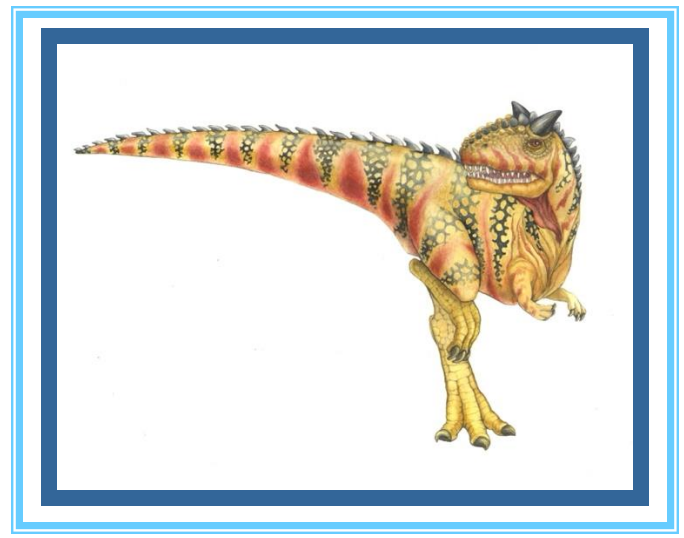
Chapter 3: Process Concept

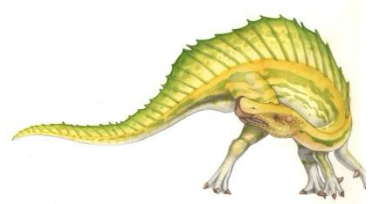


Chapter 3: Process Concept

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

Objectives

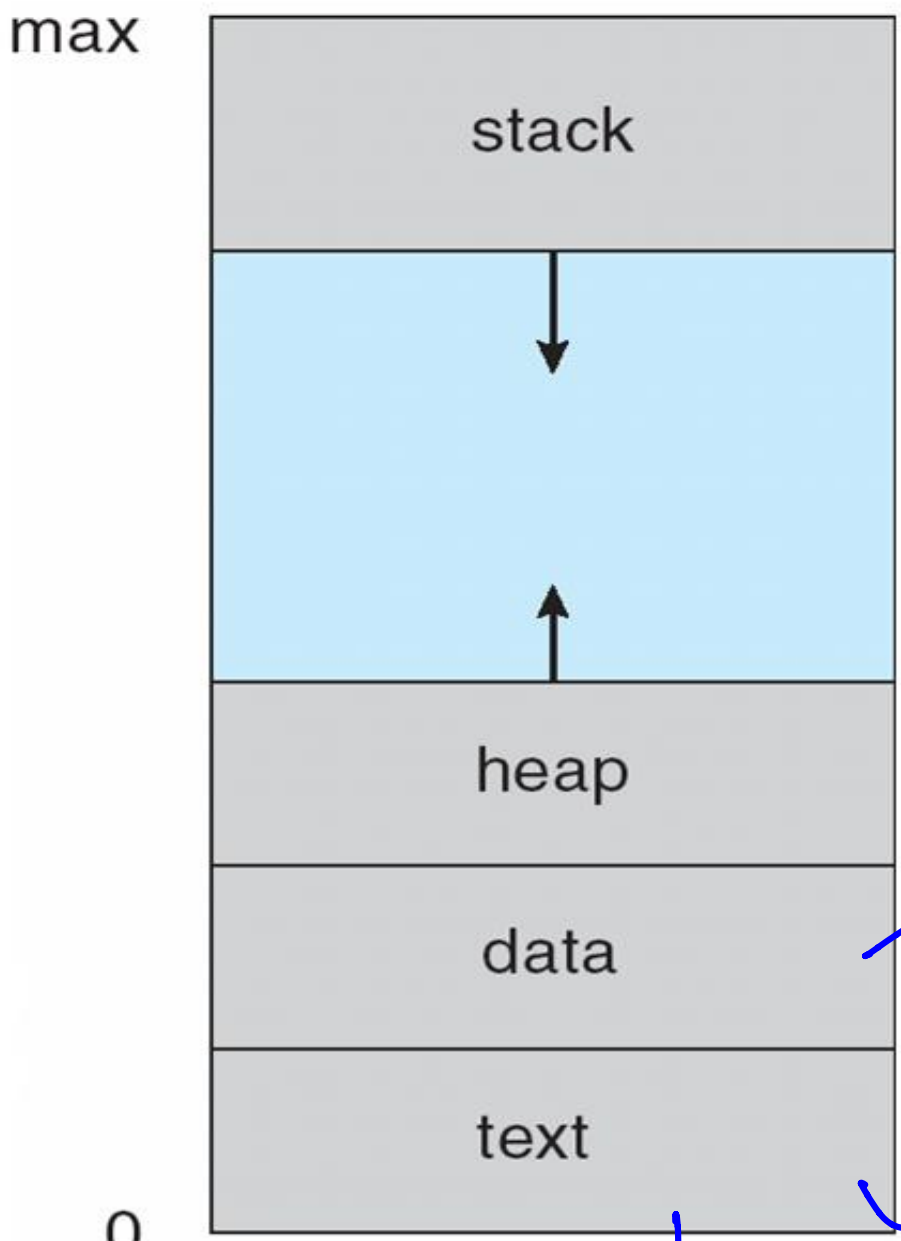
- To introduce the notion of a process -- a program in execution, which forms the basis of all computation
- To describe the various features of processes, including scheduling, creation and termination, and communication
- To explore interprocess communication using shared memory and mes- sage passing
- 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**
- 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
- 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

