Processes

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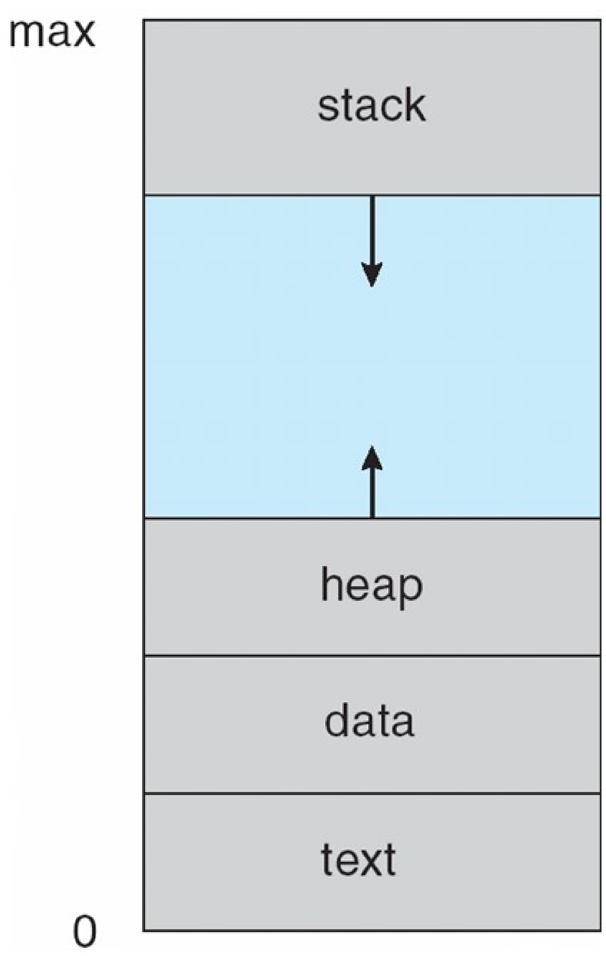
Process Concept

- Process – a program in execution
- An operating system executes a variety of programs:
  - Batch system – jobs
  - Time-shared systems – user programs or tasks
  - All these activities are *processes*
- Textbook uses the terms *job* and *process* almost interchangeably

The Process

- Multiple parts
  - The program code, also called **text section**
  - Current activity including **program counter**, processor registers
  - **Data section** containing global variables
  - **Stack** containing temporary data
    - Function parameters, return addresses, local variables
  - **Heap** containing memory dynamically allocated during run time



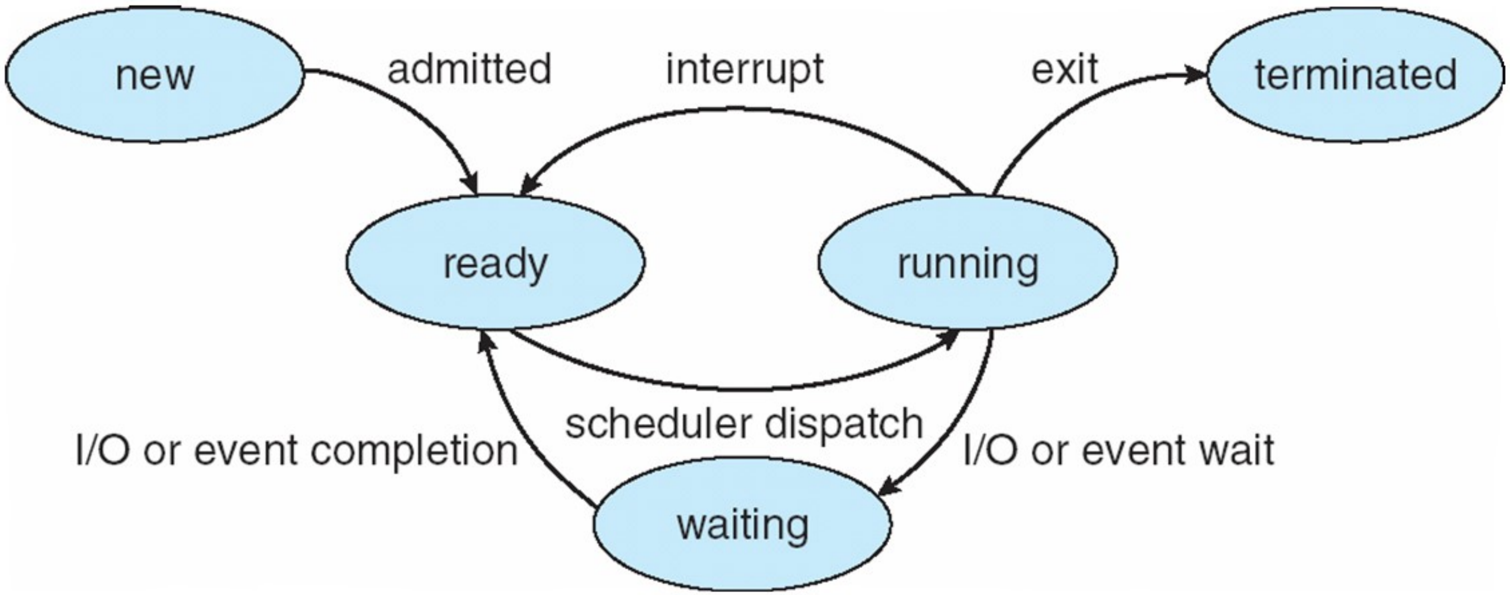
The Process (Cont.)

