Chapter 3: Processes

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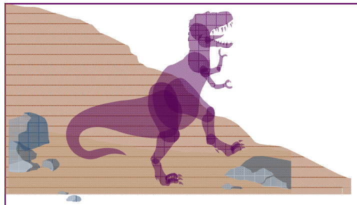
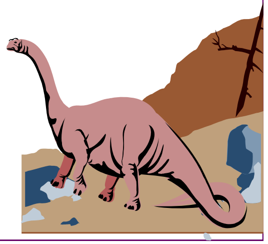
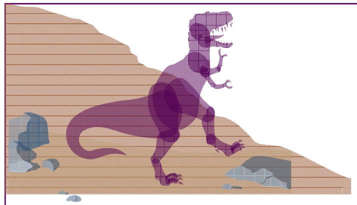


Chapter 3: Processes

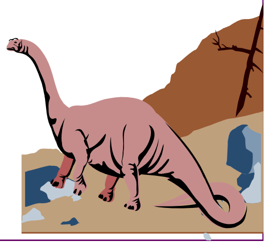
- Process Concept
- Process Scheduling
- Operations on Processes
- Cooperating Processes
- Interprocess Communication
- Communication in Client-Server Systems





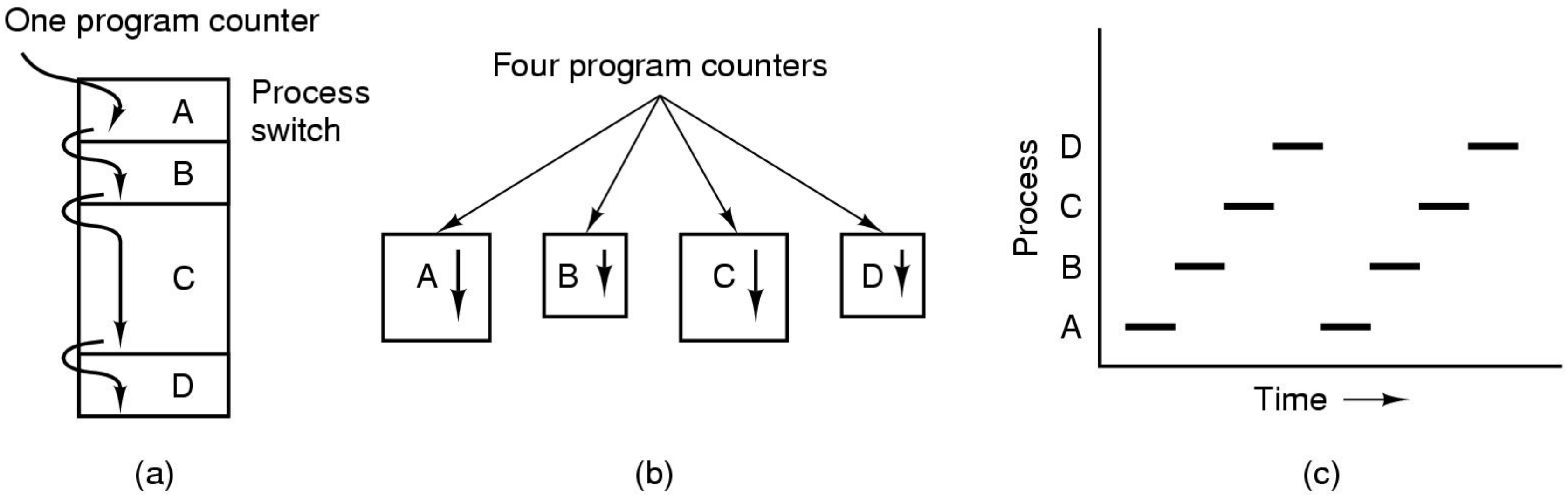
Process Concept

- 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.

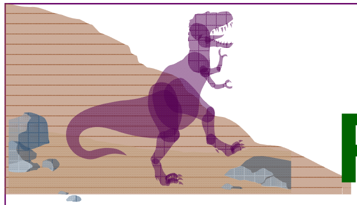


Processes

The Process Model

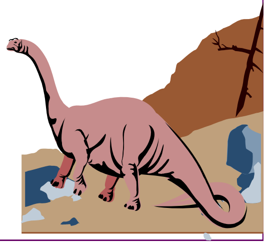


- Multiprogramming of four programs
- Conceptual model of 4 independent, sequential processes
- Only one program active at any instant

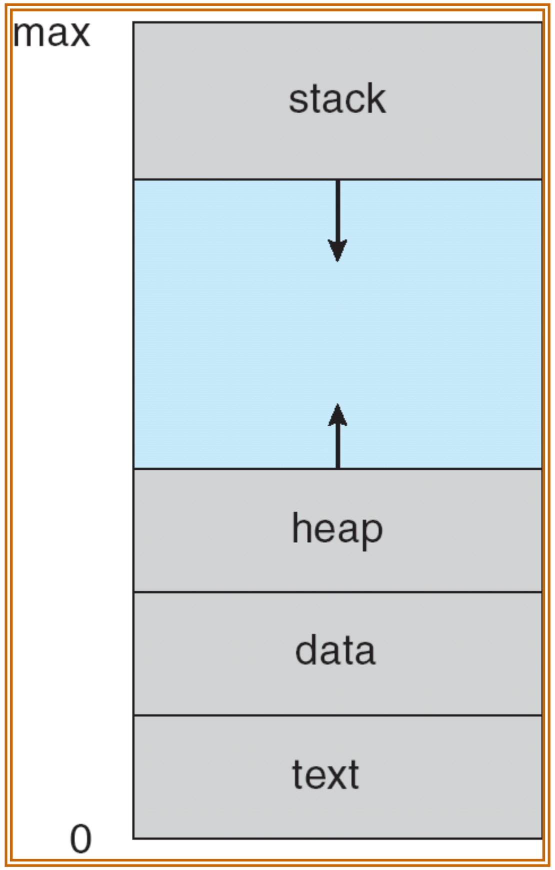


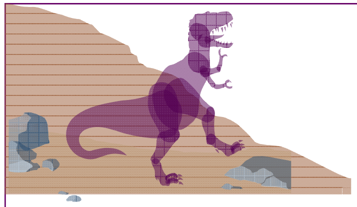
Process Concept (Cont.)

- Process – a program in execution; process execution must progress in sequential fashion.
- A process includes:
  - program counter
  - contents of the processor’s registers
  - stack
  - data section



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.

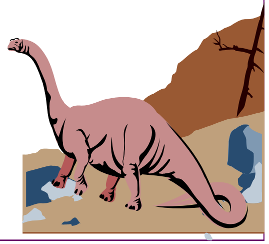
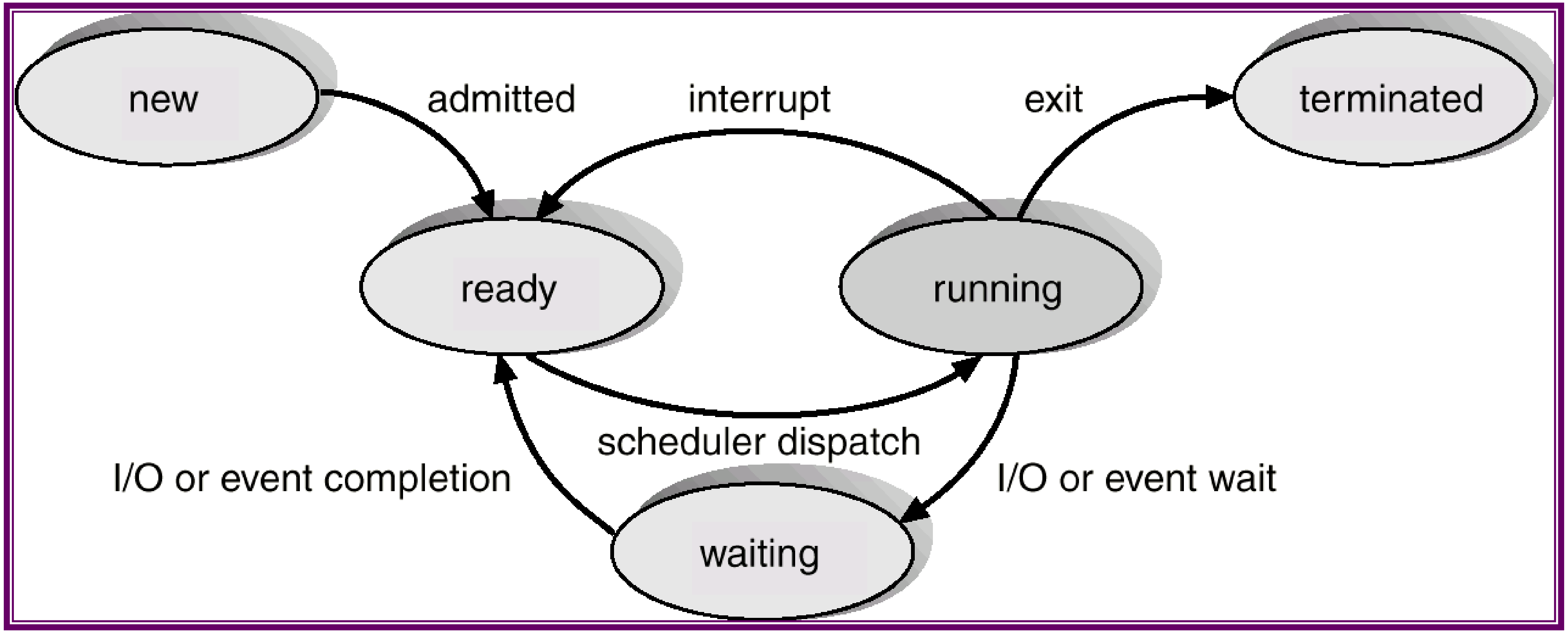
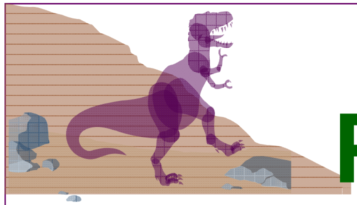


