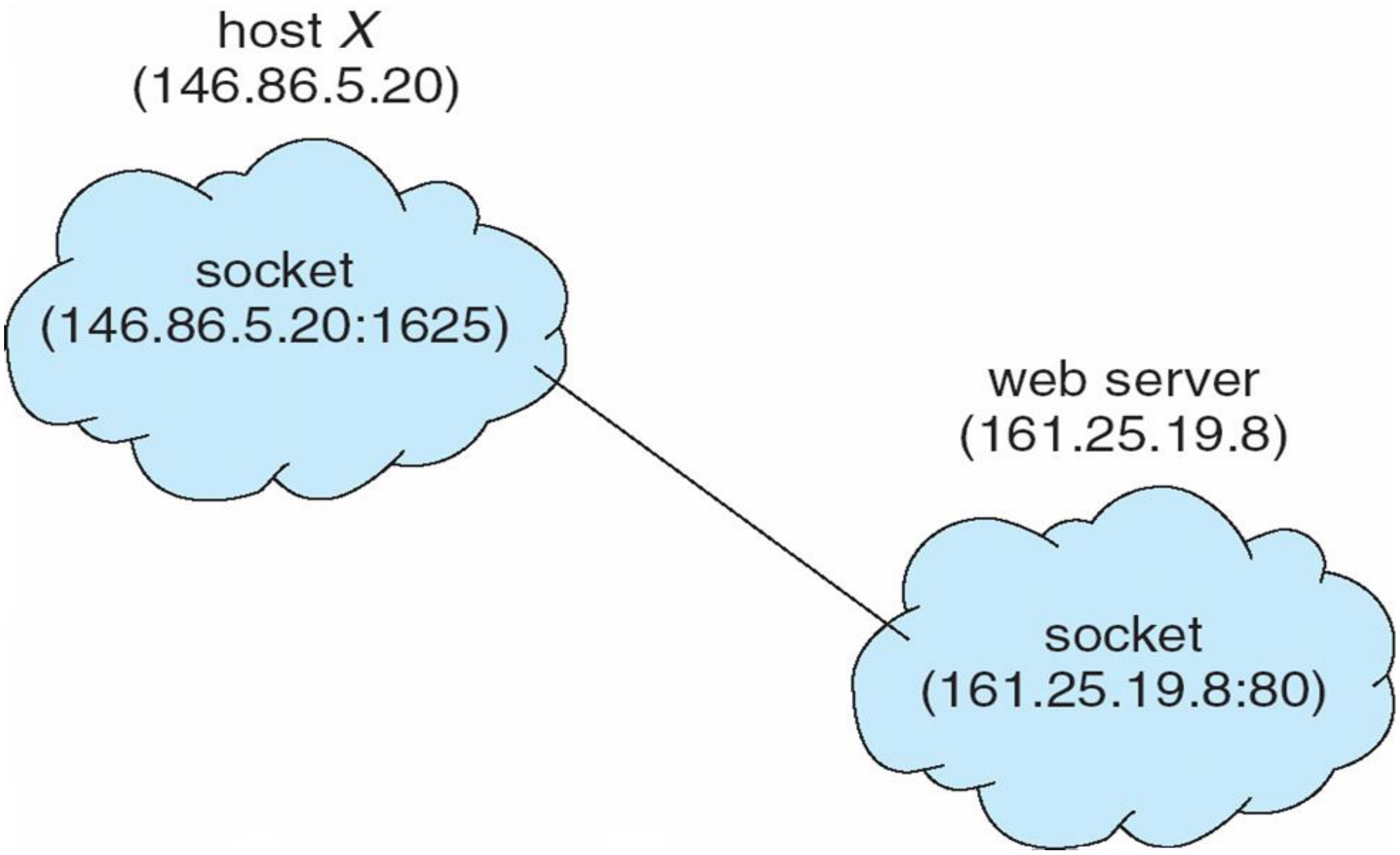
Communications in Client-Server Systems

- Sockets
- Remote Procedure Calls
- Pipes
- Remote Method Invocation (Java)

Sockets

- A **socket** is defined as an *endpoint for communication*
- Concatenation of IP address and port
- The socket **161.25.19.8:1625** refers to port **1625** on host **161.25.19.8**
- Communication consists between a pair of sockets

Socket Communication



Pipes

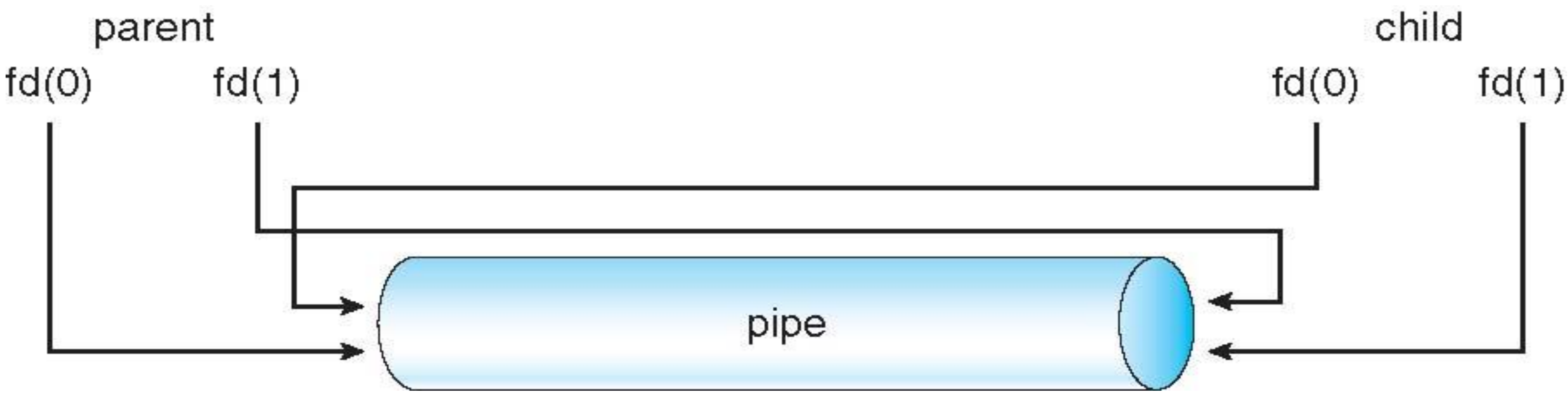
- Acts as a conduit allowing two processes to communicate

- **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 (FIFO)

- 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