- What is the difference between program and process?
  - Program is passive entity, process is active
  - Program becomes process when the executable file is 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 State

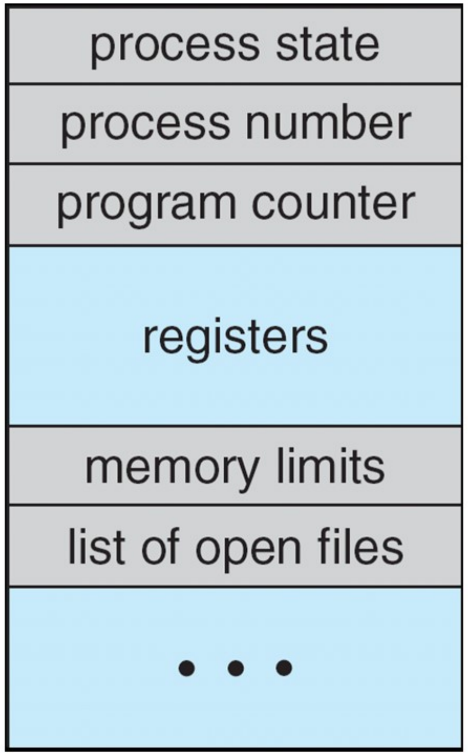
- As a process executes, it changes *state*
  - **new**: The process is being created
  - **running**: Instructions are being executed
  - **waiting**: The process is waiting for some event to occur
  - **ready**: The process is waiting to be assigned to a processor
  - **terminated**: The process has finished execution



Process Control Block (PCB)

Information associated with each process

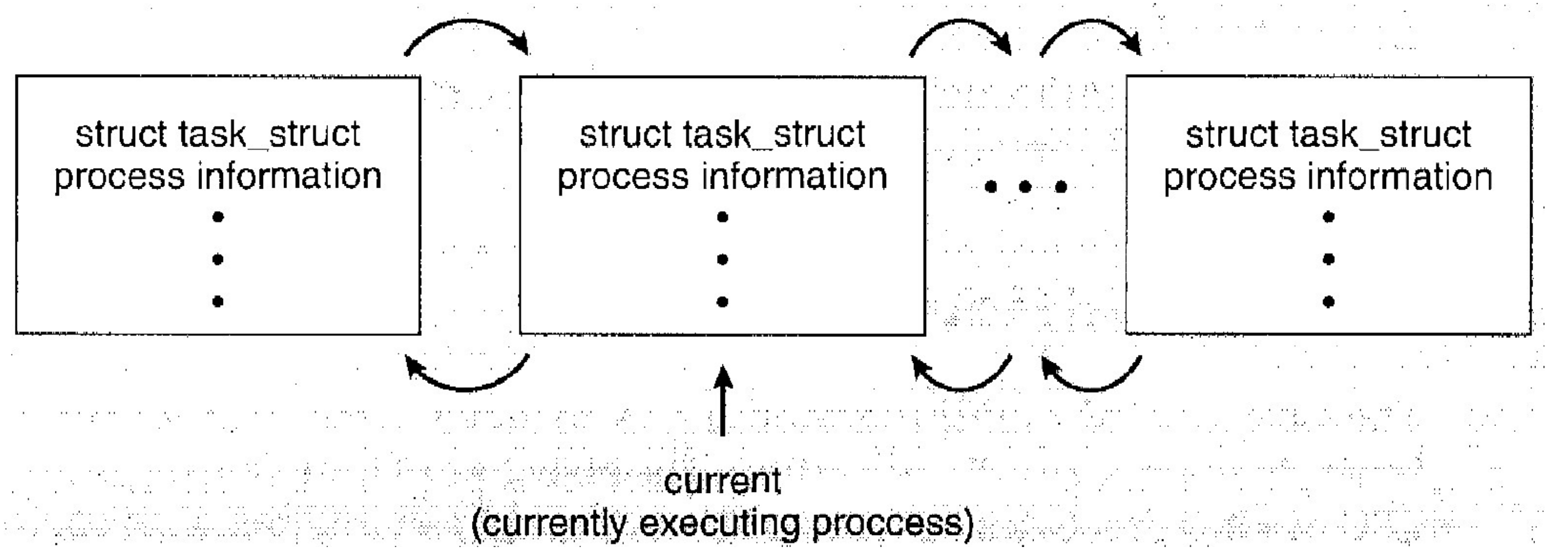
- Process state
- Process number
- Program counter
- CPU registers
- CPU scheduling information
- Memory-management information
- Accounting information
- I/O status information



