操作系统原理及应用

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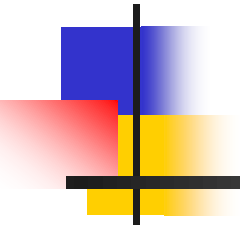
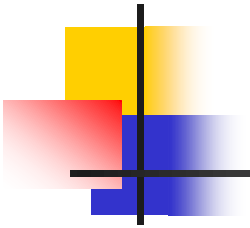
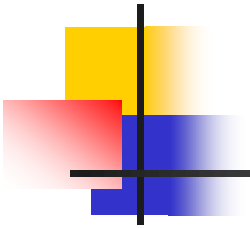


Chapter 3 Processes



Outline

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



Process Concept

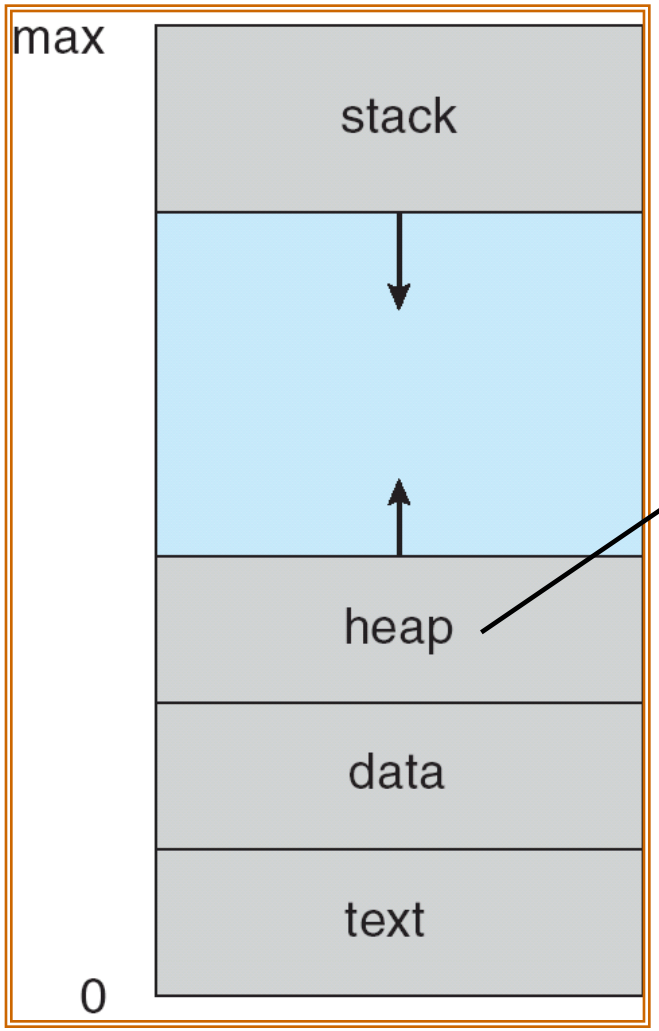
- An operating system executes a variety of programs
  - Batch system – jobs
  - Time-shared systems – user programs or tasks
- Textbook uses the terms *job* and *process* almost interchangeably.

Process Concept

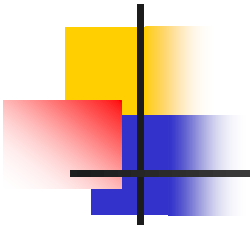
- Process – a program in execution; process execution must progress in sequential fashion.
- A process includes
  - text section (program code)
  - program counter
  - contents of the processor's registers

  - stack — temporary data (function parameters, return address, local variables)
  - data section — global variables

Process in Memory

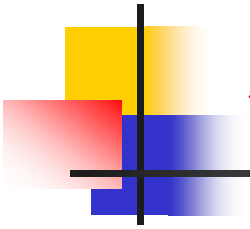


Heap (堆) is memory that is dynamically allocated during process run time.



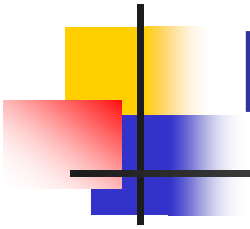
Characteristic of Process

- **Dynamic (动态性)**
- **Independency (独立性)**
- **Concurrence (并发性)**
- **Structure (结构化)**



作业1

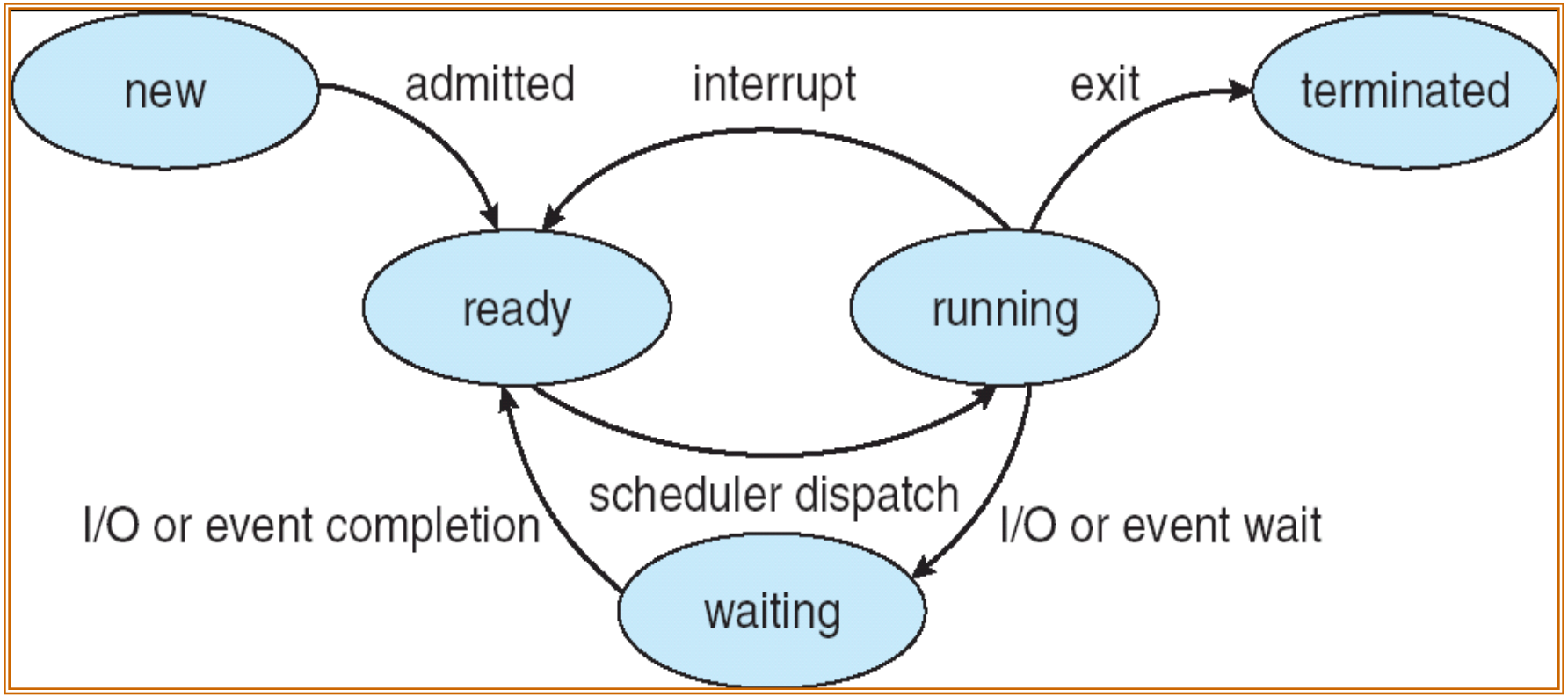
进程和程序是两个密切相关的概念，请阐述它们之间的区别和联系。



Process State

- As a process executes, it changes *state*
  - New: The process is being created.
  - Ready: The process is waiting to be assigned to a processor.
  - Running: Instructions are being executed.
  - Waiting: The process is waiting for some event to occur.
  - Terminated: The process has finished execution.