Process in Memory



ตัวแปร

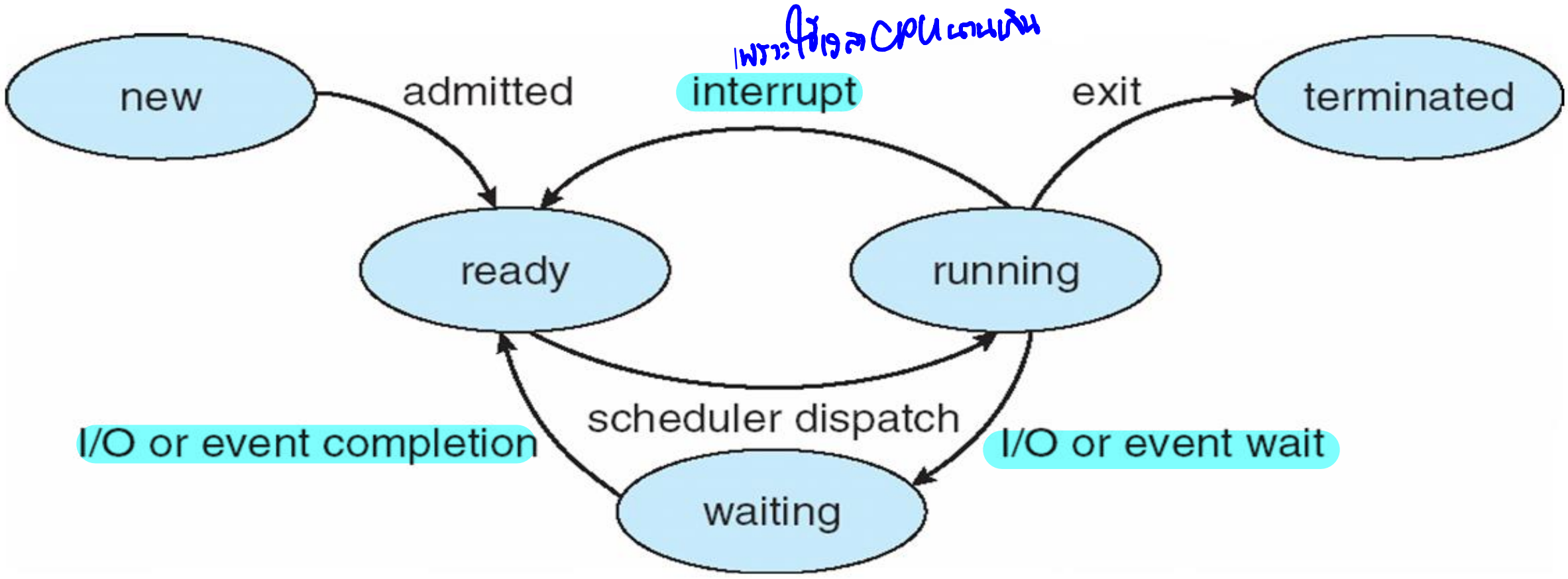
Instruction of process

แต่ละ running ไม่ได้

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

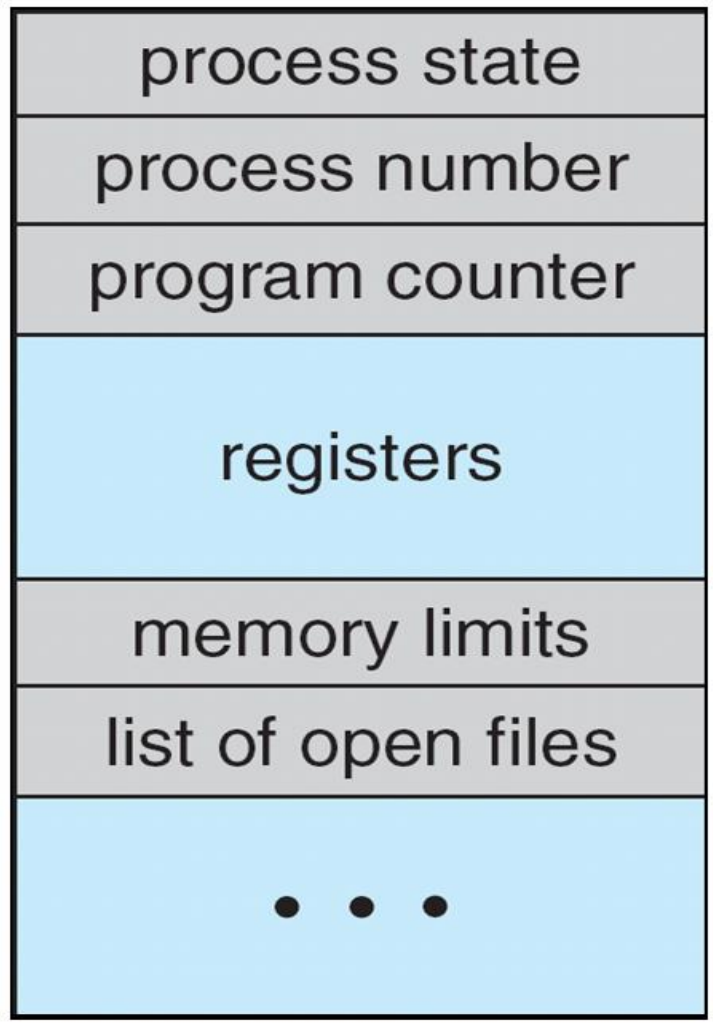


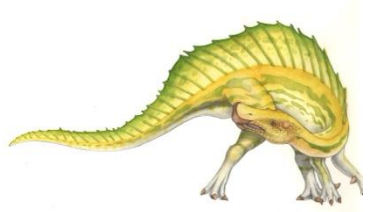
Process Control Block (PCB)

Information associated with each process

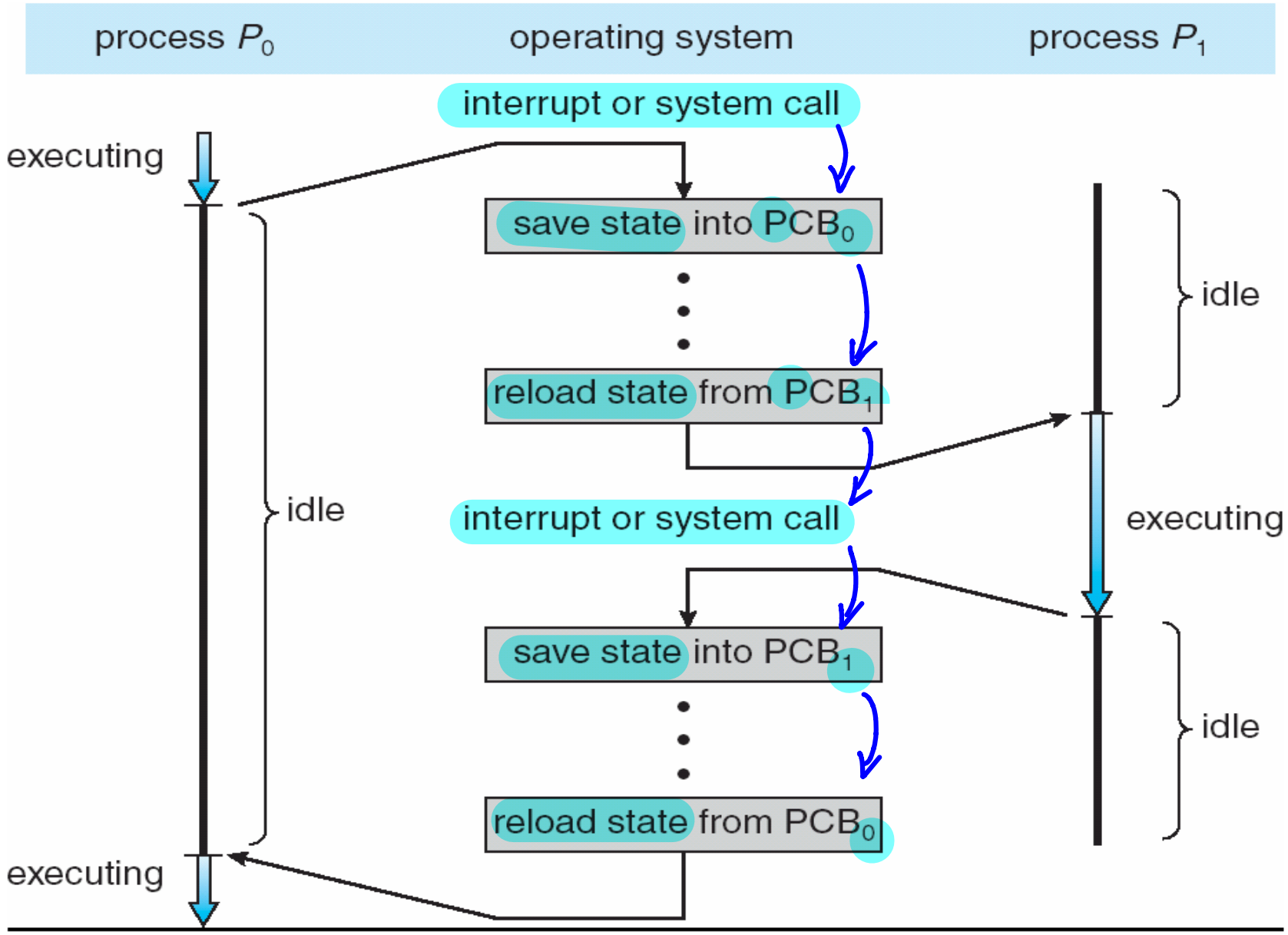
(also called **task control block**)

- 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



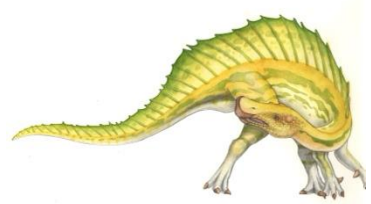


CPU Switch From Process to Process



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

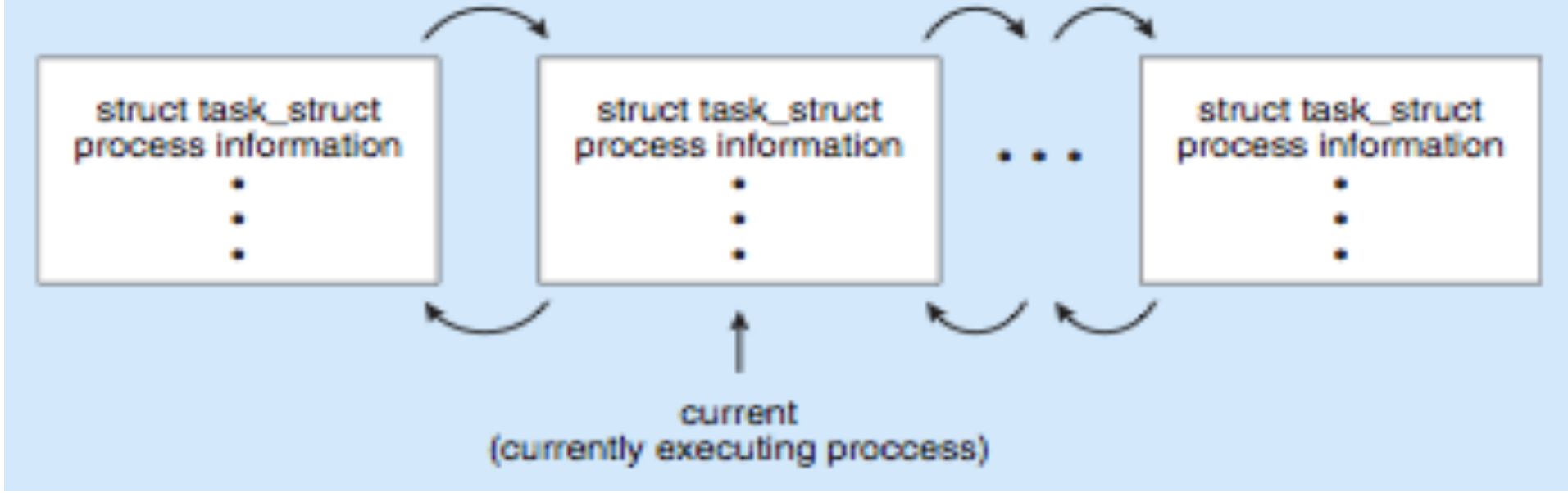


Process Representation in Linux

link list

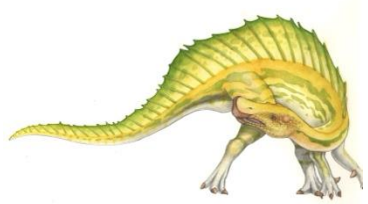
- Represented by the C structure `task_struct`

```
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; /* address space of this process */
```