Process Representation in Linux

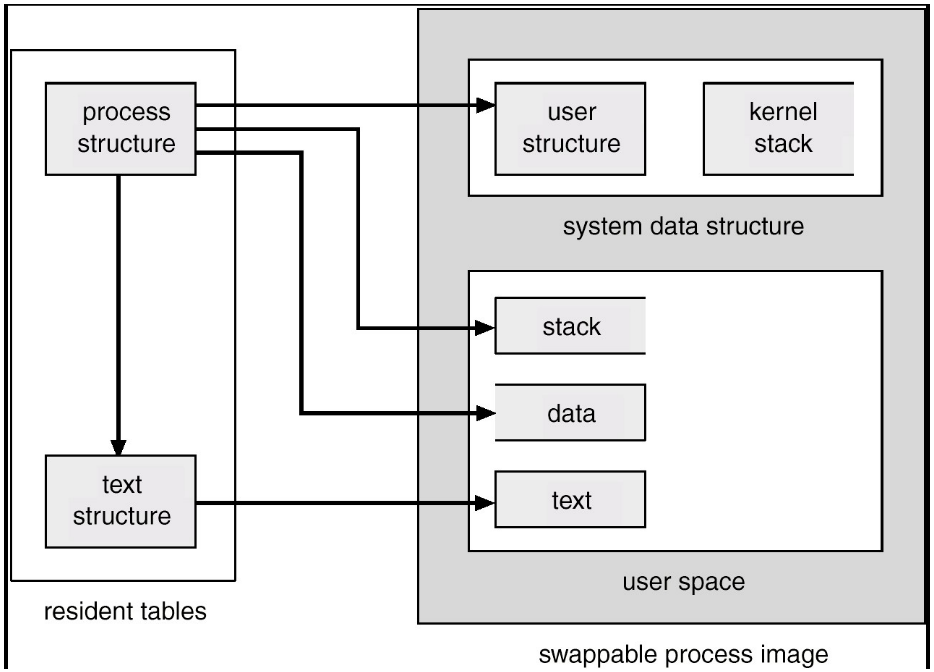
- Represented by the C structure **task_struct**

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



PCBs in UNIX

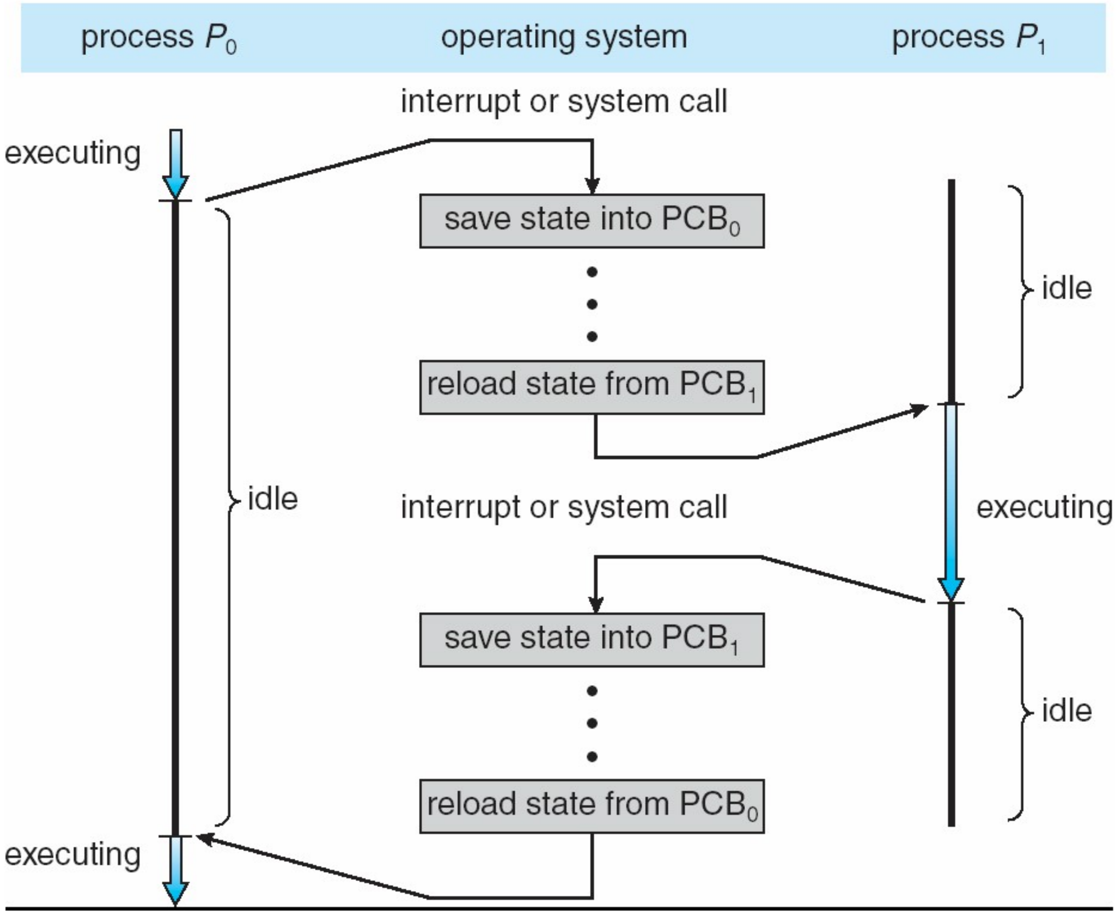
- The PCB is the box labeled **process structure**, but the **user structure** maintains some of the information as well (only required when the process is resident).