Diagram of Process State



Exercise

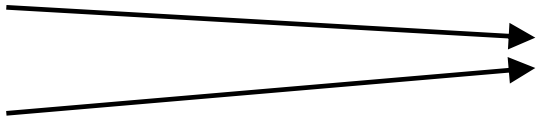
- 在一个只有单处理机（不考虑多核）的操作系统中，进程有运行、就绪、等待三个基本状态。假如某时刻该系统中有10个用户进程并发执行，且CPU为非核心态情况下，试问：
  - 这时刻系统中处于运行状态的用户进程数最多有几个？最少有几个？
  - 这时刻系统中处于就绪状态的用户进程数最多有几个？最少有几个？
  - 这时刻系统中处于等待状态的用户进程数最多有几个？最少有几个？

作业2

画出进程在就绪、运行和等待三个基本状态之间的状态转换图，并简述发生相应状态转换的原因。

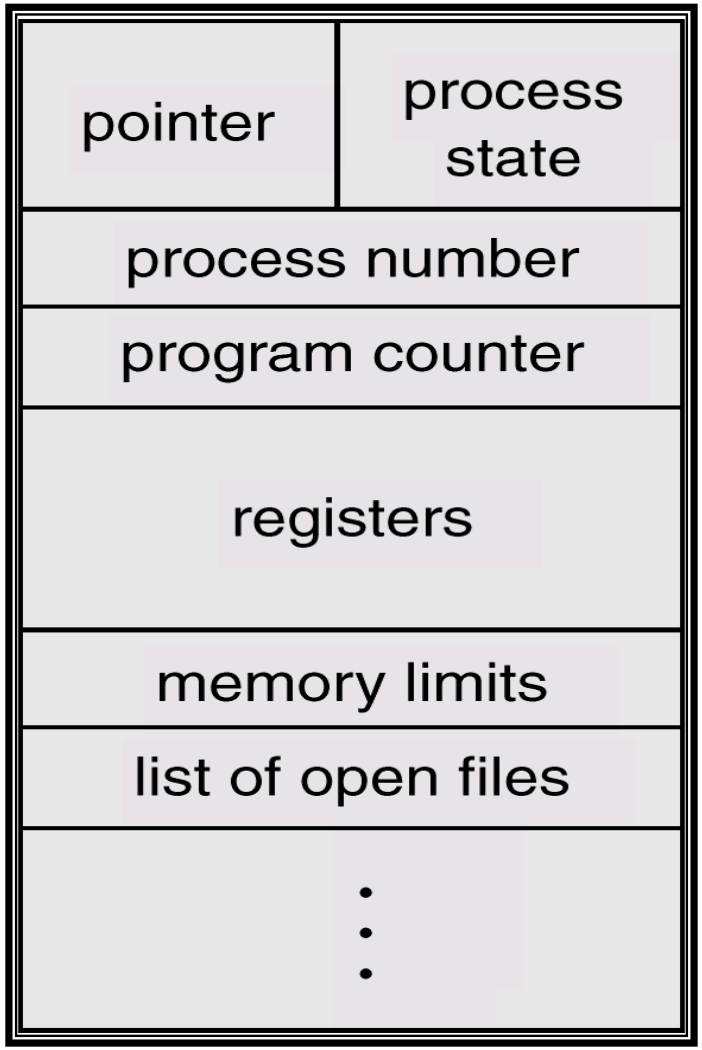
Process Control Block (PCB)

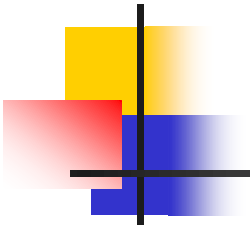
- Containing the information associated with a specific process
  - Process state
  - Program counter
  - CPU registers
  - CPU scheduling information
  - Memory-management information
  - Accounting information
  - I/O status information
  - … …



Must be saved when an interrupt occurs

Process Control Block (PCB)





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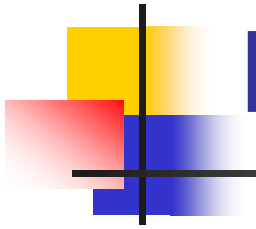
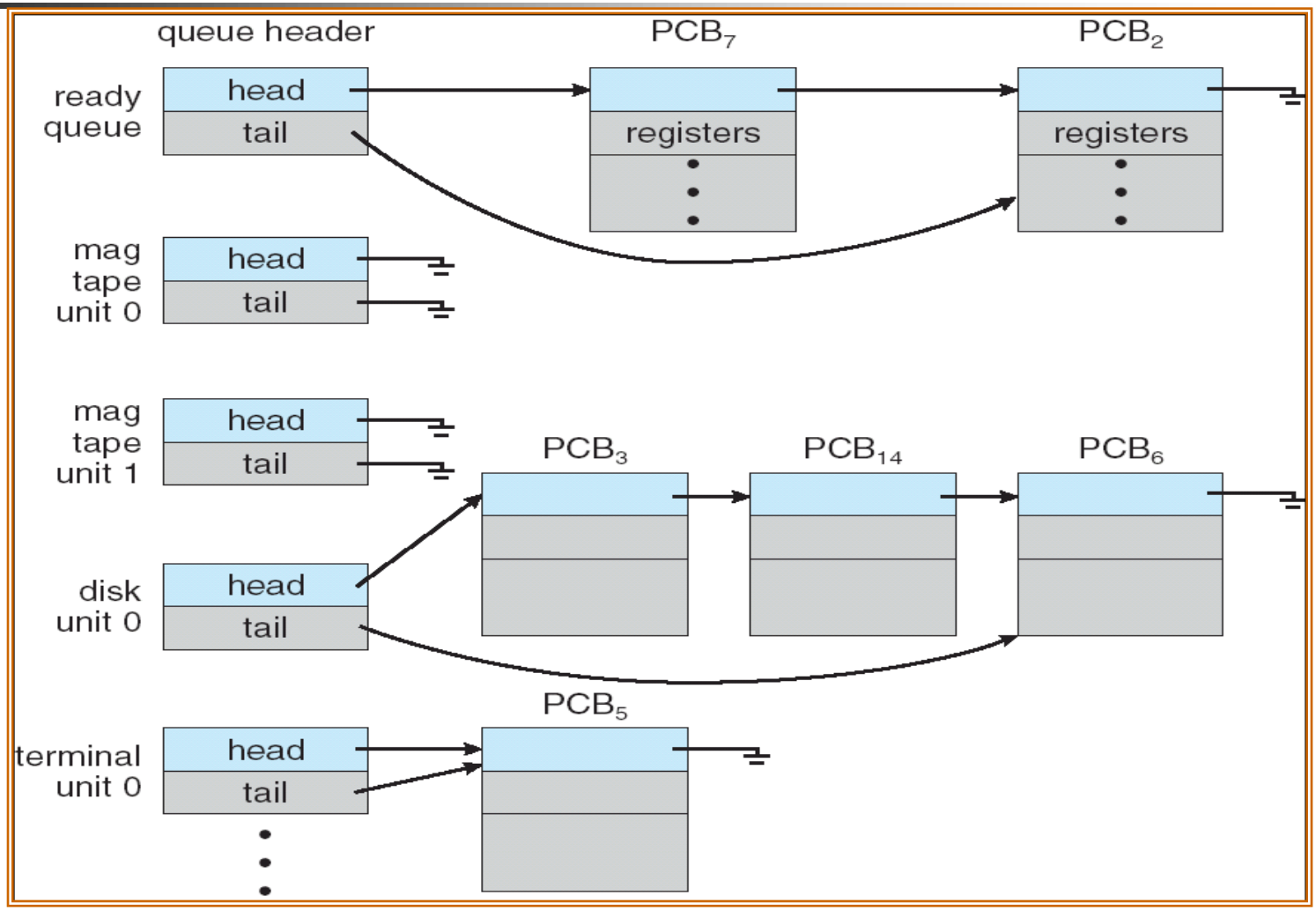
Process Scheduling Queues