Diagram of Process State

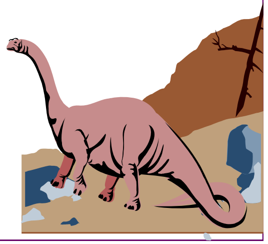




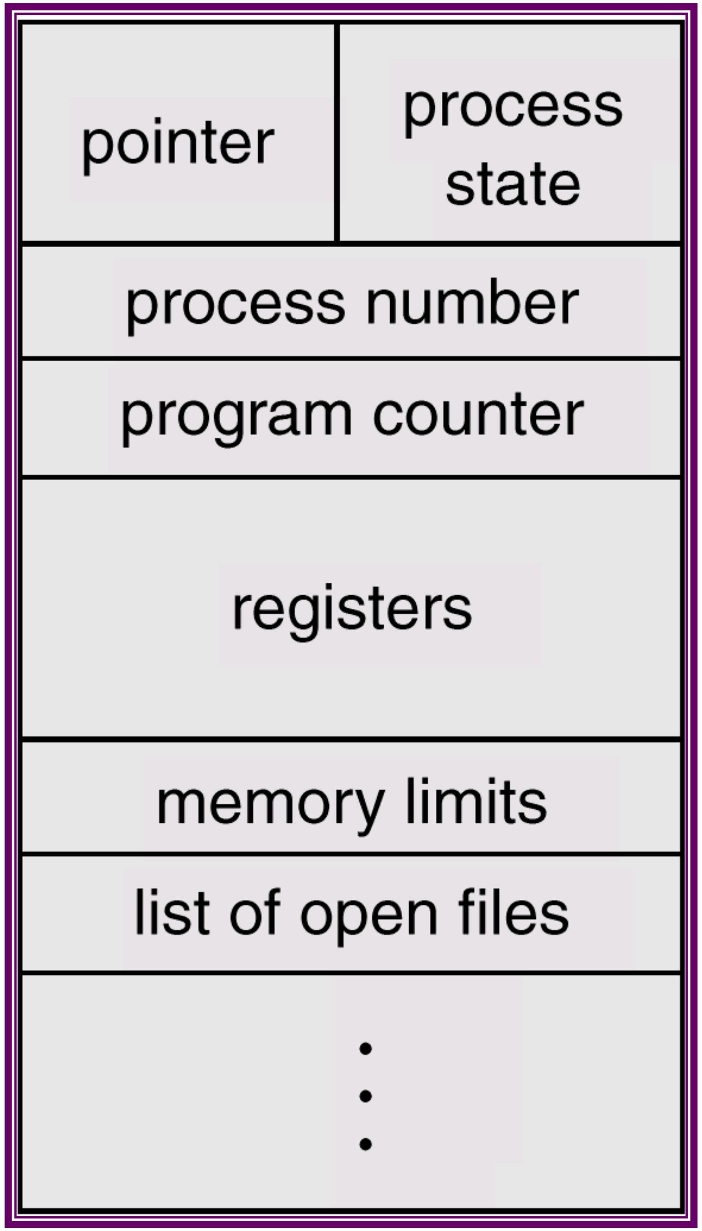
Process Control Block (PCB)

Information associated with each process.

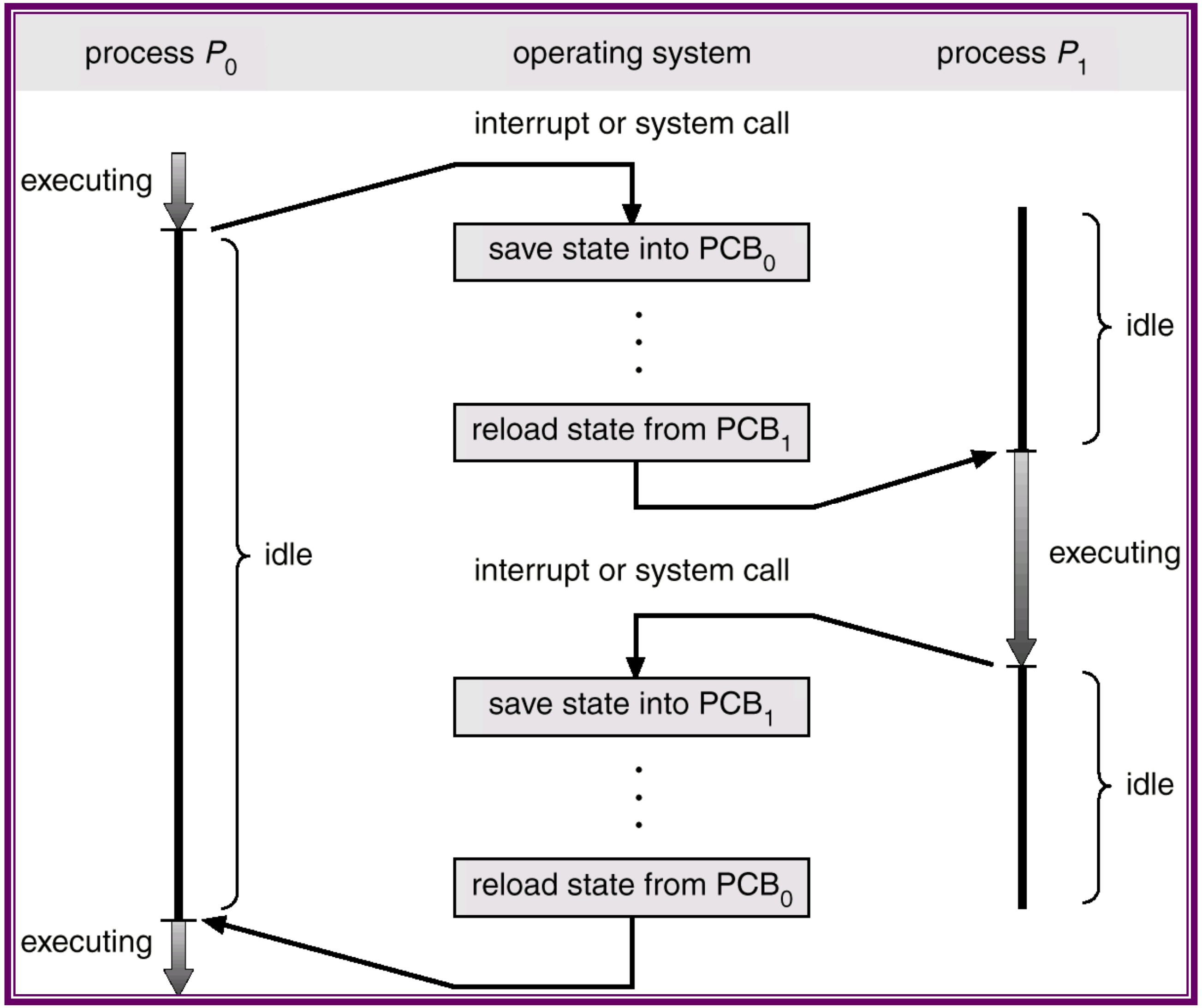
- Process state
- Program counter
- CPU registers
- CPU scheduling information
- Memory-management information
- Accounting information
- File usage and I/O status information

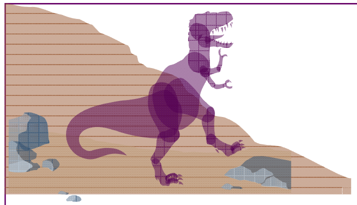


Process Control Block (PCB)



CPU Switch From Process to Process





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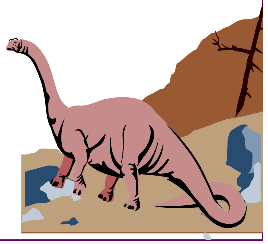
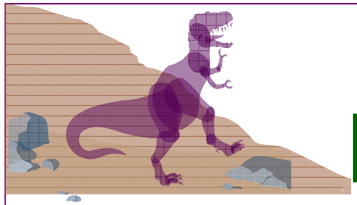
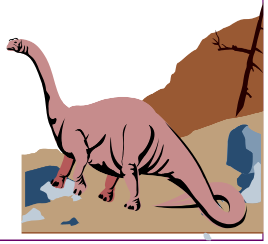