PCBs in Windows NT

- Information is scattered in a variety of objects.
  - Executive Process Block (**EPROCESS**)
  - Kernel Process Block (**KPROCESS**)
  - Process Environment Block (**PEB**)

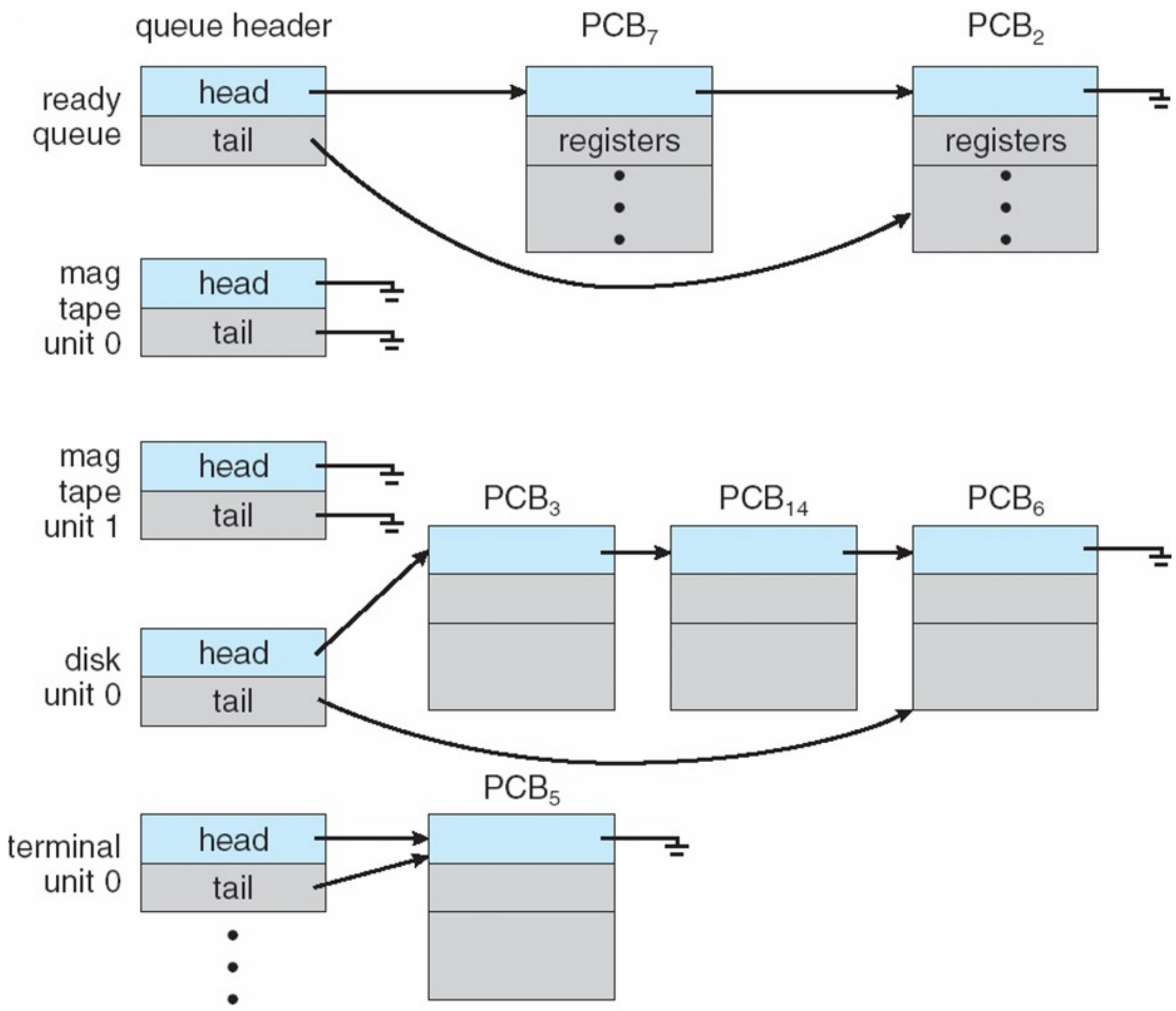
CPU Switch From Process to Process



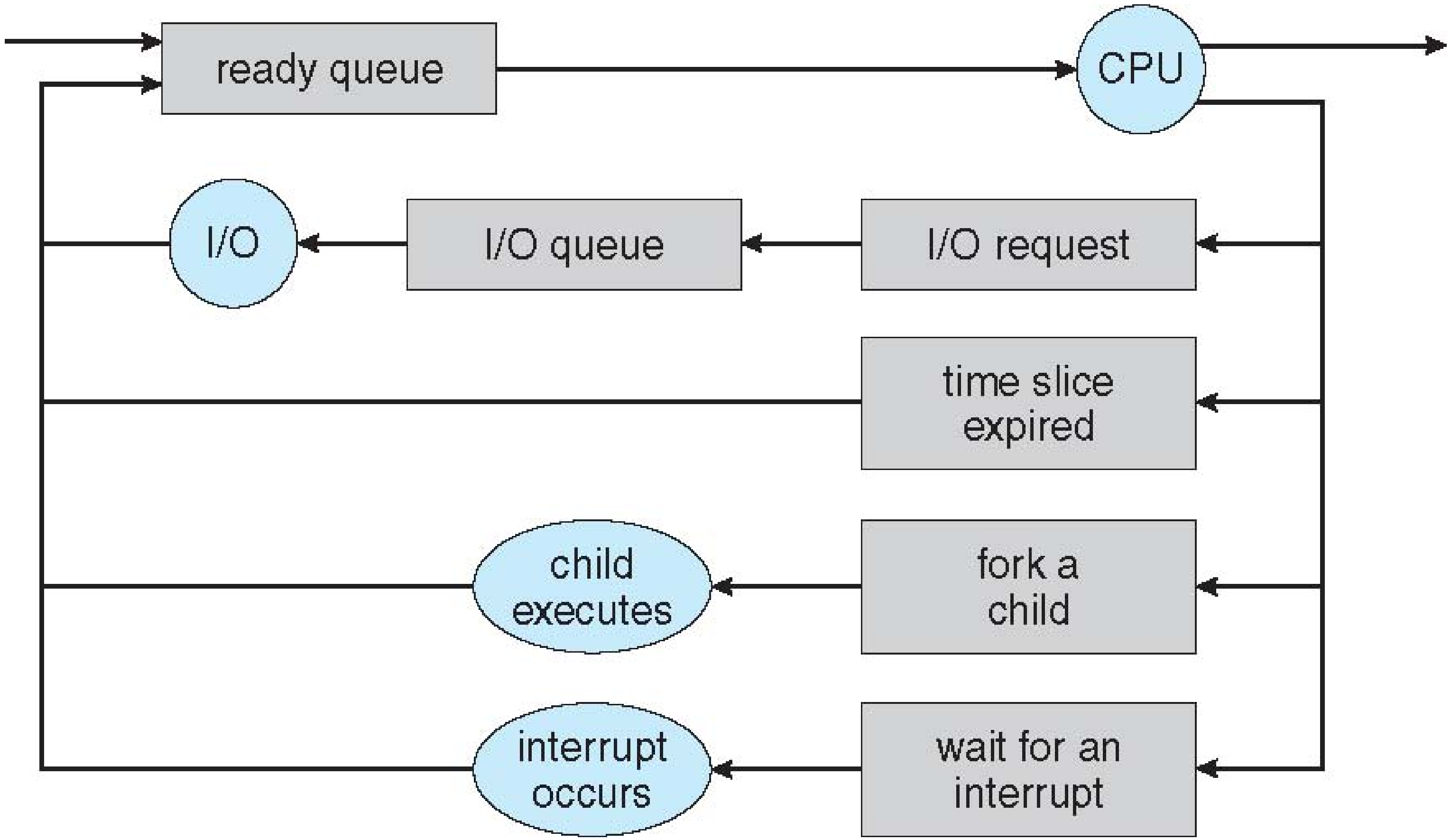
Process Scheduling

- Maximize CPU use, quickly switch processes onto CPU for time sharing
- **Process scheduler** selects among available processes for next execution on CPU
- Maintains **scheduling queues** of processes
  - **Job queue** – set of all processes in the system
  - **Ready queue** – set of all processes residing in main memory, ready and waiting to execute
  - **Device queues** – set of processes waiting for an I/O device
  - Processes migrate among the various queues

Ready Queue And Various I/O Device Queues



Representation of Process Scheduling



Schedulers

- **Long-term scheduler** (or job scheduler) – selects which processes should be brought into the ready queue

- **Short-term scheduler** (or CPU scheduler) – selects which process should be executed next and allocates CPU
  - Sometimes the only scheduler in a system

Schedulers (Cont.)