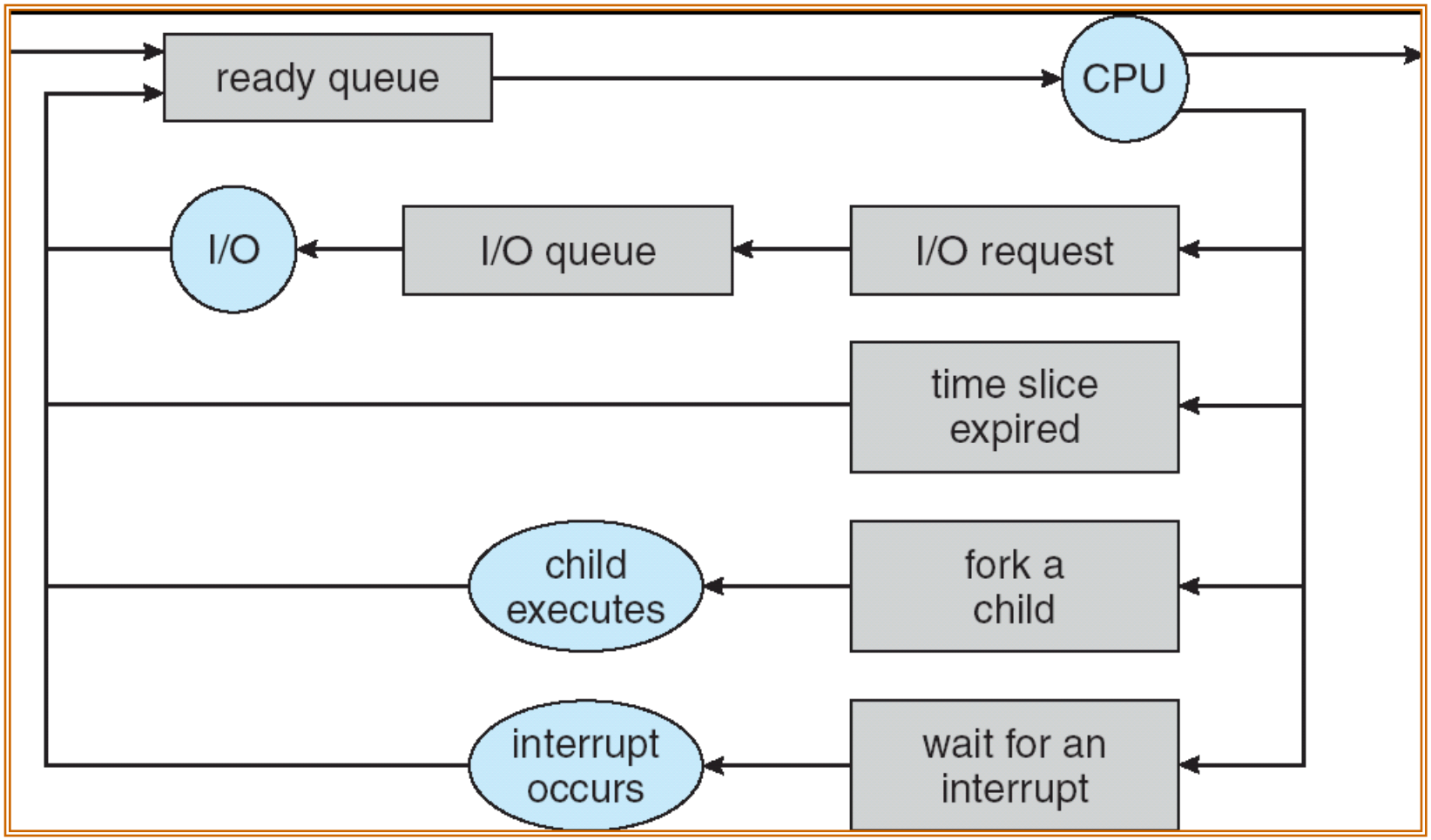


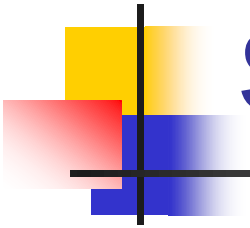
- **Job queue – set of all processes in the system**
  - **Ready queue – set of all processes residing in main memory, ready and waiting to execute**
  - **Device queues – set of processes waiting for an I/O device**
  - **Process migration between the various queues**

Ready Queue And Various I/O Device Queues



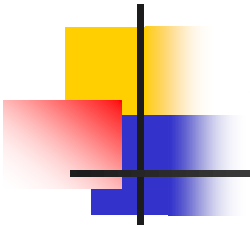
Representation of Process Scheduling





Schedulers

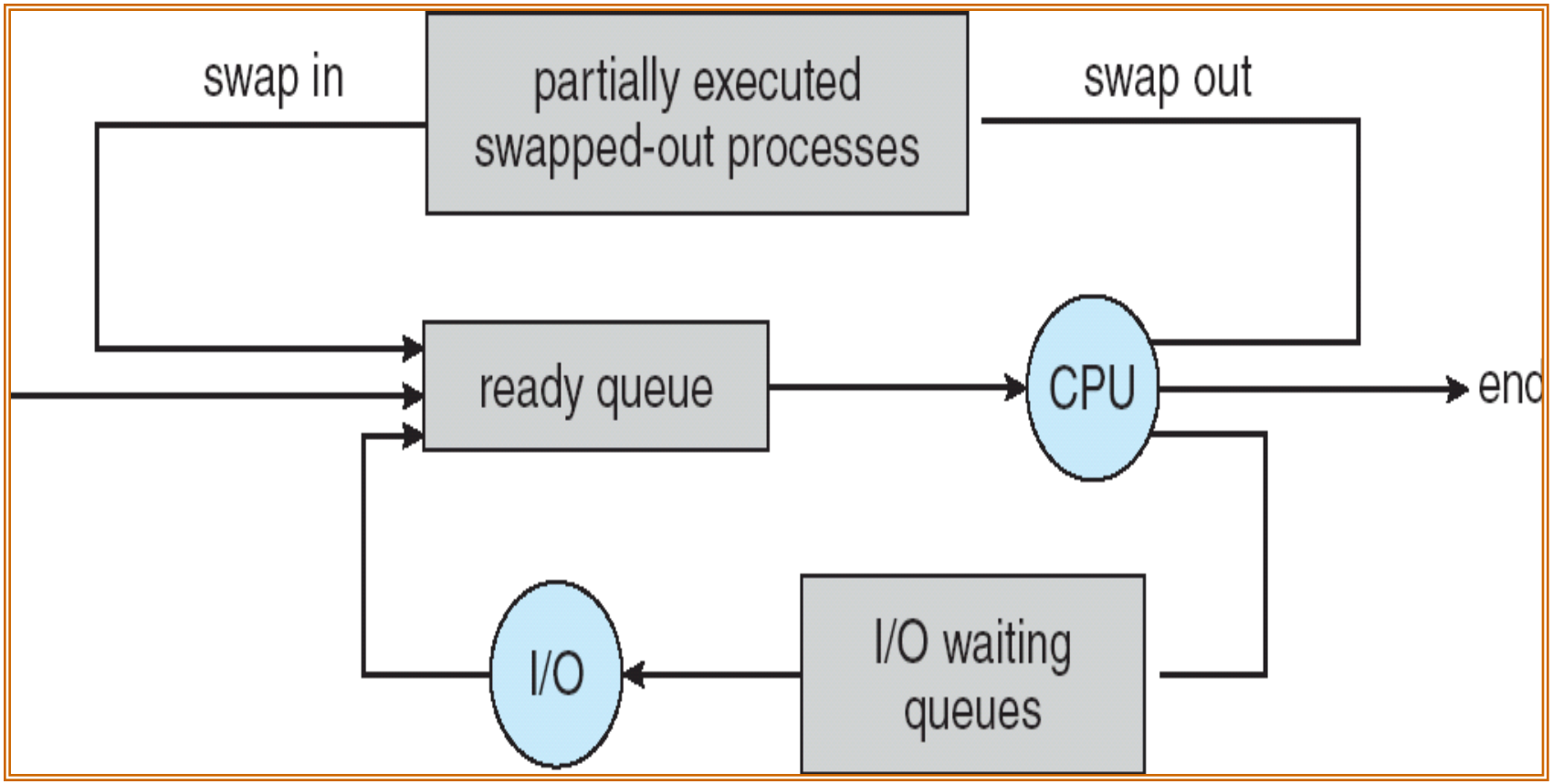
- **Long-term scheduler (or job scheduler) – selects which processes should be loaded into memory for execution.**
- **Short-term scheduler (or CPU scheduler) – selects which process should be executed next and allocates CPU.**
- **Medium-term scheduler – remove processes from memory and reintroduce them into memory later (swapping).**