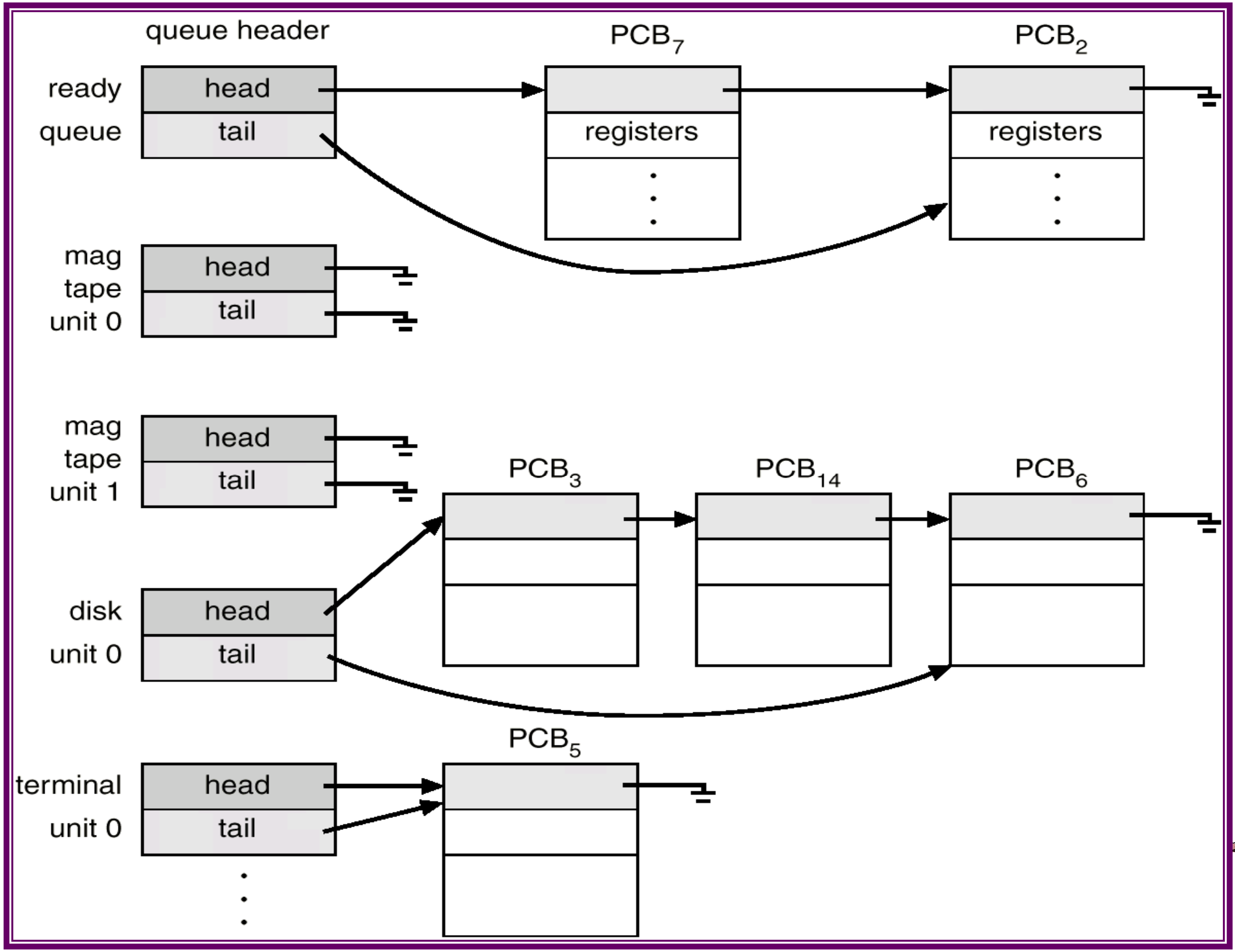


Process Scheduling Queues

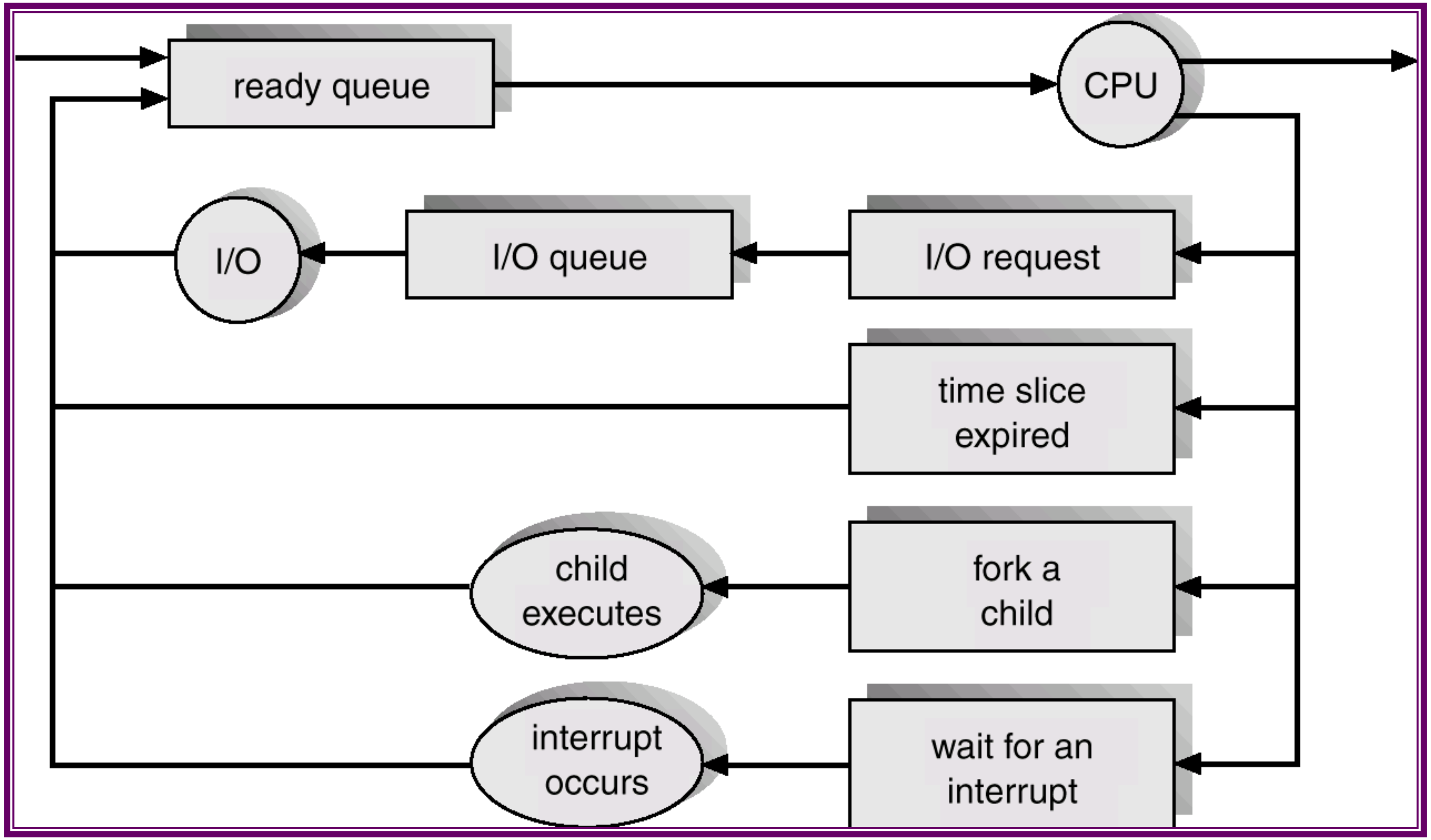
- Job queue – set of all processes in the system.
- Ready queue – set of all processes residing in main memory, ready and waiting to execute.
- Device queues – set of processes waiting for an I/O device.
- Process migration between the various queues.

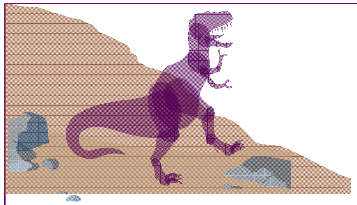


Ready Queue And Various I/O Device Queues



Representation of Process Scheduling

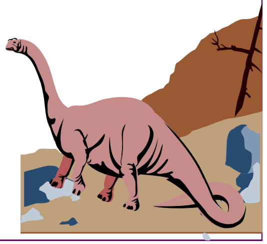


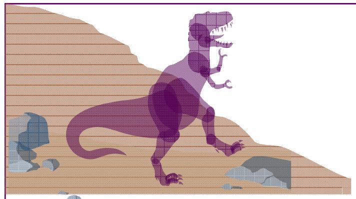


Schedulers

- Long-term scheduler (or job scheduler) – selects which processes should be loaded into memory for execution.

- Short-term scheduler (or CPU scheduler) – selects which process should be executed next and allocates CPU.



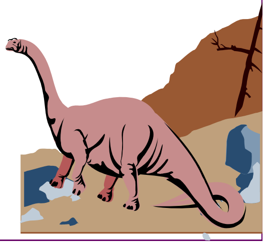


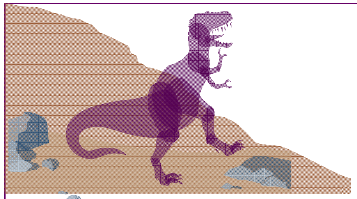
Schedulers (Cont.)

- Short-term scheduler is invoked very frequently (milliseconds) ⇒ (must be fast).

- Long-term scheduler is invoked very infrequently (seconds, minutes) ⇒ (may be slow).

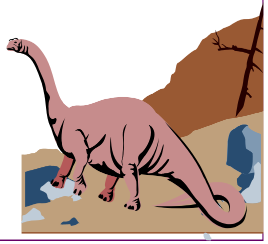
- The __________ scheduler controls the *degree of multiprogramming*.
  - long-term
  - short-term





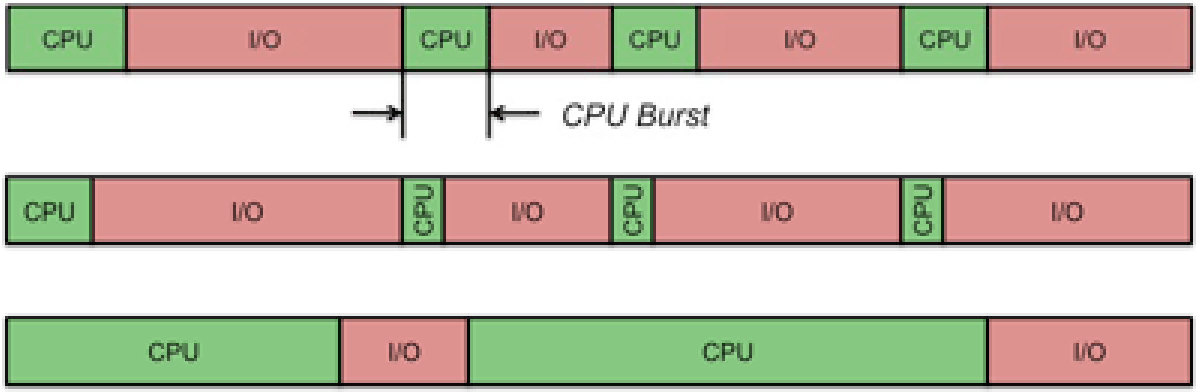
Schedulers (Cont.)