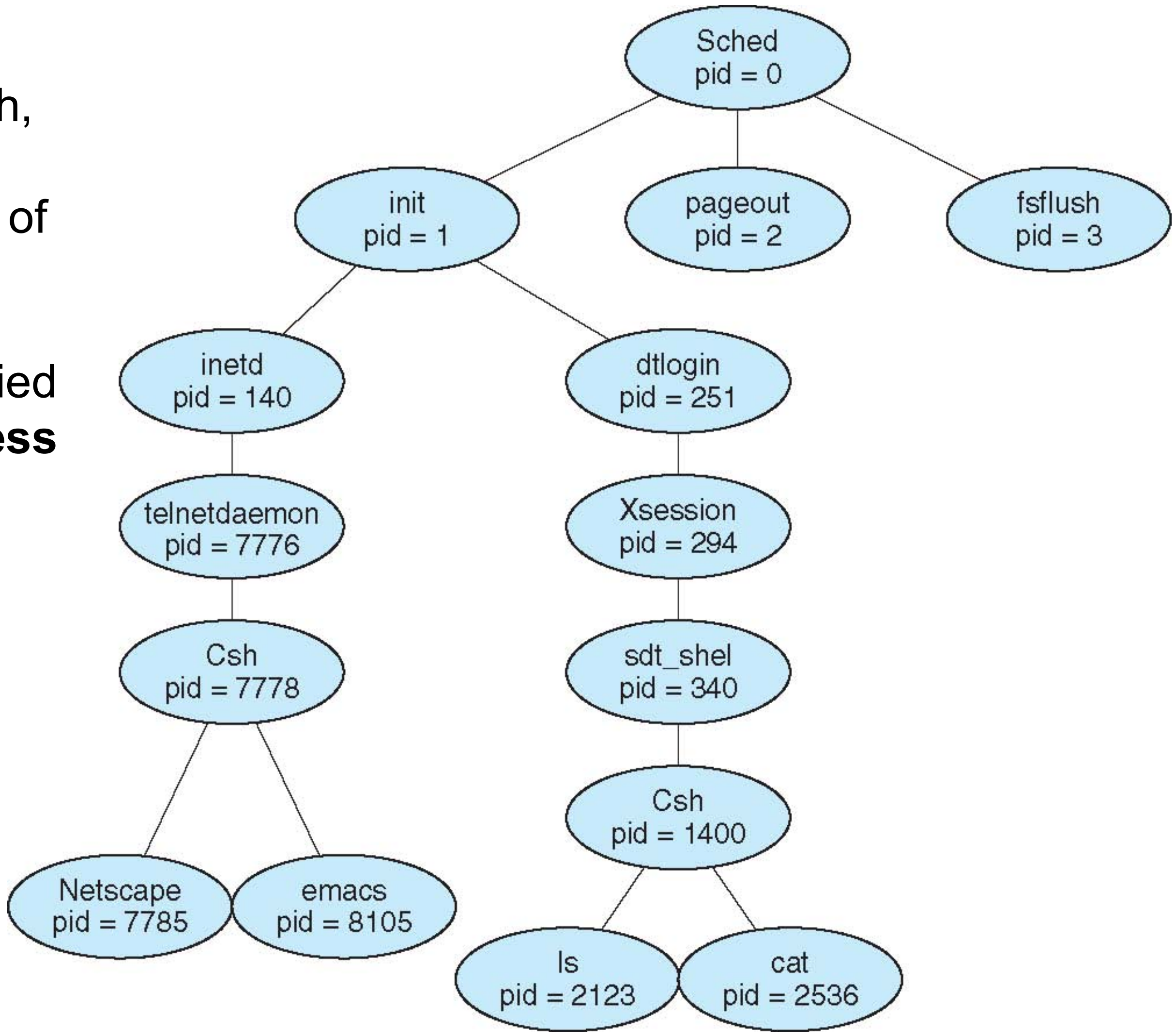
- Short-term scheduler is invoked very frequently (milliseconds) $\Rightarrow$ (must be fast)
- Long-term scheduler is invoked very infrequently (seconds, minutes) $\Rightarrow$ (may be slow)
- The long-term scheduler controls the *degree of multiprogramming*
- Processes can be described as either:
  - **I/O-bound process** – spends more time doing I/O than computations, many short CPU bursts
  - **CPU-bound process** – spends more time doing computations; few very long CPU bursts

Operations on Processes

- Process Creation
- Process Termination

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**)



Process Creation (Cont.)