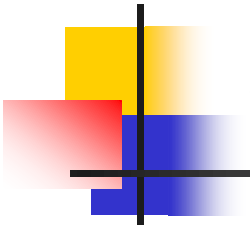


Schedulers

- **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* *(the number of processes in memory).***

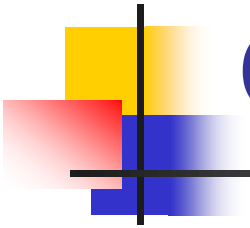
Medium-Term Scheduling





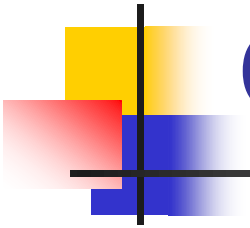
Schedulers

- **Processes can be described as either**
  - ***I/O-bound process* – spends more time doing I/O than doing computations.**
  - ***CPU-bound process* – spends more time doing computations than doing I/O.**
- **The long-term scheduler select a good process mix of I/O-bound and CPU-bound processes.**



Context Switch

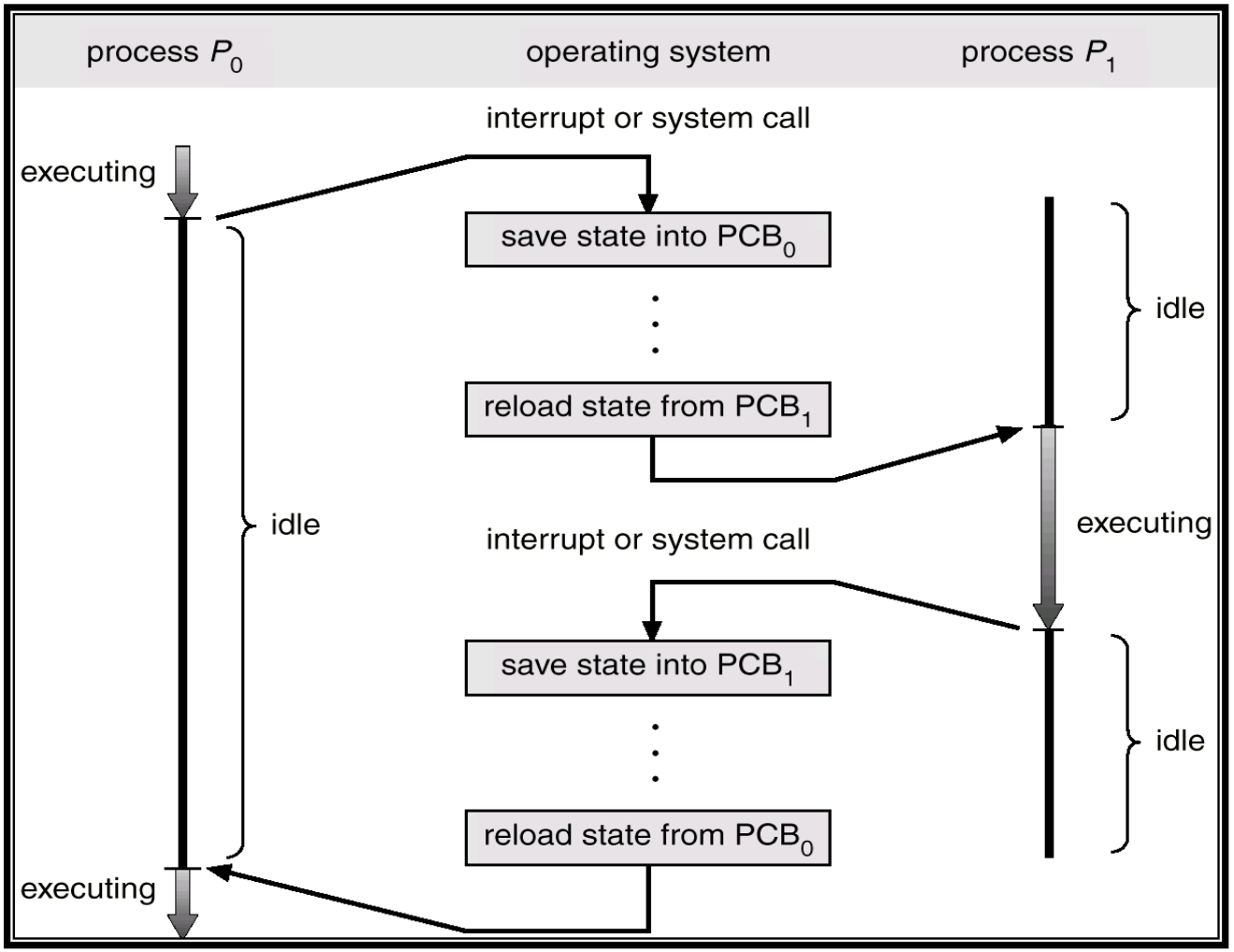
- **What is a process context?**
  - **The *context* of a process is represented in the PCB of the process and includes the values of CPU registers, the process state, the program counter, and other memory/file management information.**



Context Switch

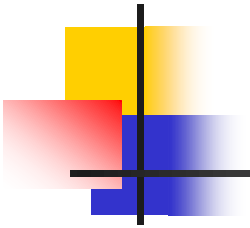
- When CPU switches to another process, the system must save the state of the old process and load the saved state for the new process.
- Context-switch time is overhead; the system does no useful work while switching.
- Context-switch time dependent on hardware support.