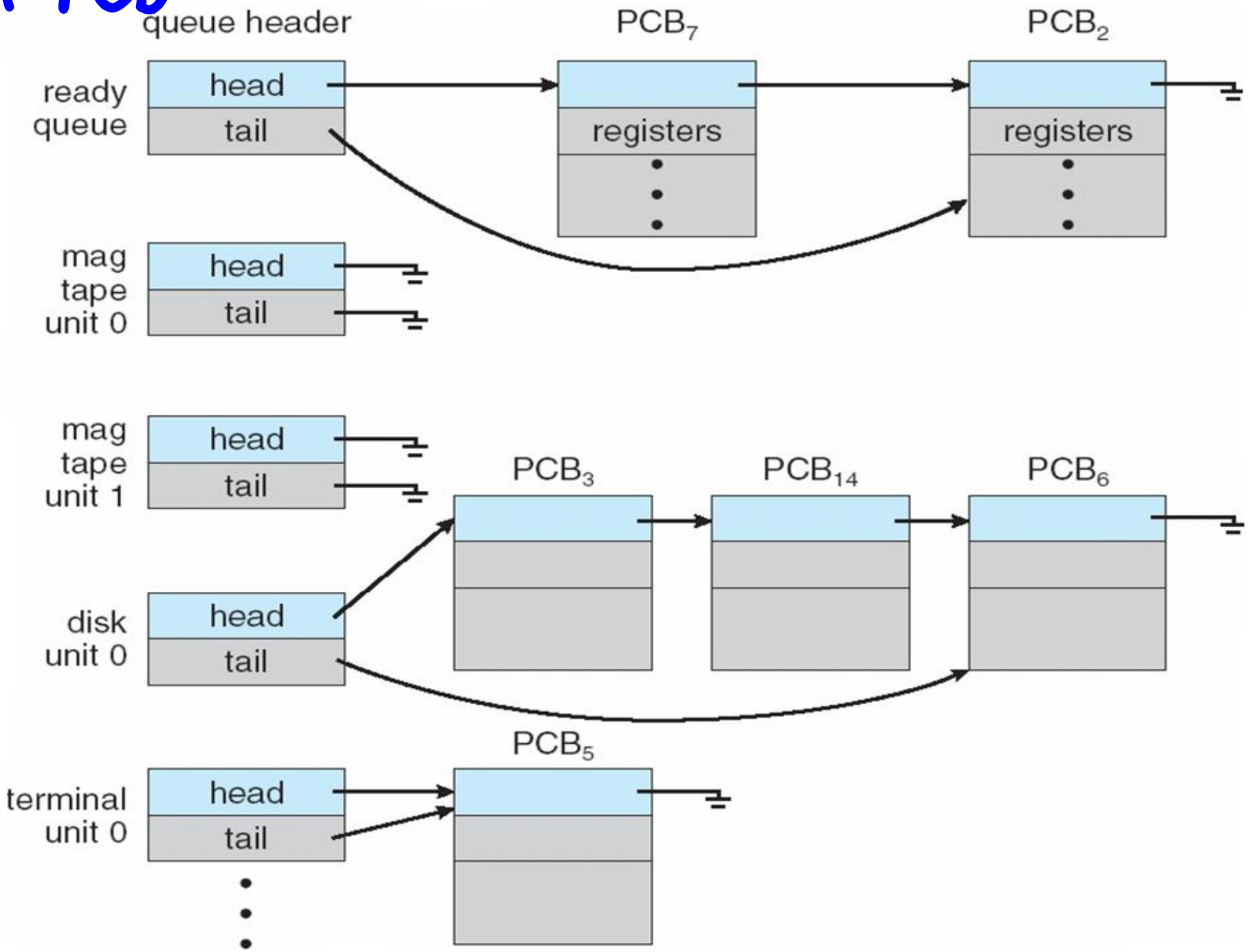
Process Scheduling

- 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



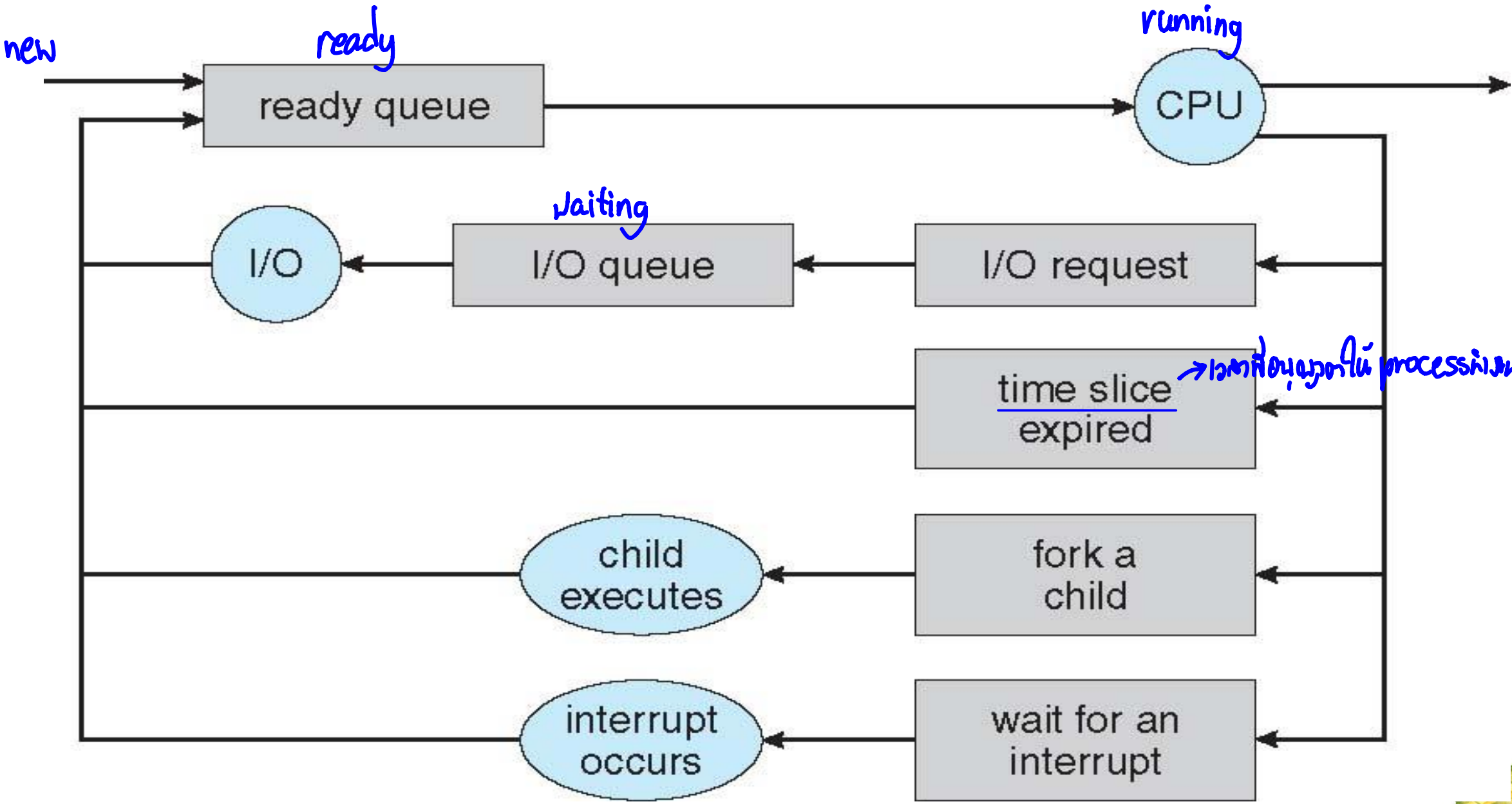
Ready Queue And Various I/O Device Queues