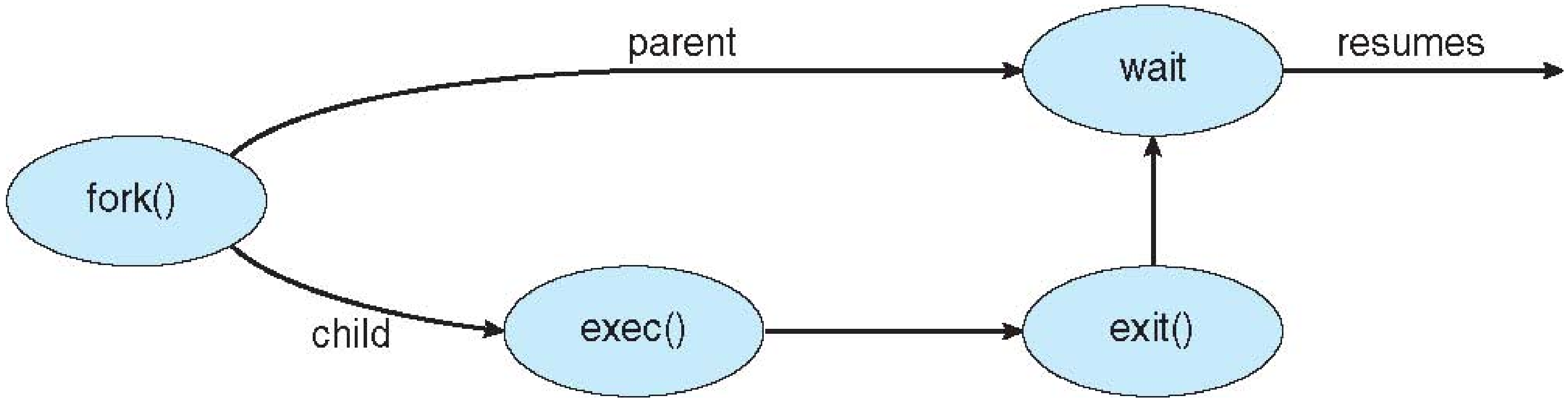
- Resource sharing
  - Parent and children share all resources
  - Children share subset of parent's resources
  - Parent and child share no resources
- Initialization data
- Execution
  - Parent and children execute concurrently
  - Parent waits until children terminate
- Address space
  - Child duplicate of parent
  - Child has a program loaded into it

C Program Forking Separate Process

- 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

```
#include <sys/types.h>
#include <stdio.h>
#include <unistd.h>
int main()
{
    int i = 1;
    pid_t  pid;
    /* fork another process */
    pid = fork();
    if (pid < 0) { /* error occurred */
          fprintf(stderr, "Fork Failed");
          return 1;
    }
    else if (pid == 0) { /* child process */
          printf( "This is child.");
    }
    else { /* parent process */
          /* parent will wait for the child */
          wait (NULL);
          printf ("Child Complete.");
    }
    return 0;
}
```