CPU Switch From Process to Process



Exercise

- 下列哪一种情况不会引起进程之间的切换？
  - A. 进程调用本程序中定义的函数进行计算
  - B. 进程处理I/O请求
  - C. 进程创建子进程并等待子进程结束
  - D. 产生中断



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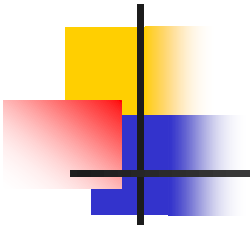
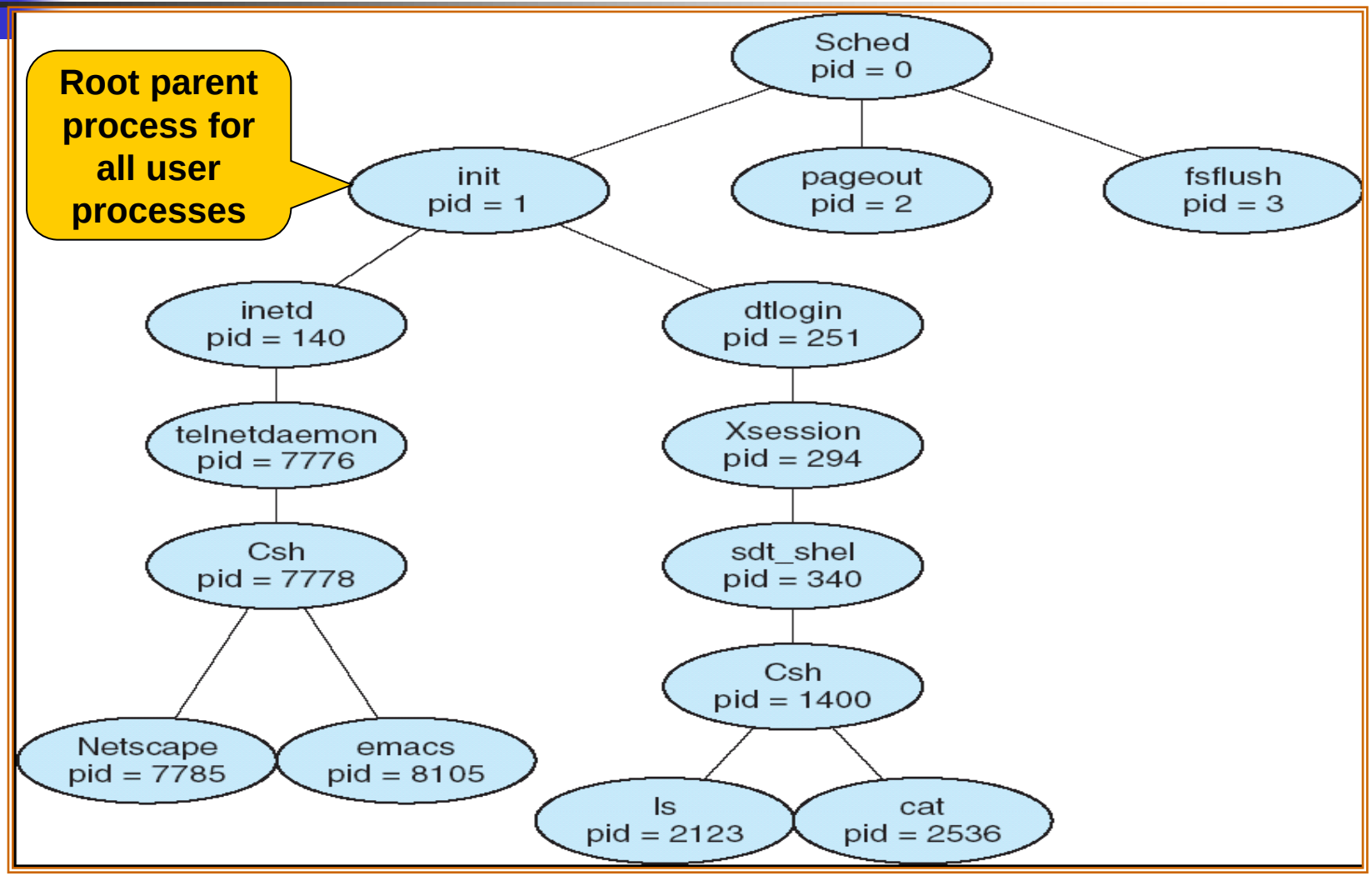
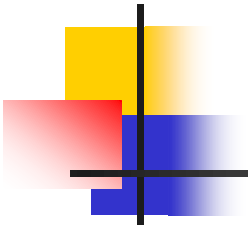


Process Creation

- **Parent process create children processes, which, in turn create other processes, forming a tree of processes.**
- **A unique process identifier (an integer number) is used to identify process.**

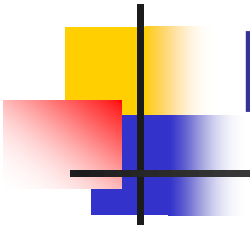
Processes Tree on Solaris





Process Creation

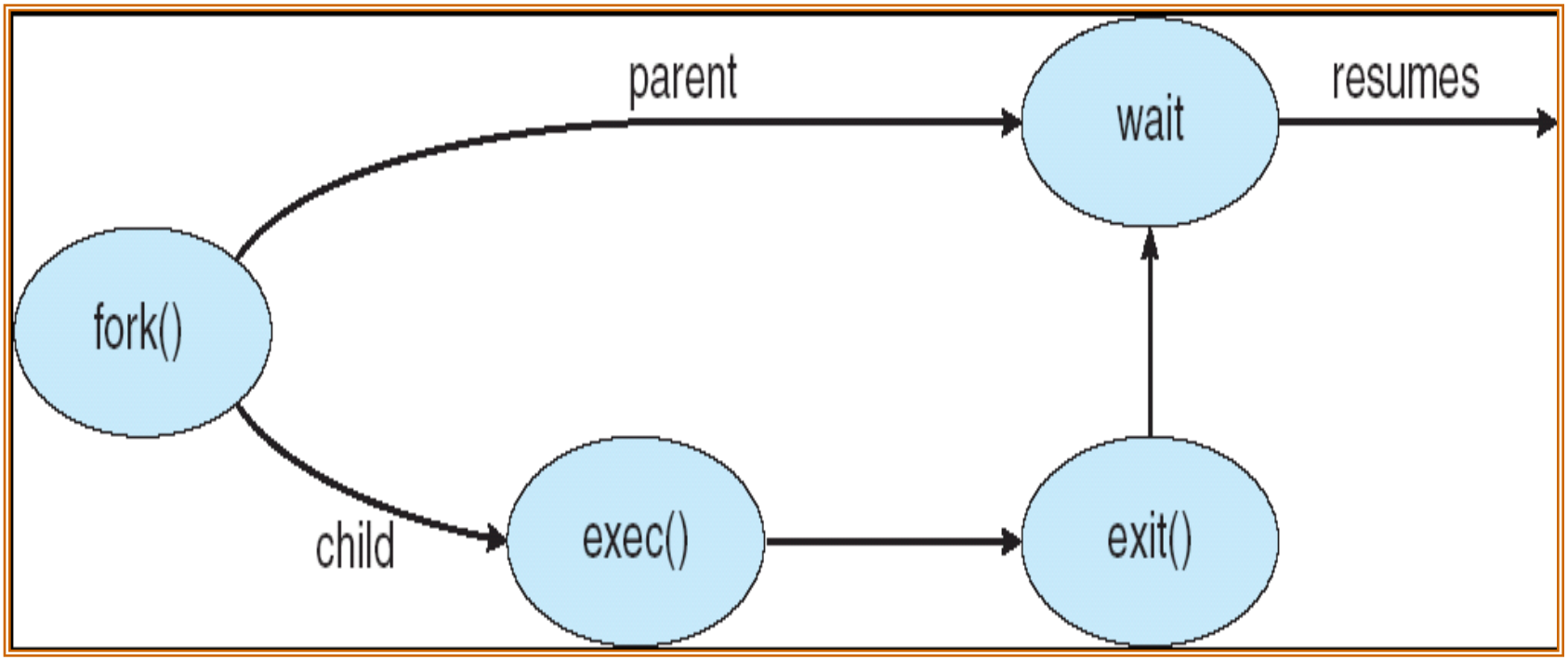
- Resource sharing
  - Parent and children share all resources.
  - Children share subset of parent's resources.
  - Parent and child share no resources.
- Execution
  - Parent and children execute concurrently.
  - Parent waits until children terminate.