list of PCB



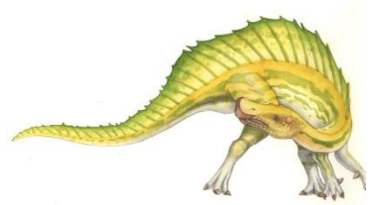
Representation of Process Scheduling

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



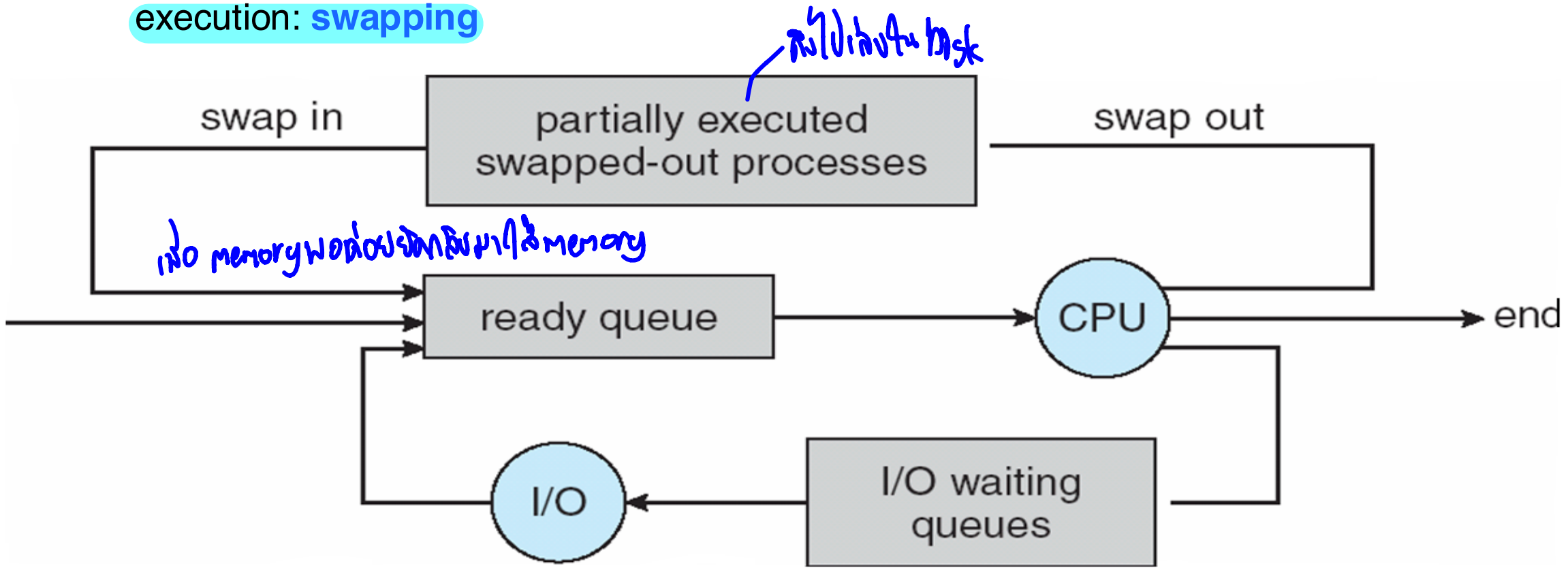
Schedulers

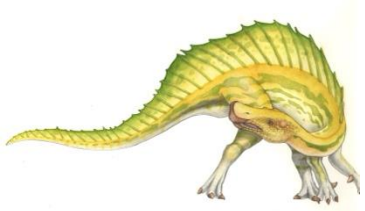
- **Long-term scheduler** (or **job scheduler**) – selects which processes should be brought into the ready queue
- **Short-term scheduler** (or **CPU scheduler**) – selects which process should be executed next and allocates CPU
  - Sometimes the only scheduler in a system
  - Short-term scheduler is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



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**





Context Switch

process/PCB

- 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

Thread เป็นอีก context switching เร็วกว่า

- Time dependent on hardware support
  - Some hardware provides multiple sets of registers per CPU -> multiple contexts loaded at once

Operations on Processes

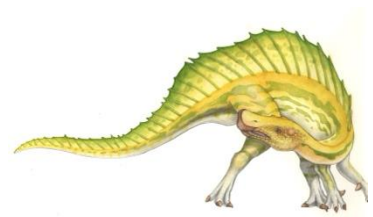
- System must provide mechanisms for process creation, termination, and so on as detailed next

Process Creation

- **Parent** process create **children** processes, which, in turn create other processes, forming a **tree** of processes

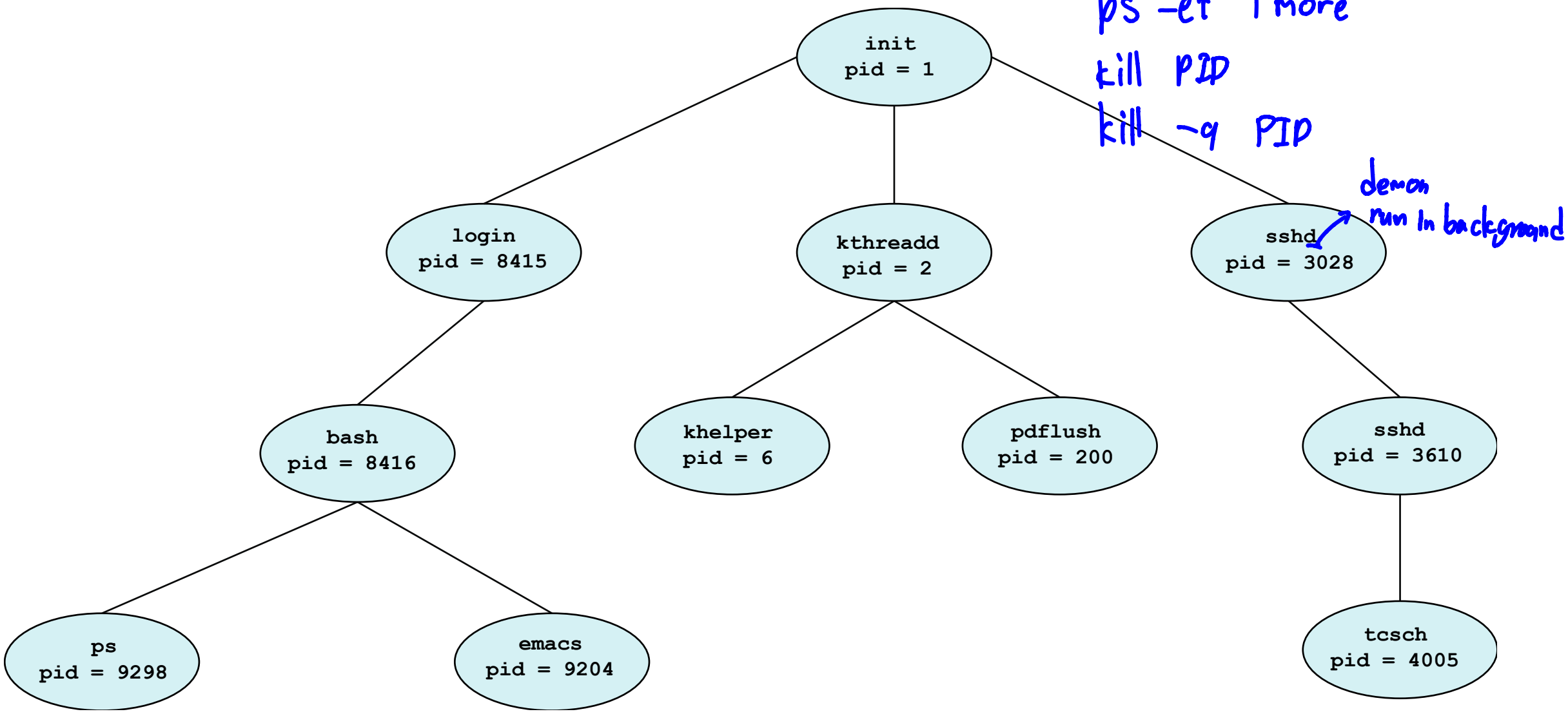
- Generally, process identified and managed via a **process identifier** (**pid**)
  = mostly int, ไม่ซ้ำกัน
- Resource sharing options
  - Parent and children share all resources
  - Children share subset of parent's resources
  - Parent and child share no resources

- Execution options
  - Parent and children execute concurrently (พร้อมกัน)
  - Parent waits until children terminate