- The long-term scheduler controls the *degree of multiprogramming*.
- Long-term scheduling performs a gatekeeping function. It decides whether there's enough memory, or room, to allow new programs into the system.
- Dispatching affects processes
  - running;
  - ready;
  - blocked;
- Long-term scheduling affects processes
  - new;
  - exited

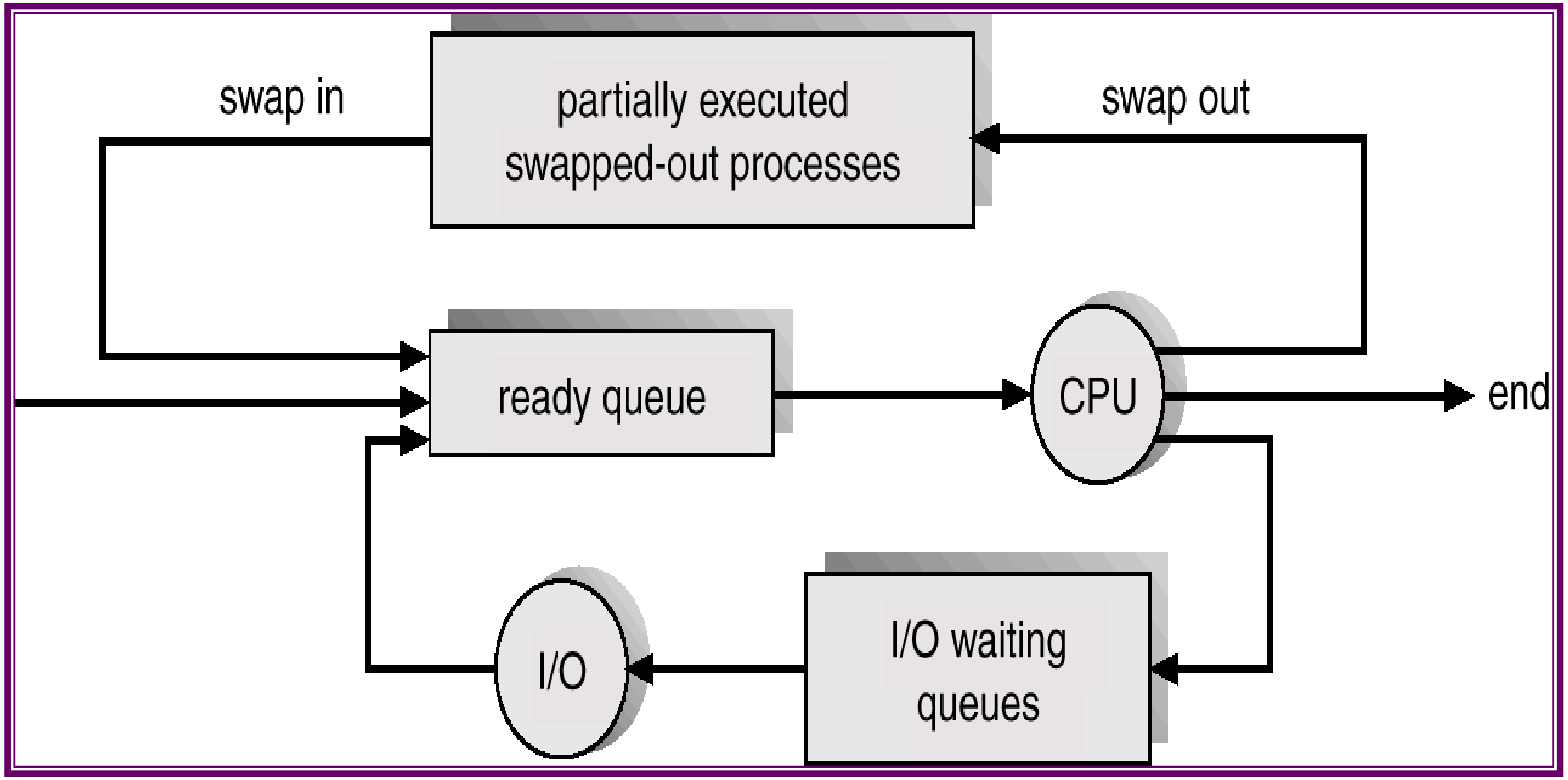


Schedulers (Cont.)

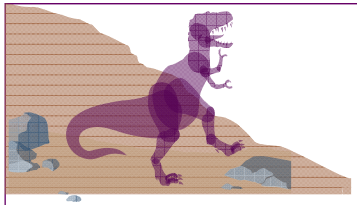
- Processes can be described as either:
  - I/O-*bound process* – spends more time doing I/O than computations, many short CPU bursts.
  - *CPU-bound process* – spends more time doing computations; few very long CPU bursts.
- The period of computation between I/O requests is called the **CPU burst**.



Addition of Medium-Term Scheduling

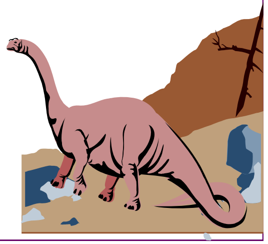


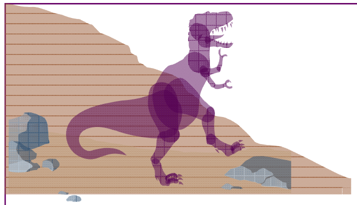
http://en.wikipedia.org/wiki/Scheduling_(computing)#Medium-term_scheduling



Context Switch

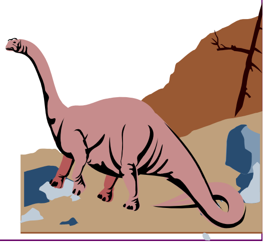
- **What is a process context?**
  - **The *context* of a process includes the values of CPU registers, the process state, the program counter, and other memory/file management information.**



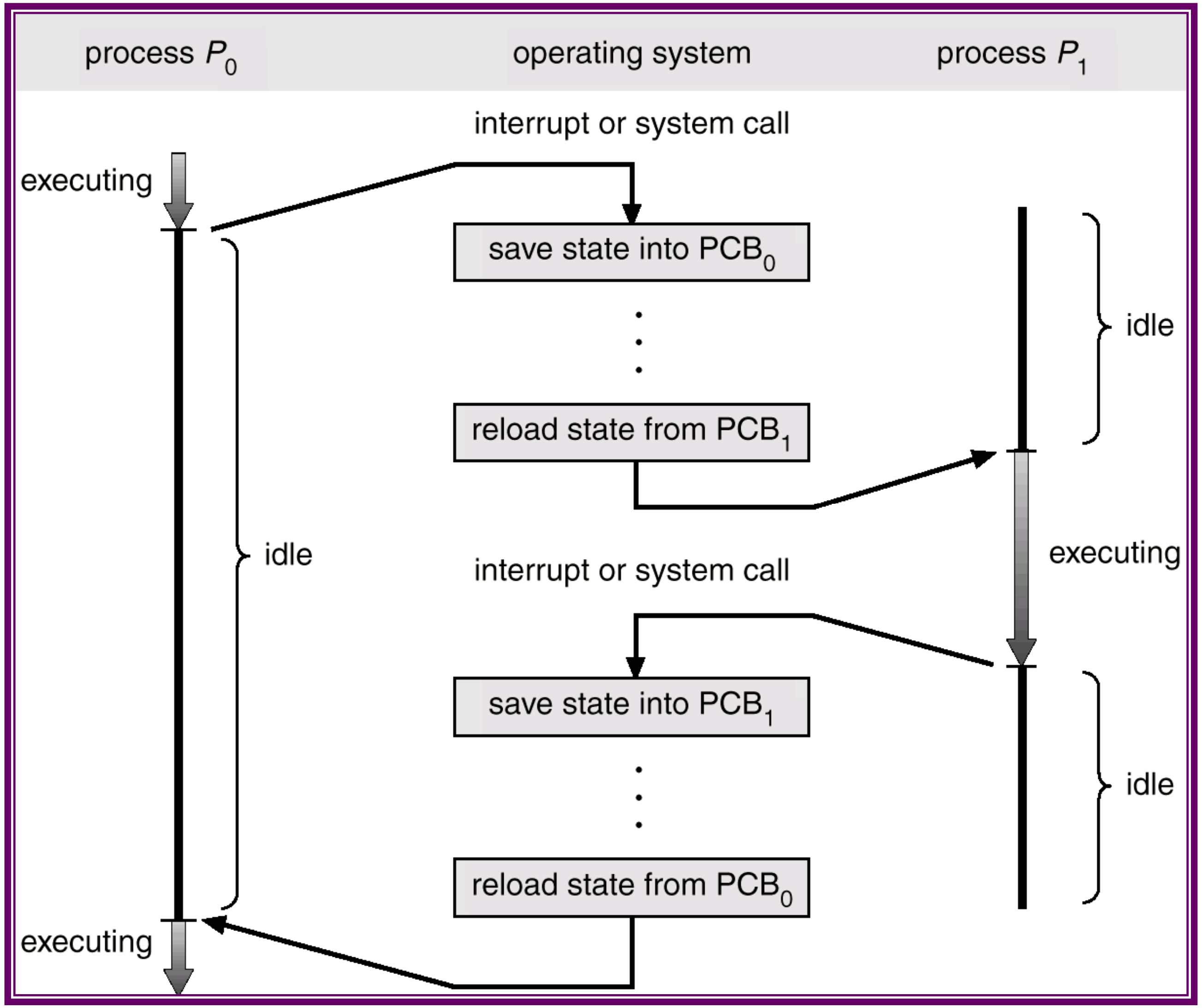


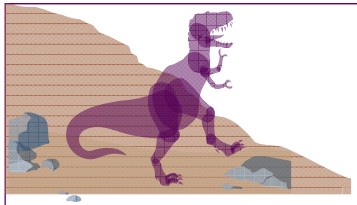
Context Switch (Cont.)