Process Creation

- 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's memory space with a new program.

Process Creation (UNIX)



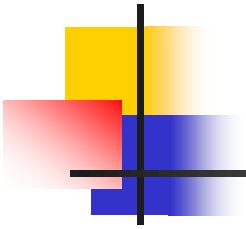
```
pid = fork();
if (pid < 0){/*error occured*/
    fprintf(stderr, “Fork failed”);
    exit(-1);}
else if(pid == 0){/*child process*/
    execlp(“/bin/ls”,”ls”,NULL);
}
else {/*parent process*/
    wait(NULL);
    printf(“Child Complete”);
    exit(0);
}
```

作业3

- 下列程序的输出是什么？

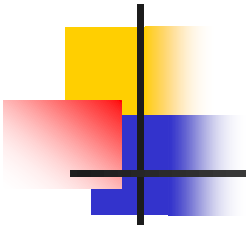
```
#include <sys/wait.h>
#include <sys/types.h>
#include <stdio.h>
#include <unistd.h>
#include <stdlib.h>
int value = 5;
int main()
{  pid_t pid;
   pid = fork();
   if (pid == 0) {   printf("child process, value1 : %d\n", value);
                     value += 15;
                     printf("child process, value2 : %d\n", value);}

    else if (pid > 0) { printf("parent process, value3 : %d\n", value);
                        wait(NULL);
                         printf("parent process, value4 : %d\n", value);
                         exit(0);   }
}
```



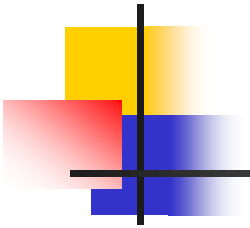
Process Termination

- **Process executes last statement and asks the operating system to delete it (exit).**
  - **Output data from child to parent (via wait).**
  - **Process's resources are deallocated by OS.**



Process Termination

- Parent may terminate execution of children processes (abort).
  - Child has exceeded allocated resources.
  - Task assigned to child is no longer required.
  - Parent is exiting.（并非所有OS都如此，UNIX）
    - Operating system does not allow child to continue if its parent terminates.
    - Cascading termination (级联终止).



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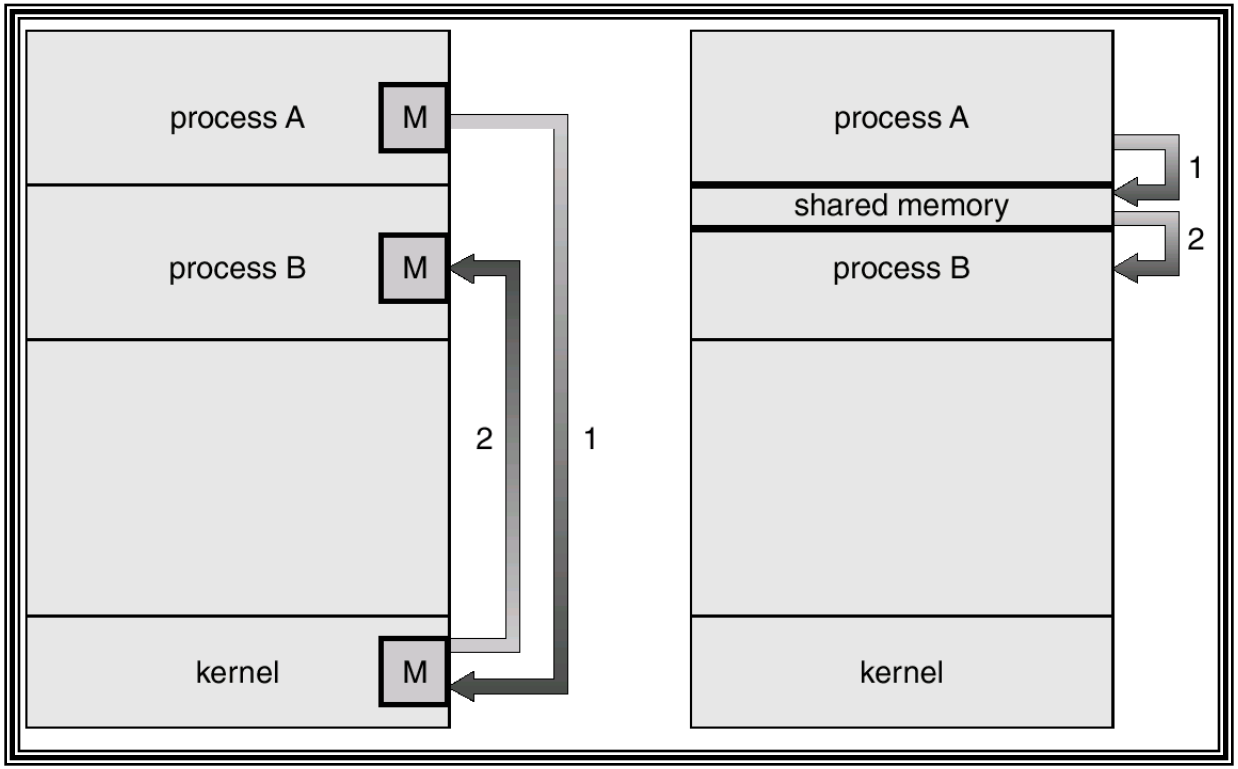
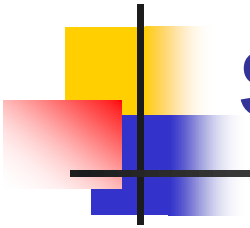
Interprocess Relationship

- ***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**

Interprocess Communication (IPC)

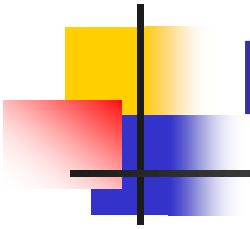
- **Communication may take place using either message passing or shared memory.**





Shared-Memory Systems

- Requiring communicating processes to establish a region of shared memory.
- A shared-memory region resides in the address space of the process creating the shared-memory segment.
- The processes are responsible for ensuring that they are not writing to the same location simultaneously.



Producer-Consumer Problem

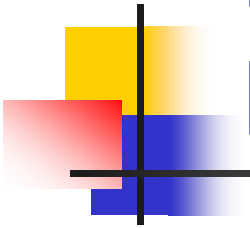
- **Paradigm for cooperating processes, *producer* process produces information that is consumed by a *consumer* process.**
  - ***unbounded-buffer* places no practical limit on the size of the buffer.**
  - ***bounded-buffer* assumes that there is a fixed buffer size.**

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



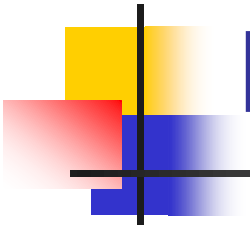
```
item nextProduced;

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;
}
```

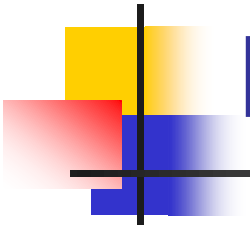


Discussion

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

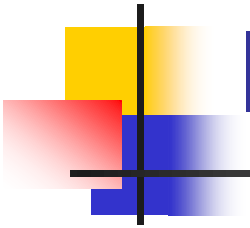
Why?