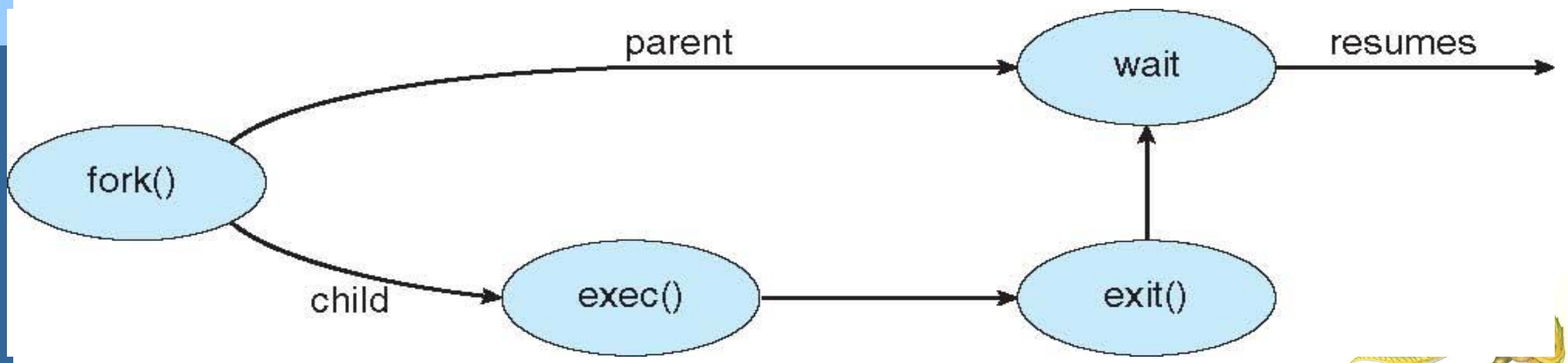
A Tree of Processes in Linux

ps
ps -ef | more
kill PID
kill -9 PID



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



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;
}
```

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

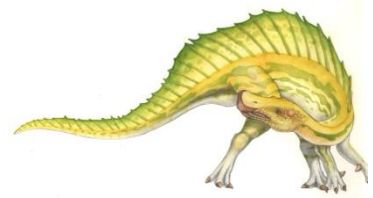
- Parent may terminate execution of children processes (**`abort()`**)
  - Child has exceeded allocated resources
  - Task assigned to child is no longer required
  - If parent is exiting
    - Some operating systems do not allow child to continue if its parent terminates
      - All children terminated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

แม่ตาย ลูกตาย, เพราะไม่อยากให้ Process ลูกค้างในระบบ

- Wait for termination, returning the pid:

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

- If no parent waiting, then terminated process is a **zombie** → process ที่เป็นไม่ตาย เพราะถูกฆ่าตาย แล้วแต่ยังมีร่องรอยหลงเหลืออยู่
- If parent terminated, processes are **orphans** → เด็กกำพร้า

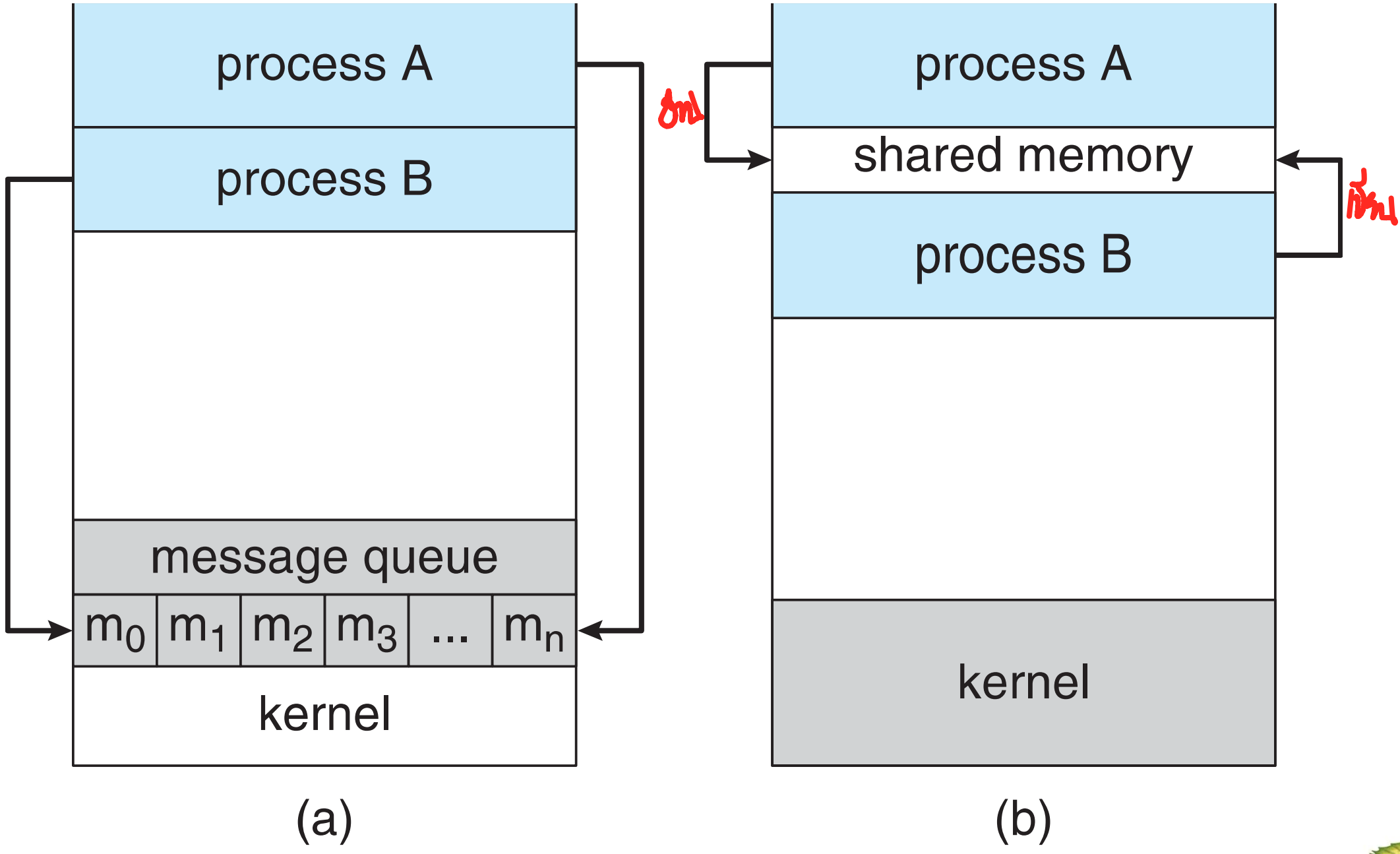


Interprocess Communication IPC

- 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 วิธีสื่อสาร 2 แบบ
  - **Shared memory** ผ่านหน่วยความจำร่วม
  - **Message passing** ส่งข้อความ

Communications Models

shared mem



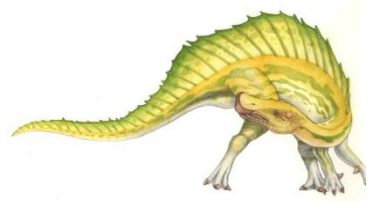
message queue

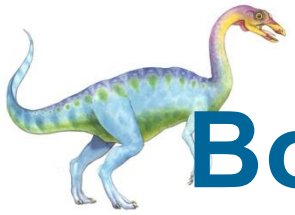
Cooperating Processes

- ***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



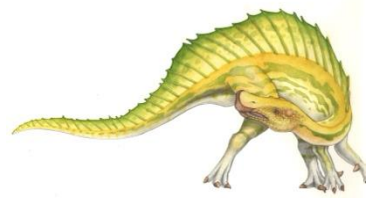


Bounded-Buffer – Shared-Memory Solution

- Shared data

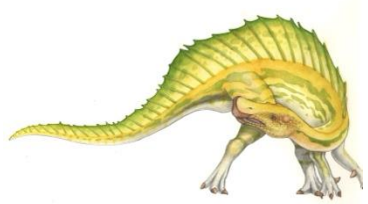
```
#define BUFFER_SIZE 10
typedef struct {
  . . .
} item;

item buffer[BUFFER_SIZE];
int in = 0;
int out = 0;
```

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



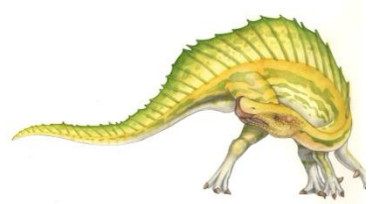
Bounded-Buffer – Producer

```
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;
}
```



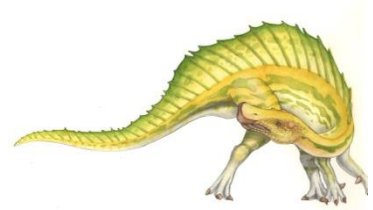
Bounded Buffer – Consumer