- **What is a context switch?**
  - **After the CPU scheduler selects a process (from the *ready queue*) and before allocates CPU to it, the CPU scheduler must**
    - ✓ **save the *context* of the currently running process,**
    - ✓ **put it into a queue,**
    - ✓ **load the *context* of the selected process, and**
    - ✓ **let it run.**



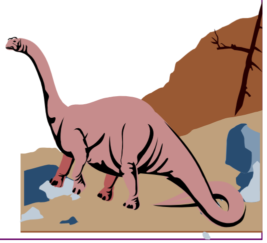
CPU Switch From Process to Process

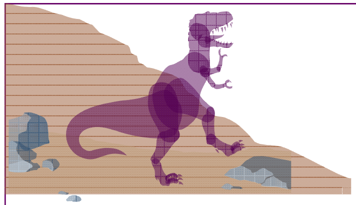




Context Switch (Cont.)

- 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.
- Context-switch time is overhead; the system does no useful work while switching.
- Time dependent on hardware support.





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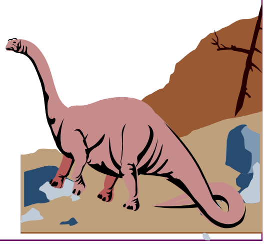
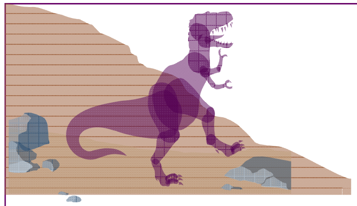
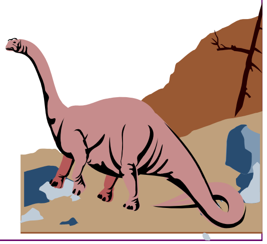
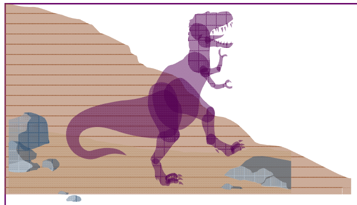




Process Creation

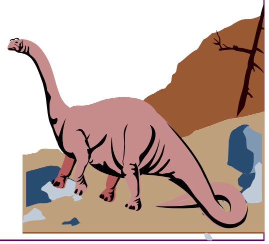
- Parent process create children processes, which, in turn create other processes, forming a tree of processes.
- Resource sharing
  - Parent and children share all resources.
  - Children share subset of parent's resources.
  - Parent and child share no resources.
- Execution
  - Parent and children execute concurrently.
  - Parent waits until children terminate.



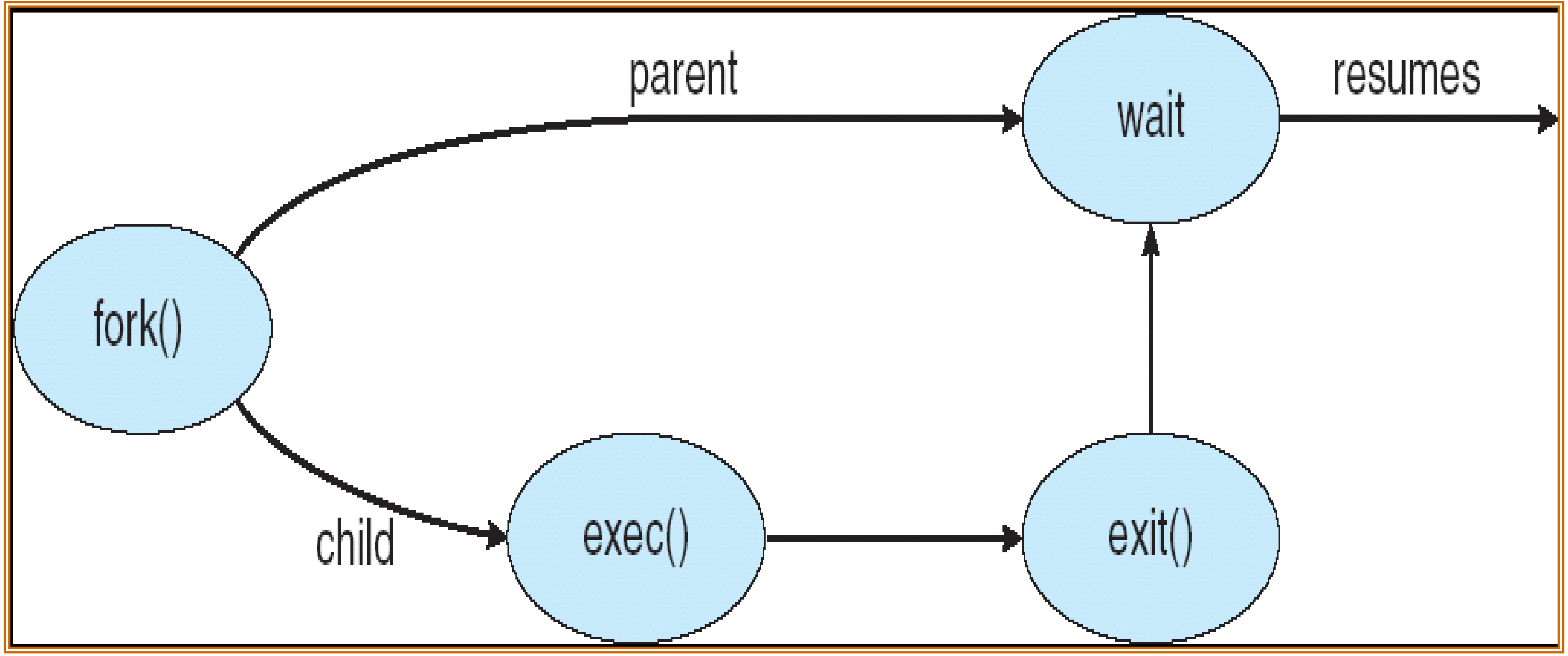


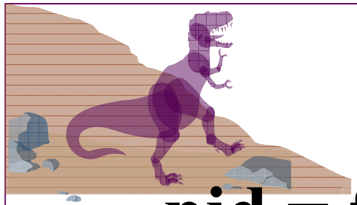
Process Creation (Cont.)

- 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.

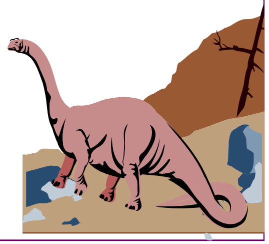


Process Creation (UNIX)

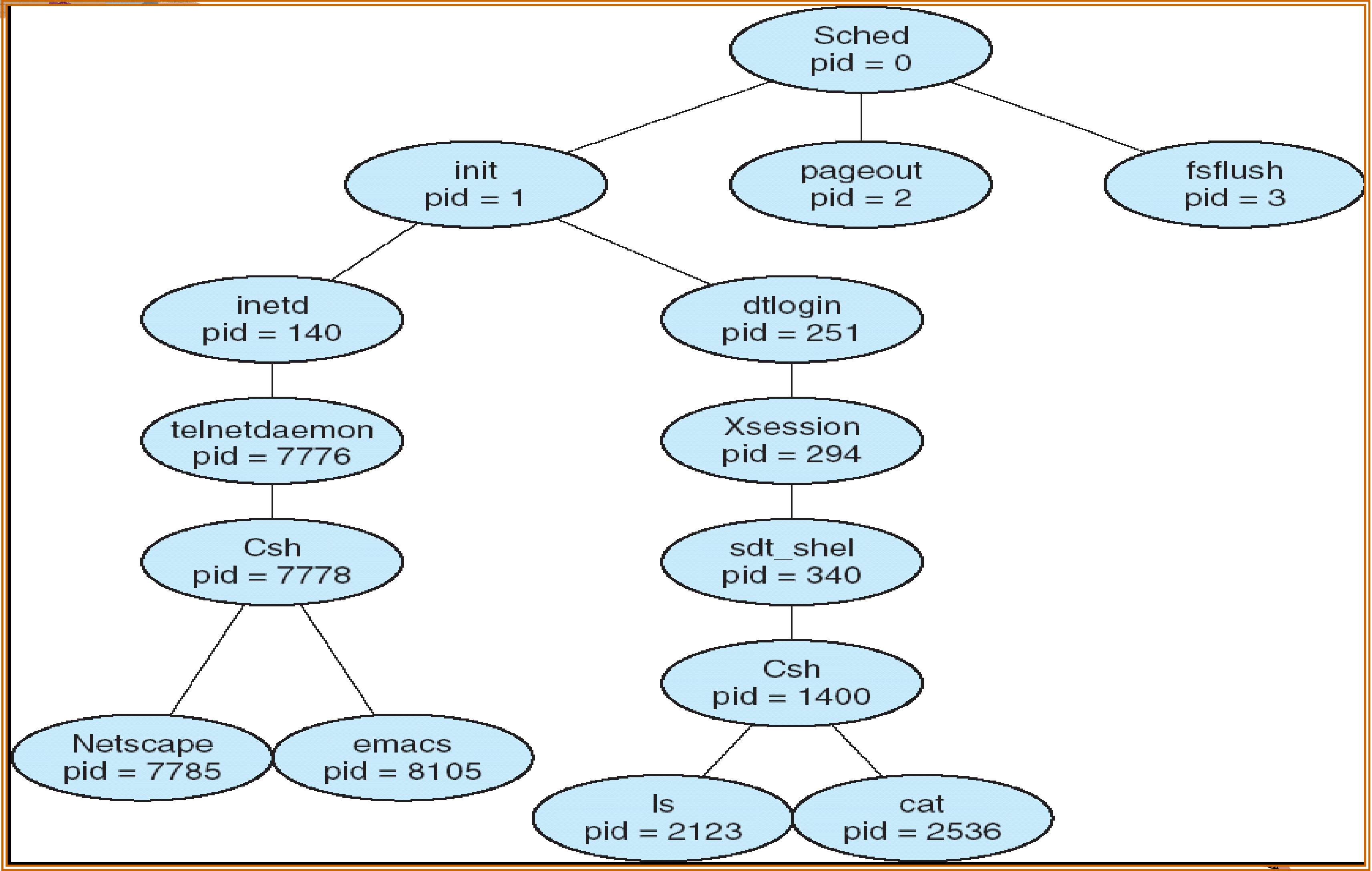


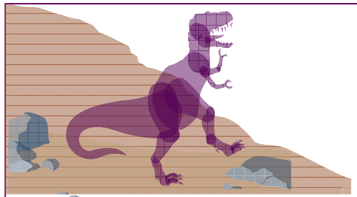


```
pid = fork();
if (pid < 0){/*error occured*/
    fprintf(stderr, “Fork failed”);
    exit(-1);}
else if(pid == 0){/*child process*/
    execlp(“/bin/ls”,”ls”,NULL);
}
else {/*parent process*/
    wait(NULL);
    printf(“Child Complete”);
    exit(0);
}
```