- *如何实现可使用缓冲的最大空间数为BUFFER_SIZE?*



Message-Passing Systems

- **MPS 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)**

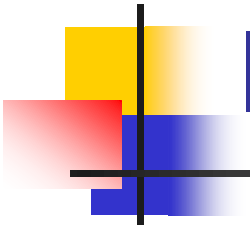


Implementation Questions

- 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?

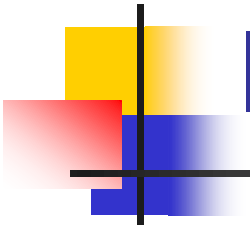
Direct Communication

- 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 bidirectional.



Indirect Communication

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



Indirect Communication

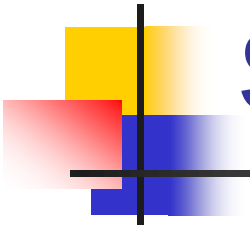
- **Operations**
  - **create a new mailbox**
  - **send and receive messages through mailbox**
  - **destroy a mailbox**
- **Primitives are defined as:**

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

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

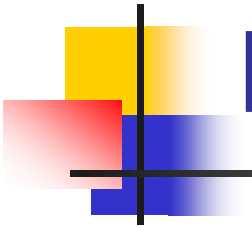
Indirect Communication

- **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.**



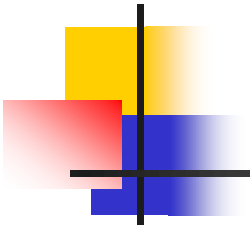
Synchronization

- 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.



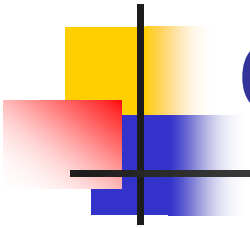
Buffering

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



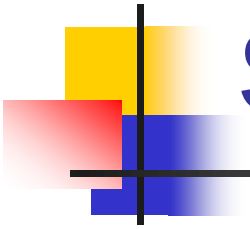
Outline

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



Client-Server Communication

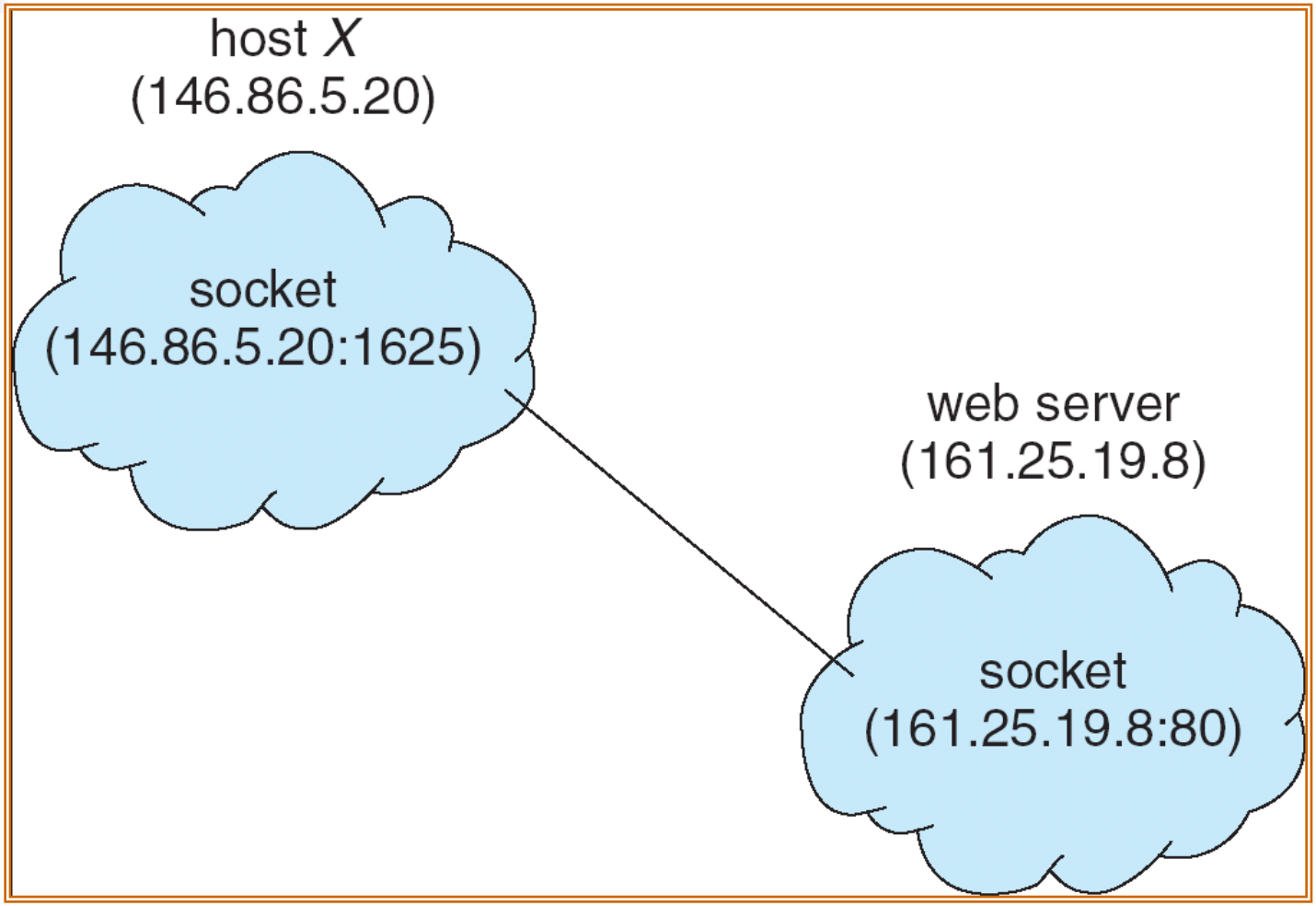
- **Sockets**
- **Remote Procedure Calls**
- **Remote Method Invocation (Java)**

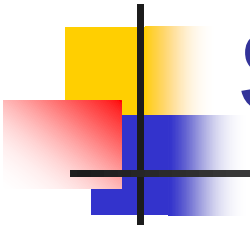


Sockets

- 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



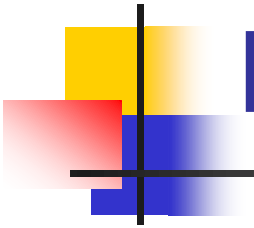


Socket Communication

- All connections must be unique.
- Common and Efficient
- A low-level form of communication between distributed processes
- Sockets allow only an unstructured stream of bytes to be exchanged between the communicating processes.