```
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 */

}
```



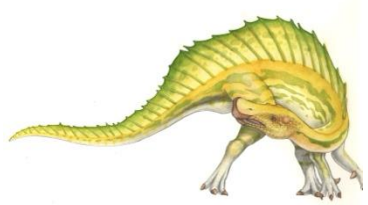
Interprocess Communication – Message Passing

- 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?



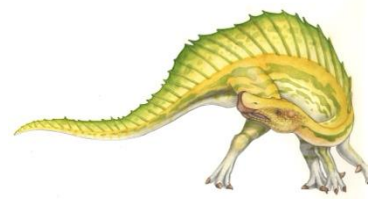
Direct Communication

- 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 (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

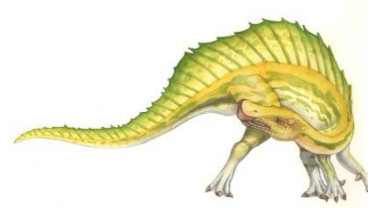
- Mailbox sharing
  - P_1, P_2, and P_3 share mailbox A
  - P_1, sends; P_2 and P_3 receive
  - Who gets the message?

- 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

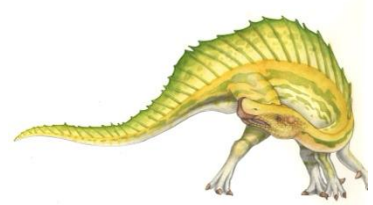
}



Synchronization (Cont.)

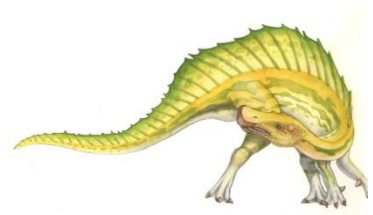
- Different combinations possible
  - If both send and receive are blocking, we have a **rendezvous**
- Producer-consumer becomes trivial

```
message next produced;
while (true) {
        /* produce an item in next produced */
    send(next produced);
}

message next consumed;
while (true) {
    receive(next consumed);

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



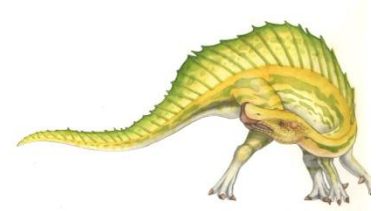
Buffering

- 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



Communications in Client-Server Systems

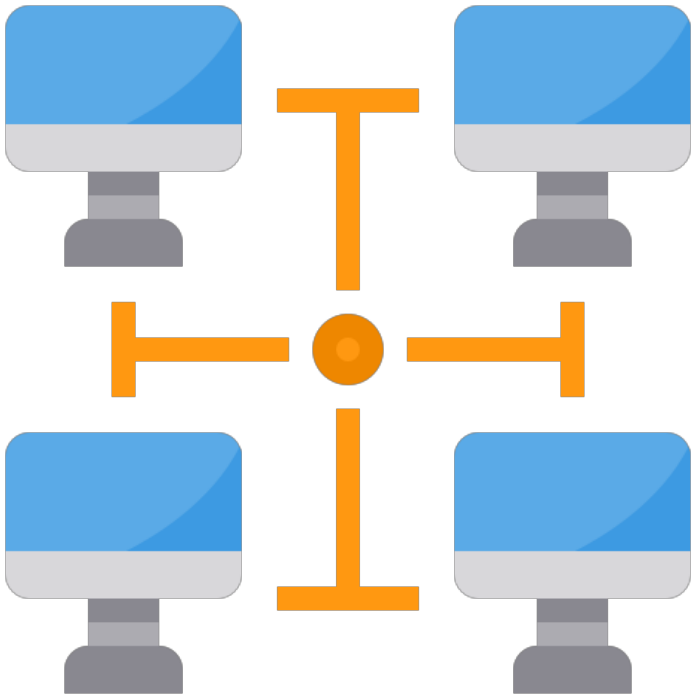
- Remote Procedure Calls
- Pipes



Remote Procedure Calls

- Remote procedure call (RPC) abstracts procedure calls between processes on networked systems
  - Again uses ports for service differentiation
- **Stubs** – client-side proxy for the actual procedure on the server
- The client-side stub locates the server and **marshalls** the parameters
- The server-side stub receives this message, unpacks the marshalled parameters, and performs the procedure on the server
- On Windows, stub code compile from specification written in **Microsoft Interface Definition Language** (**MIDL**)
- Data representation handled via **External Data Representation** (**XDL**) format to account for different architectures
  - **Big-endian** and **little-endian**
- Remote communication has more failure scenarios than local
  - Messages can be delivered ***exactly once*** rather than ***at most once***
- OS typically provides a rendezvous (or **matchmaker**) service to connect client and server

Remote Procedure Call (RPC)