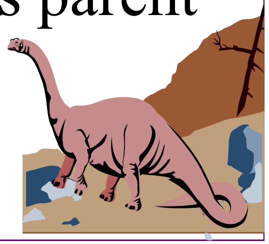
Processes Tree on Solaris

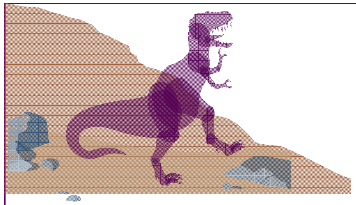




Process Termination

- 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 OS.
- Parent may terminate execution of children processes (**abort**).
  - Child has exceeded allocated resources.
  - Task assigned to child is no longer required.
  - Parent is exiting.
    - ✓Operating system does not allow child to continue if its parent terminates.
    - ✓Cascading termination.Z





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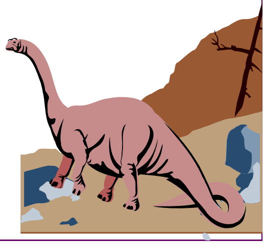
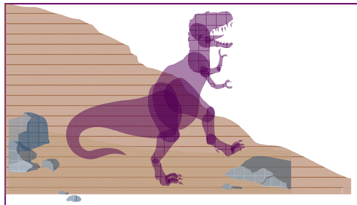
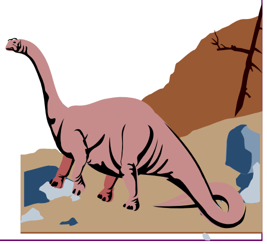
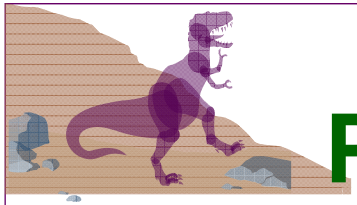




Cooperating Processes

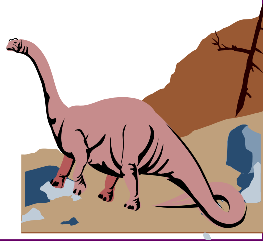
- *Independent* process cannot affect or be affected by the execution of another process.
- *Cooperating* process can affect or be affected by the execution of another process
- Advantages of process cooperation
  - Information sharing
  - Computation speed-up
  - Modularity
  - Convenience





Producer-Consumer Problem

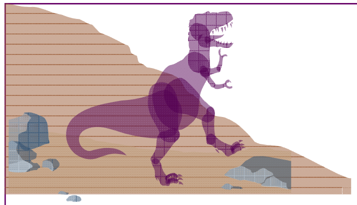
- Paradigm for cooperating processes, *producer* process produces information that is consumed by a *consumer* process.
  - *unbounded-buffer* places no practical limit on the size of the buffer.
  - *bounded-buffer* assumes that there is a fixed buffer size.



Bounded-Buffer – Shared-Memory Solution

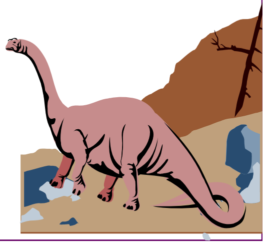
- Shared data

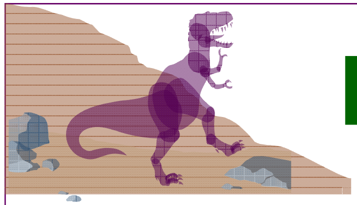
```
#define BUFFER_SIZE 10
Typedef struct {
   . . .
} item;
item buffer[BUFFER_SIZE];
int in = 0;
int out = 0;
```



Bounded-Buffer – Producer Process

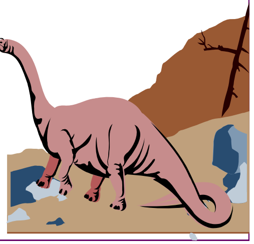
```
item nextProduced;

while (1) {
    while (((in + 1) % BUFFER_SIZE) == out)
            ; /* do nothing */
    buffer[in] = nextProduced;
    in = (in + 1) % BUFFER_SIZE;
}
```

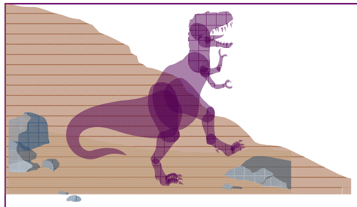




Bounded-Buffer – Consumer Process

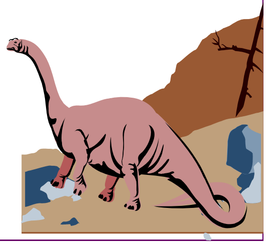
```
item nextConsumed;

while (1) {
        while (in == out)
                ; /* do nothing */
        nextConsumed = buffer[out];
        out = (out + 1) % BUFFER_SIZE;
}
```

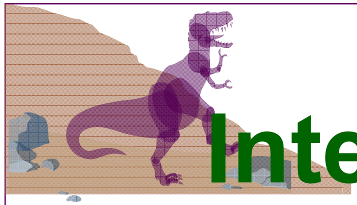




Bounded-Buffer

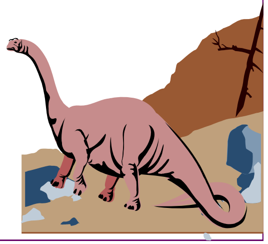
- Solution is correct, but can only use BUFFER_SIZE-1 elements





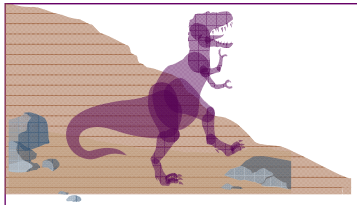
Interprocess Communication (IPC)

- Mechanism for processes to communicate and to synchronize their actions.
- Message system – processes communicate with each other without resorting to shared variables.



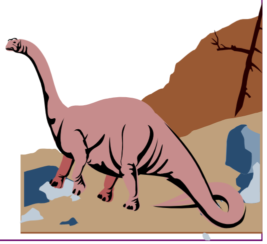
Interprocess Communication (Cont.)

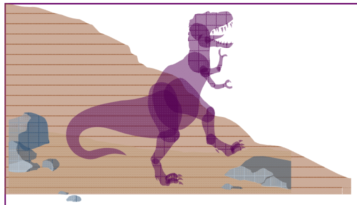
- IPC facility provides two operations:
  - **send**(*message*) – message size fixed or variable
  - **receive**(*message*)
- If *P* and *Q* wish to communicate, they need to:
  - establish a *communication link* between them
  - exchange messages via send/receive
- Implementation of communication link
  - physical (e.g., shared memory, hardware bus)
  - logical (e.g., logical properties)



Implementation Questions

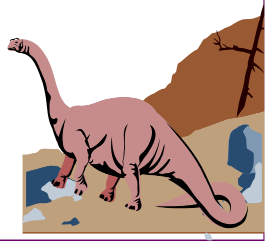
- How are links established?
- Can a link be associated with more than two processes?
- How many links can there be between every pair of communicating processes?
- What is the capacity of a link?
- Is the size of a message that the link can accommodate fixed or variable?
- Is a link unidirectional or bi-directional?

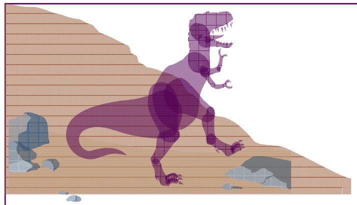




Direct Communication

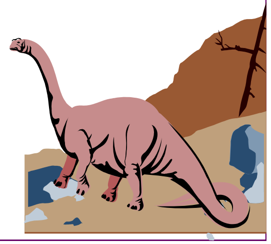
- Processes must name each other explicitly:
  - **send** (*P*, *message*) – send a message to process P
  - **receive**(*Q*, *message*) – receive a message from process Q
- Properties of communication link
  - Links are established automatically.
  - A link is associated with exactly one pair of communicating processes.
  - Between each pair there exists exactly one link.
  - The link may be unidirectional, but is usually bi-directional.

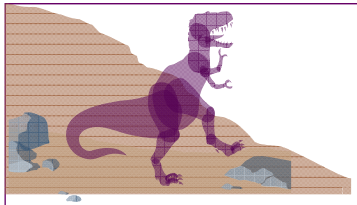




Indirect Communication

- Messages are directed and received from mailboxes (also referred to as ports).
  - Each mailbox has a unique id.
  - 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.