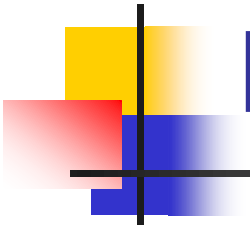
Remote Procedure Calls

- **Remote procedure call (RPC) abstracts procedure calls between processes on networked systems.**
- **Messages exchanged in RPC communication are well structured.**
- **Each message contains an identifier of the function and the parameters to pass to it.**
- **The function is executed and any output is send back to the requester in a separate message.**



Remote Procedure Calls

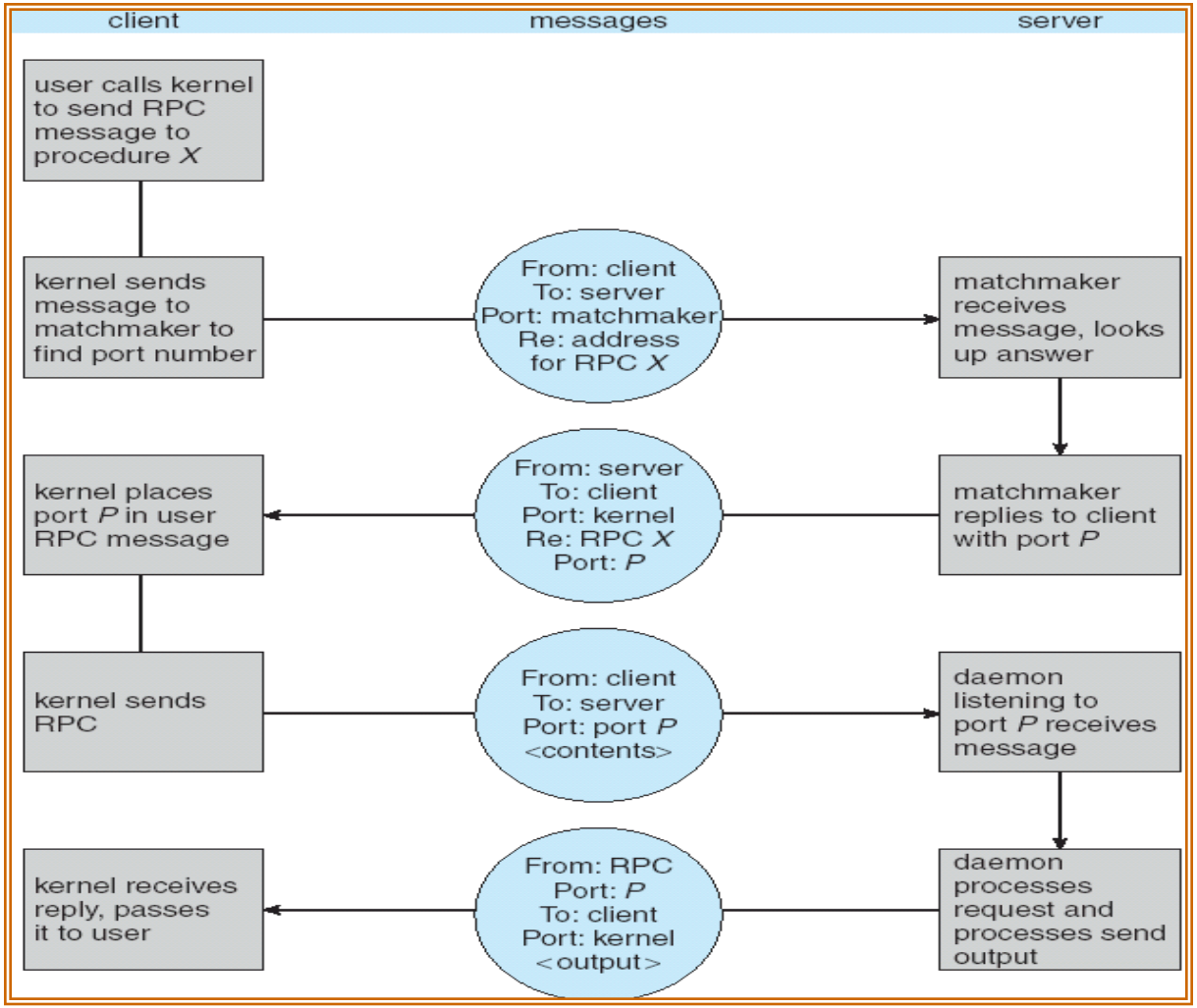
- **RPC allow a client to invoke a procedure on a remote host as it would invoke a procedure locally.**
- **Stubs – client-side proxy for the actual procedure on the server.**
- **The client-side stub locates the port on the server and *marshals* the parameters.**
- **The server-side stub receives this message, unpacks the marshaled parameters, and performs the procedure on the server.**



Remote Procedure Calls

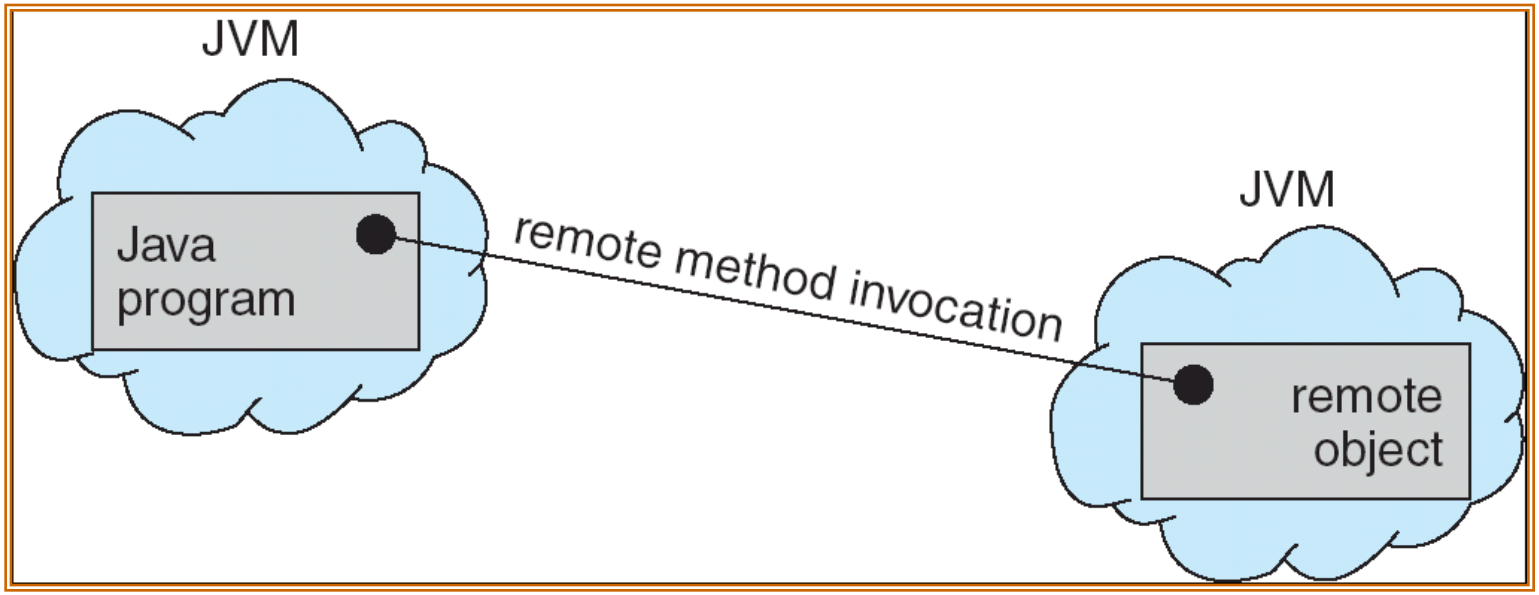
- **Some Issues**
  - **The differences in data representation on the client and server machines.**
    - **External Data Representation (XDR)**
  - **The semantics of a call**
    - **At most once: attaching a timestamp to each message.**
    - **Exactly once: ACK Messages**

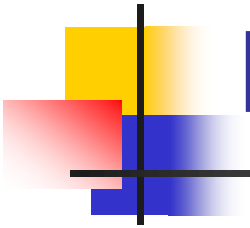
Execution of RPC



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.**





Remote Method Invocation

- **Differences between RPC and RMI**
  - **RPC only calls remote procedures or functions, and RMI supports invocation of methods on remote objects**
  - **The parameters to remote procedures are ordinary data structures in RPC, and that are objects in RMI**

Remote Method Invocation

- **RMI implements the remote object using stubs and skeletons.**
  - **Stub is a proxy for the remote object and resides with the client.**
  - **Skeleton resides with the server, receives the messages from stub and invokes the desired method on the server.**

Marshalling Parameters