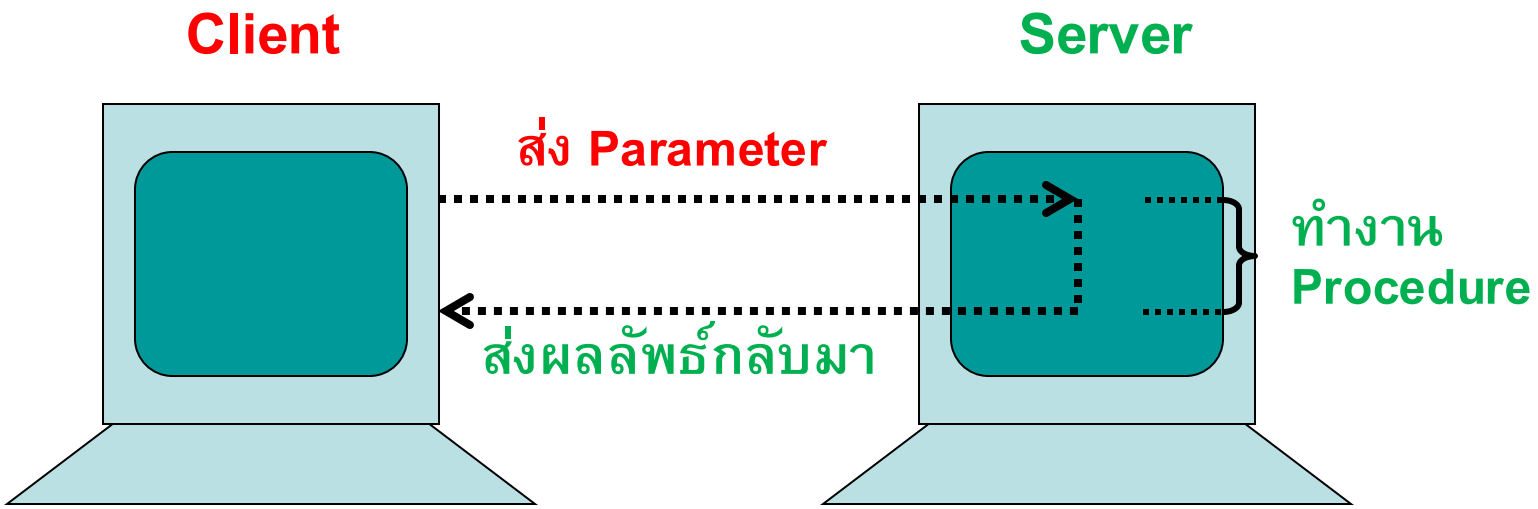


Motivation for RPC

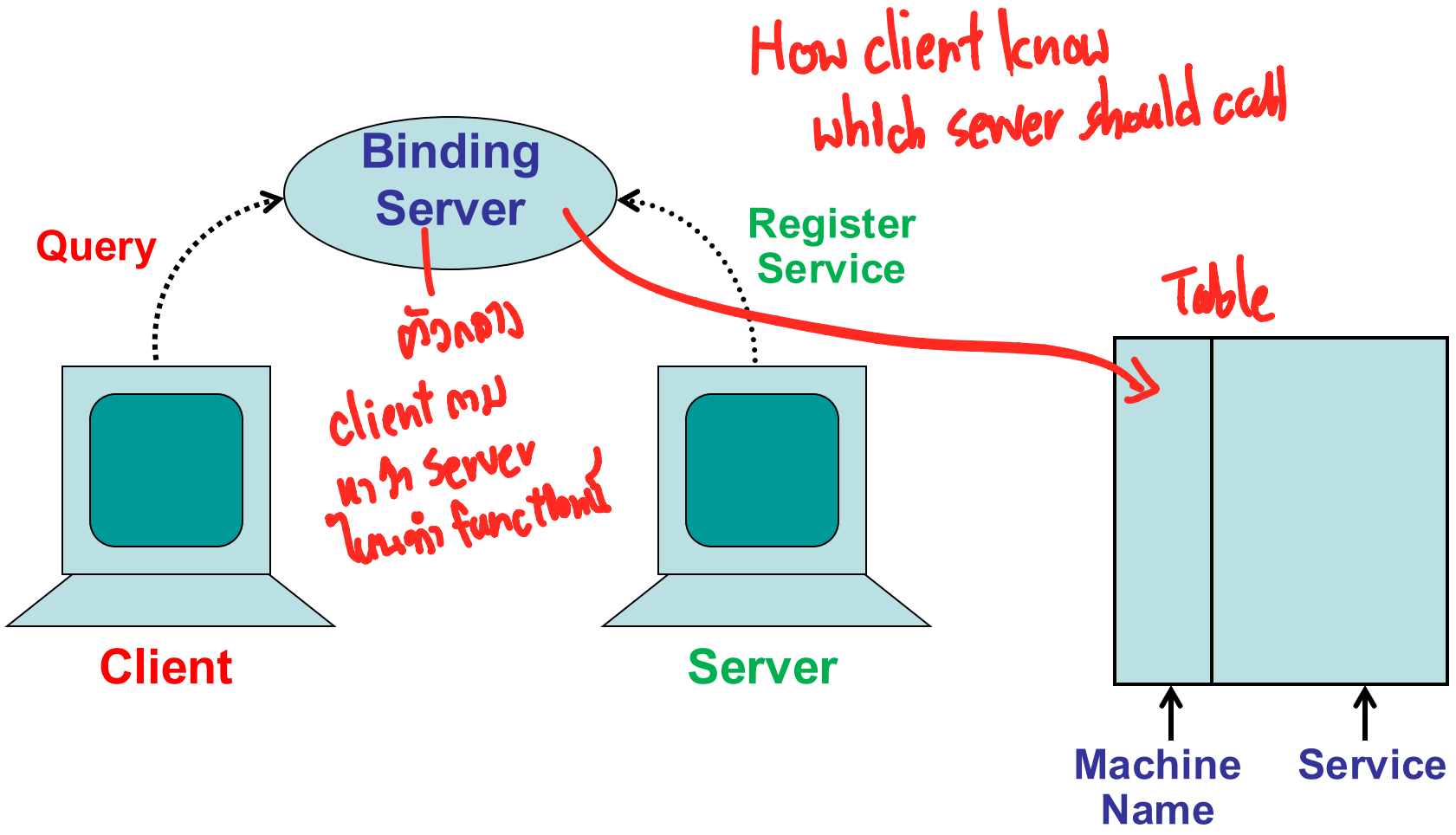
function call

- Procedure call เป็นวิธีที่รู้จักกันดีอยู่แล้วในการ transfer control และ data ในคอมพิวเตอร์เครื่องเดียวกัน
- ดังนั้นขยายแนวคิดนี้ไปใน network ข้ามเครื่อง