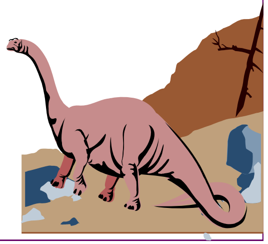


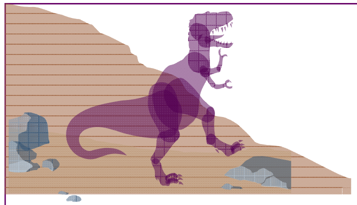
Indirect Communication

- 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

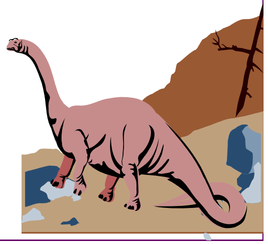
receive(*A*, *message*) – receive a message from mailbox A

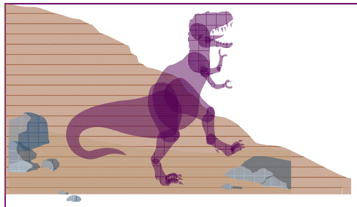




Indirect Communication

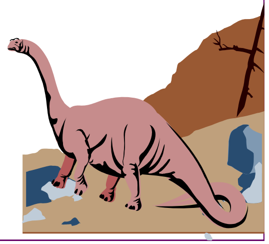
- Mailbox sharing
  - P_1, P_2, and P_3 share mailbox A.
  - P_1, sends; P_2 and P_3 receive.
  - Who gets the message?
- Solutions
  - Allow a link to be associated with at most two processes.
  - Allow only one process at a time to execute a receive operation.
  - Allow the system to select arbitrarily the receiver. Sender is notified who the receiver was.

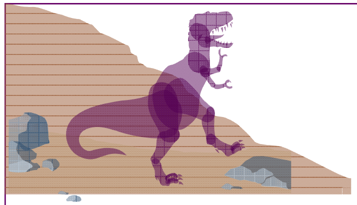




Synchronization

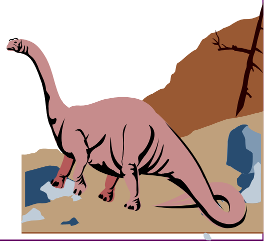
- Message passing may be either blocking or non-blocking.
- **Blocking** is considered **synchronous**
- **Non-blocking** is considered **asynchronous**
- **send** and **receive** primitives may be either blocking or non-blocking.

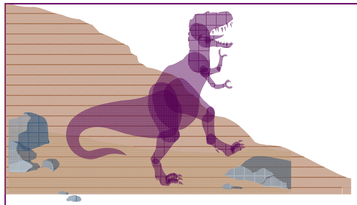




Buffering

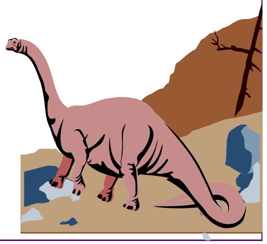
- Queue of messages attached to the link; implemented in one of three ways.
  1. Zero capacity – 0 messages
     Sender must wait for receiver (rendezvous).
  2. Bounded capacity – finite length of *n* messages
     Sender must wait if link full.
  3. Unbounded capacity – infinite length
     Sender never blocks.

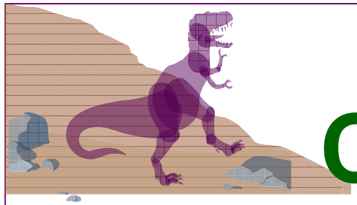




Chapter 3: Processes

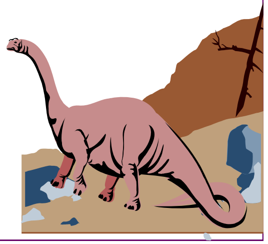
- Process Concept
- Process Scheduling
- Operations on Processes
- Cooperating Processes
- Interprocess Communication
- Communication in Client-Server Systems

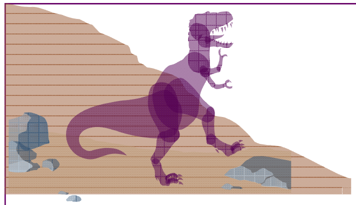




Client-Server Communication

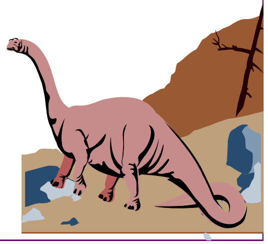
- Sockets
- Remote Procedure Calls
- Remote Method Invocation (Java)



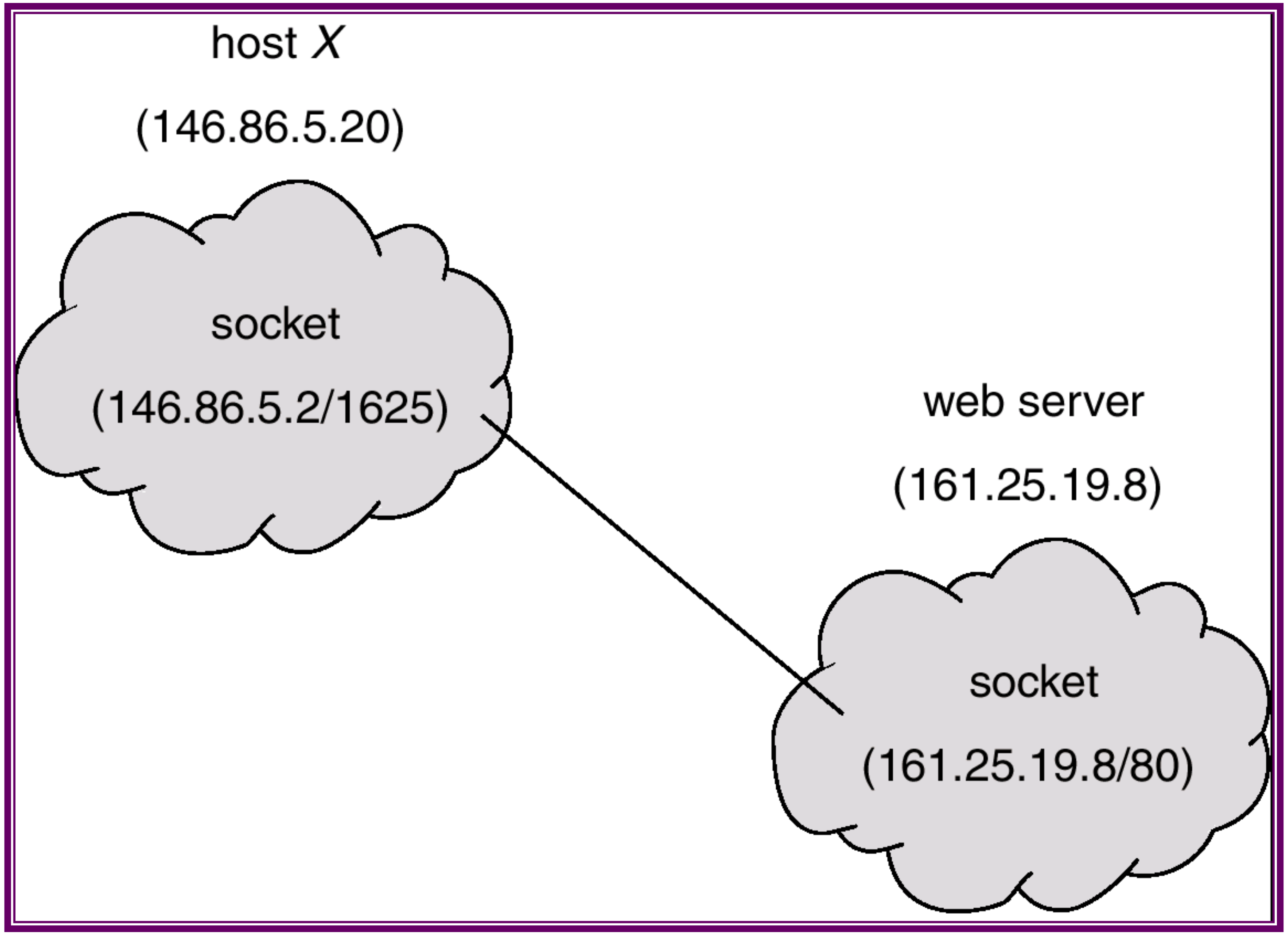


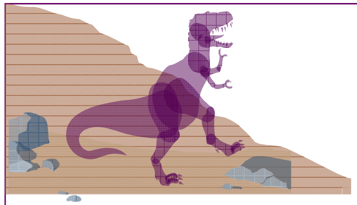
Sockets

- 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.