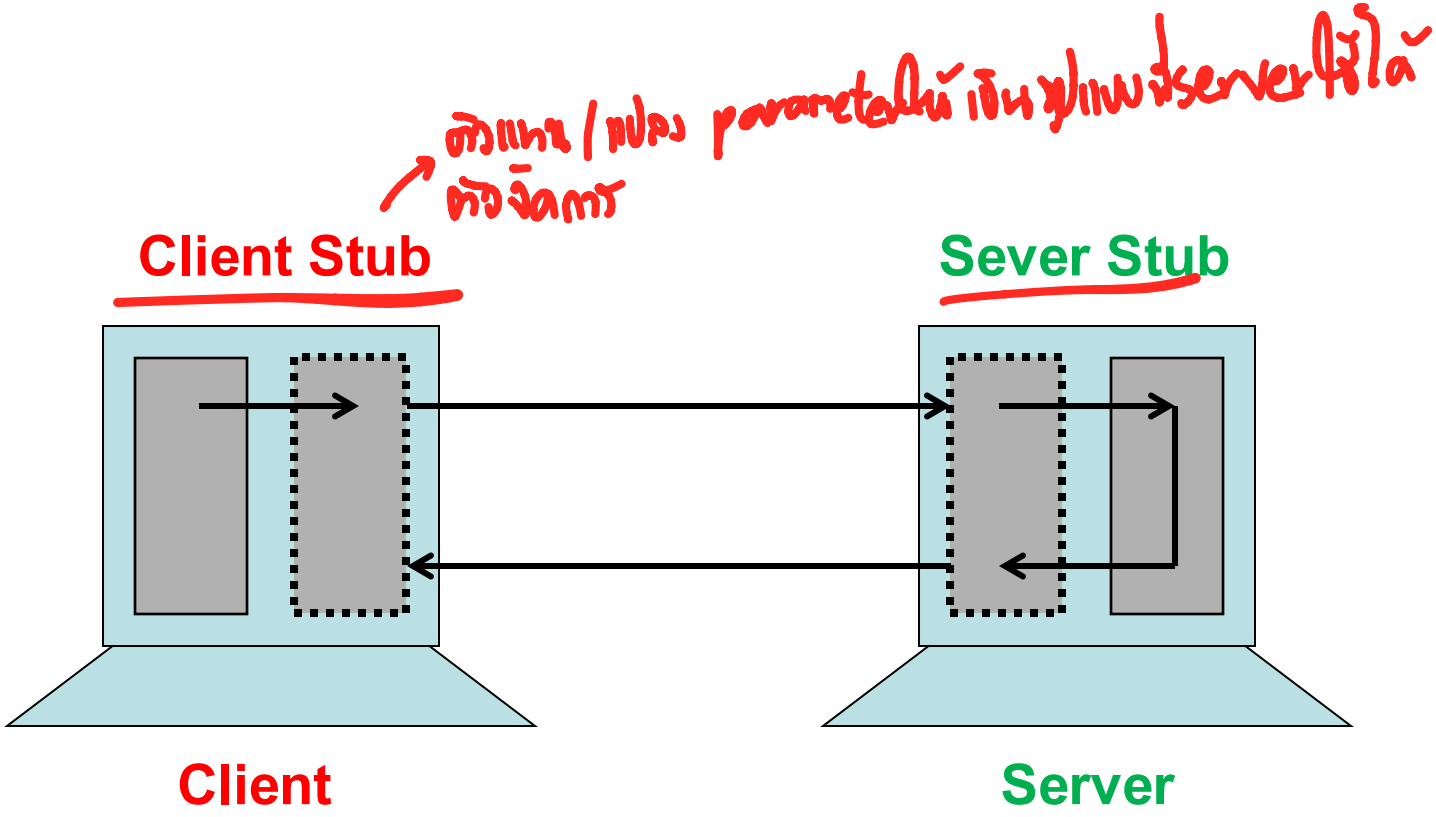
Basic RPC Operation



Binding Server



การใช้ stub



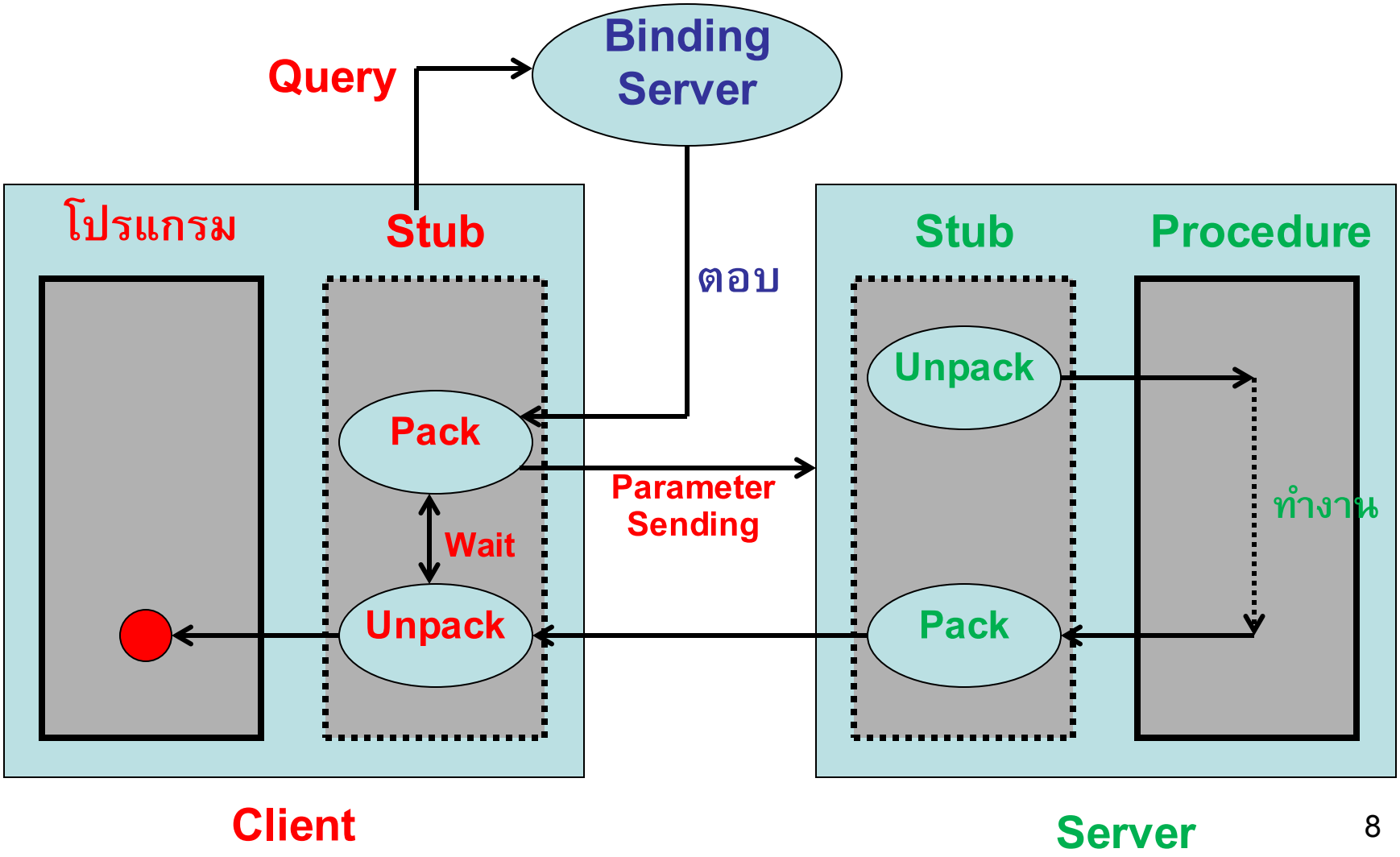
Stub procedure

- Dummy procedure ใน client และ server
- ทำหน้าที่สร้าง message ประกอบด้วย parameter และส่งให้ server
- Server stub ส่ง parameter ให้ procedure จริงทำงานและส่งผลลัพธ์กลับให้ client

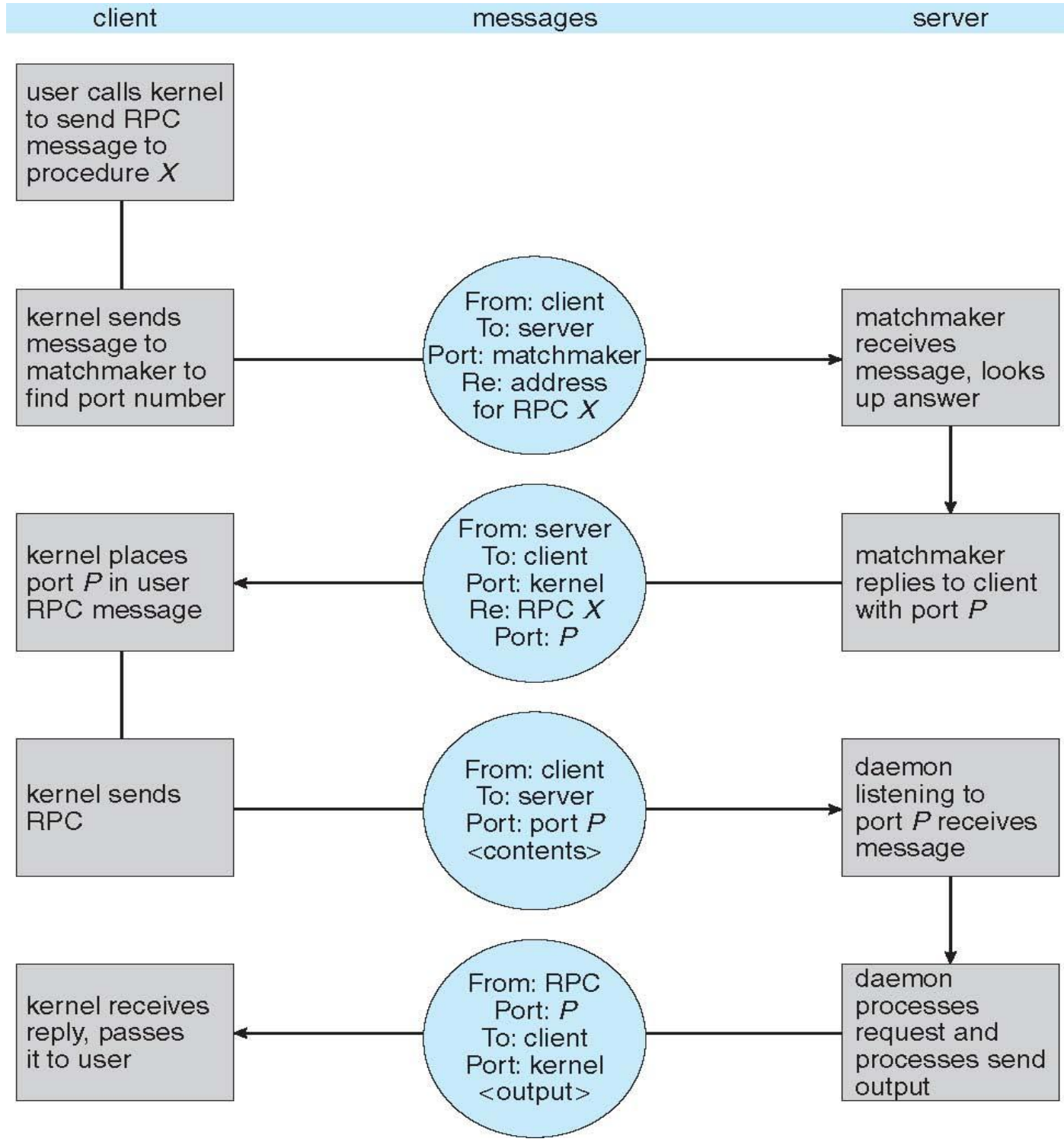
การทำ parameter passing

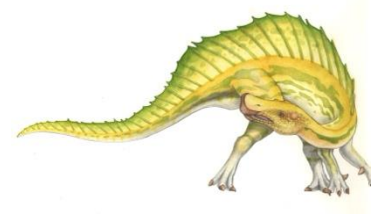
- แปลงเป็น network representation (XDR) ที่เข้าใจกันทั้งสองฝ่าย
- Pack parameter ให้สามารถส่งใน network ได้อย่างเหมาะสม เรียกว่า parameter marshalling

การทำงานของ RPC



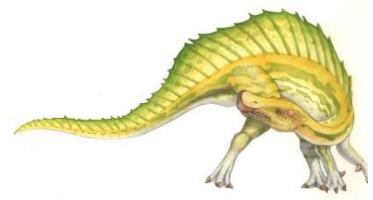
Execution of RPC





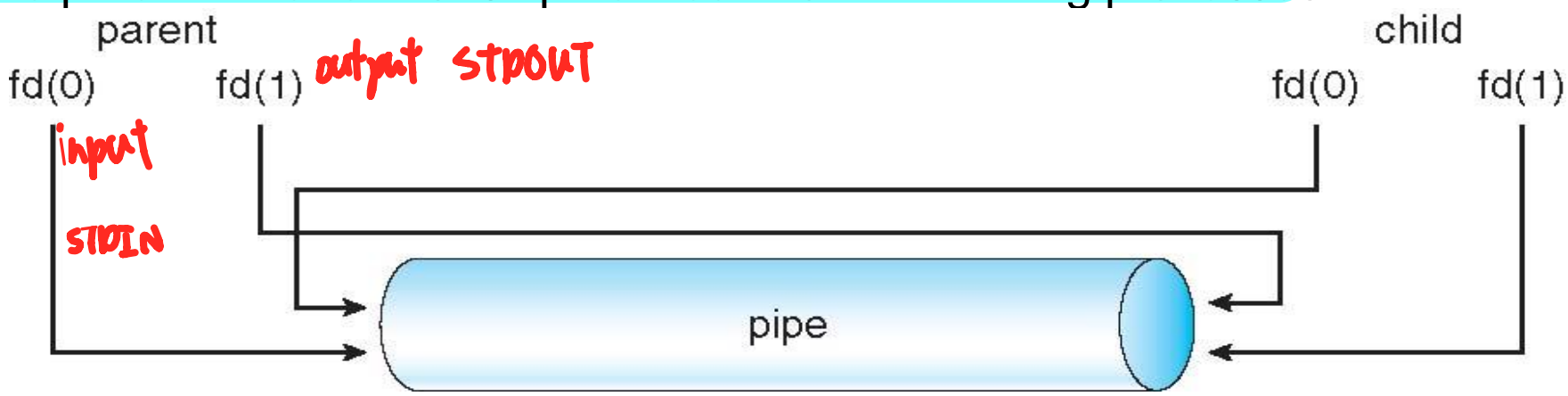
Pipes

- 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



- Windows calls these **anonymous pipes**
- See Unix and Windows code samples in textbook

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