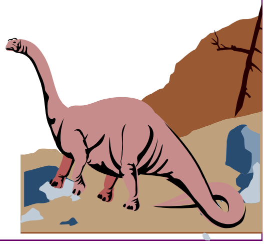
Socket Communication



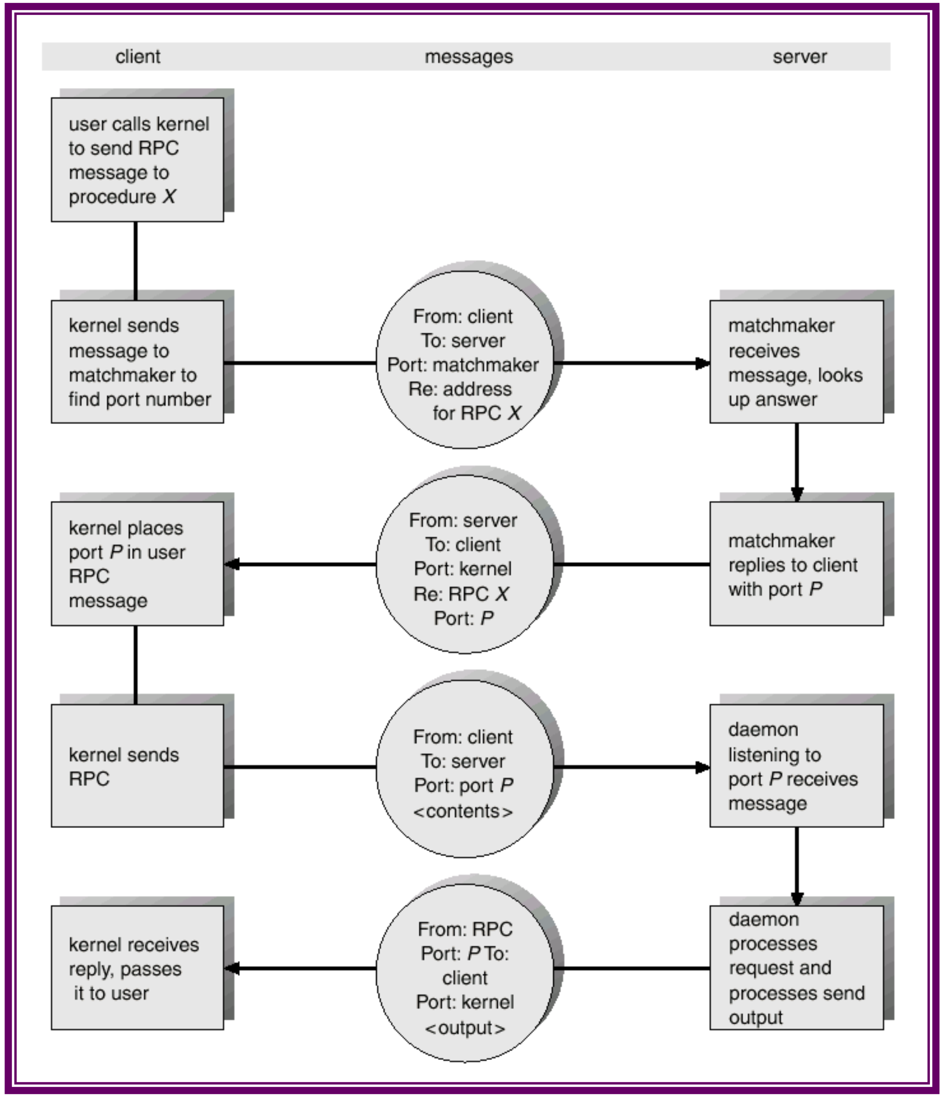


Remote Procedure Calls

- Remote procedure call (RPC) abstracts procedure calls between processes on networked systems.
- **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 peforms the procedure on the server.

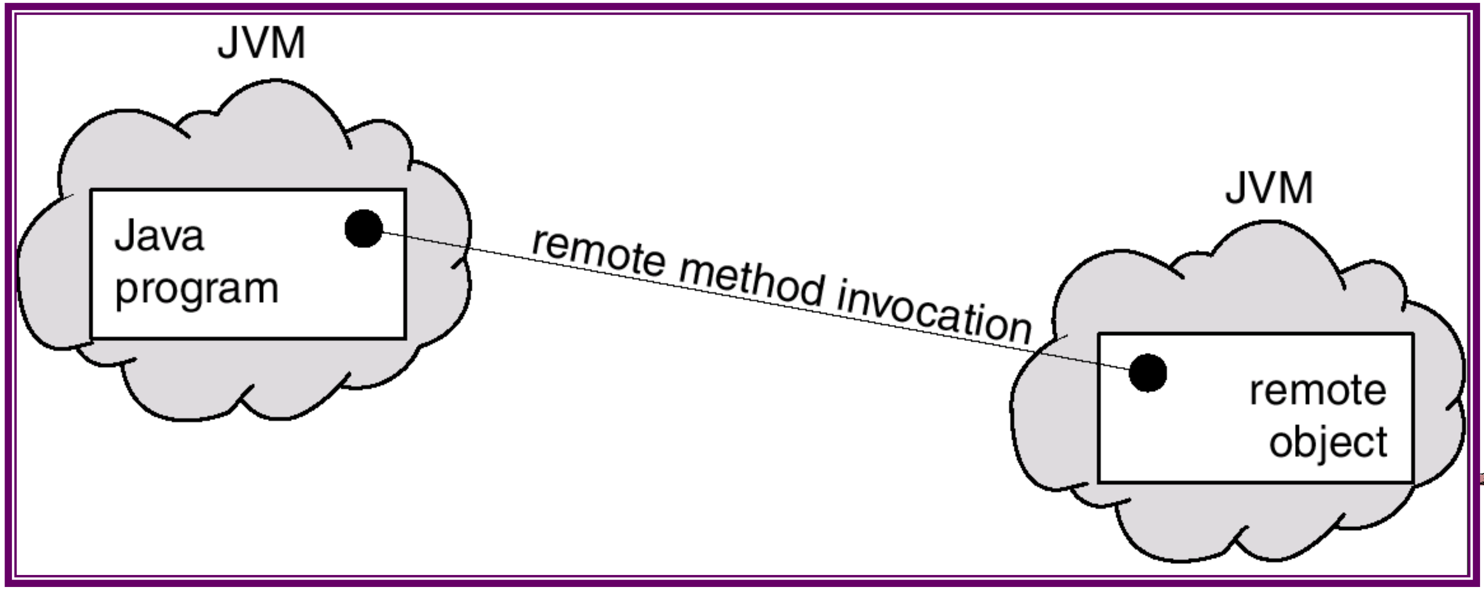


Execution of RPC

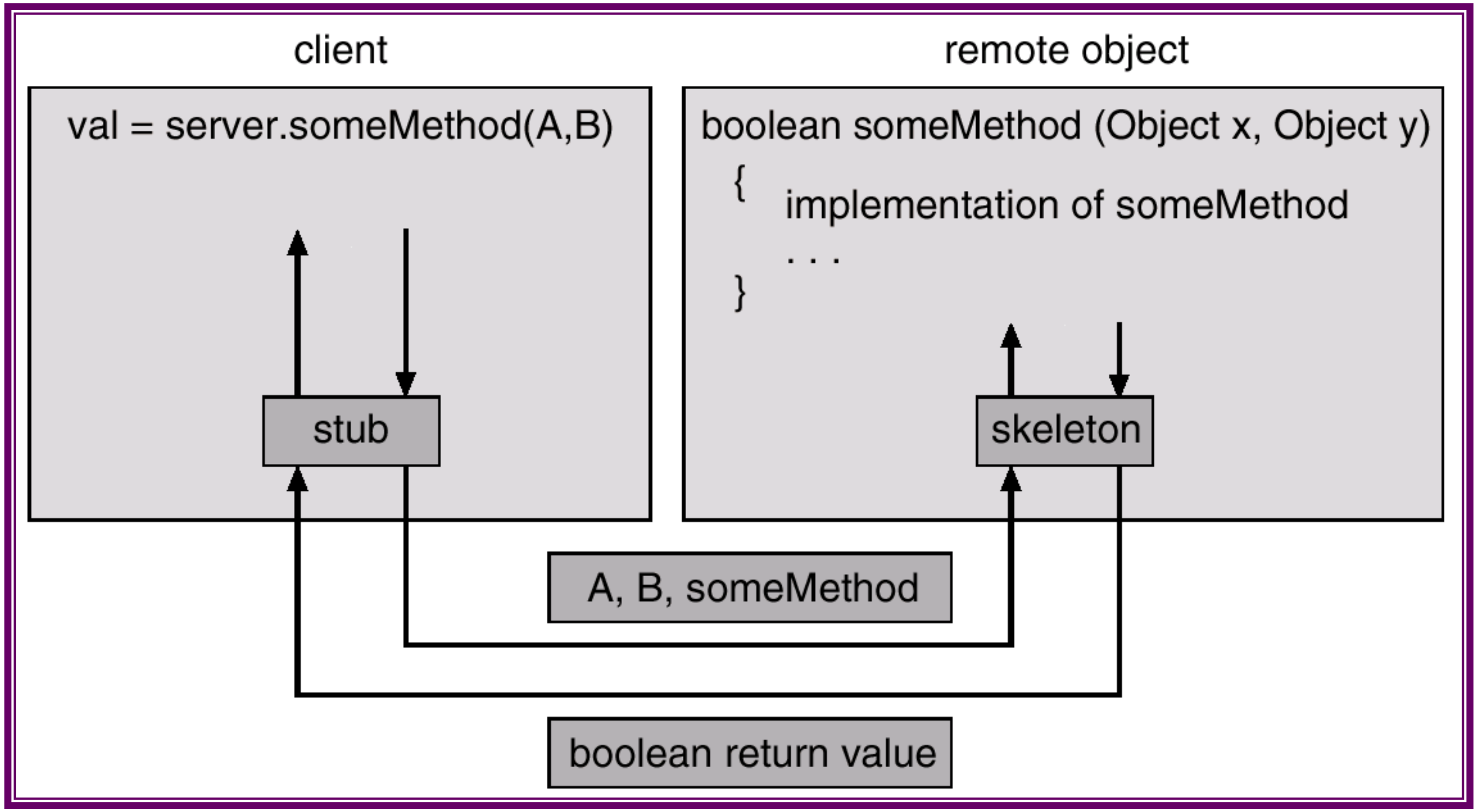

client
messages
server
user calls kernel to send RPC message to procedure *X*
kernel sends message to matchmaker to find port number
From: client To: server Port: matchmaker Re: address for RPC *X*
matchmaker receives message, looks up answer
matchmaker replies to client with port *P*
From: server To: client Port: kernel Re: RPC *X* Port: *P*
kernel places port *P* in user RPC message
kernel sends RPC
From: client To: server Port: port *P* <contents>
daemon listening to port *P* receives message
daemon processes request and processes send output
From: RPC Port: *P* To: client Port: kernel <output>
kernel receives reply, passes it to user

Remote Method Invocation

- Remote Method Invocation (RMI) is a Java mechanism similar to RPCs.
- RMI allows a Java program on one machine to invoke a method on a remote object.



Marshalling Parameters


client
remote object
val = server.someMethod(A,B)
boolean someMethod (Object x, Object y)
{
implementation of someMethod
. . .
}
stub
skeleton
A, B, someMethod
boolean return value