Process Execution



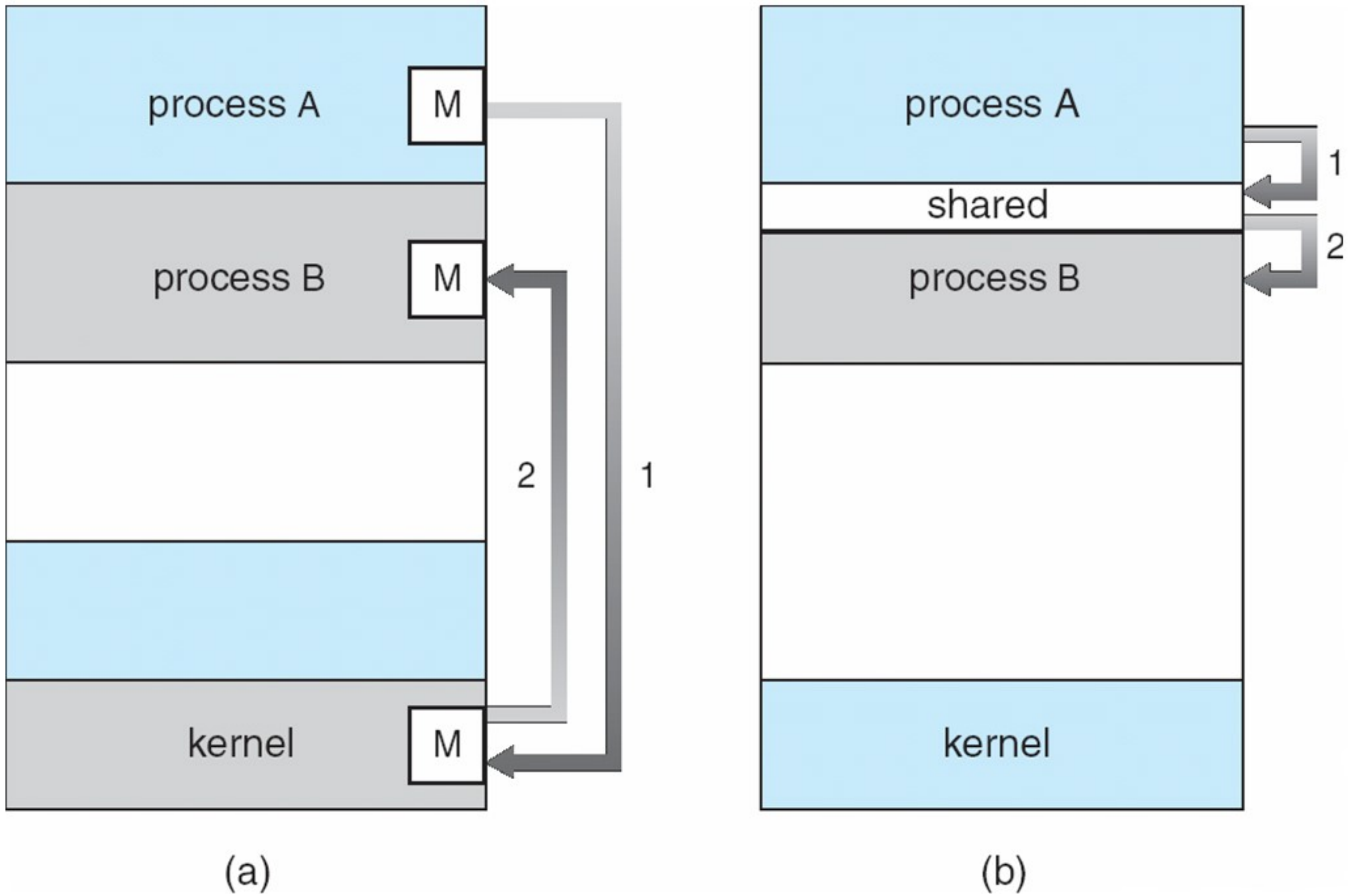
Process Termination

- 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**

Interprocess Communication

- Processes within a system may be **independent** or **cooperating**
- Cooperating process can affect or be affected by other processes, including sharing data
- Reasons for cooperating processes:
  - Information sharing
  - Computation speedup
  - Modularity
  - Convenience
- Cooperating processes need **InterProcess Communication** (**IPC**)
- Two models of IPC
  - Shared memory
  - Message passing

Communications Models



Message Passing

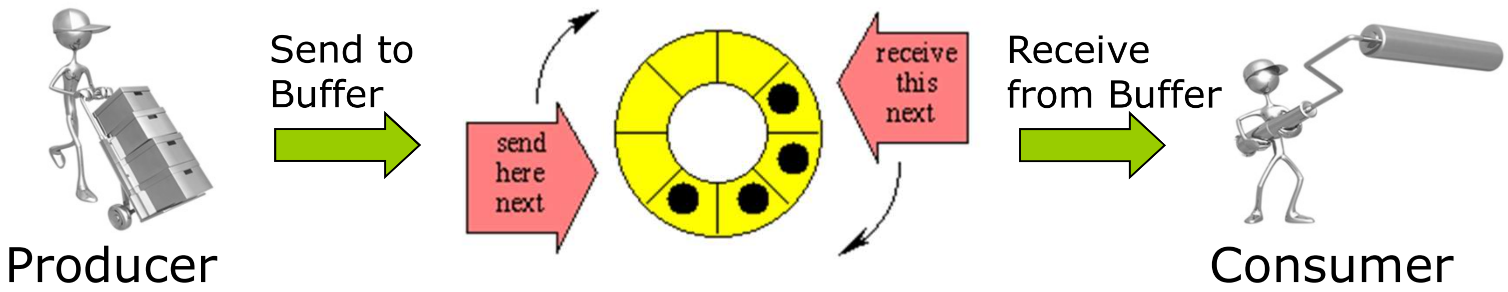
Shared Memory

Interprocess Communication – Shared Memory

- A region of memory that is shared by cooperating processes is established.
- Processes can then exchange information by reading and writing data to the shared region.

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 – Shared-Memory Solution

Producer

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

Consumer

```
while (true) {
  while (in == out)
          ; // do nothing
    // remove an item from the buffer
    item = buffer[out];
    out = (out + 1) % BUFFER_SIZE;
       return item;
}
```

Bounded-Buffer – Shared-Memory Solution

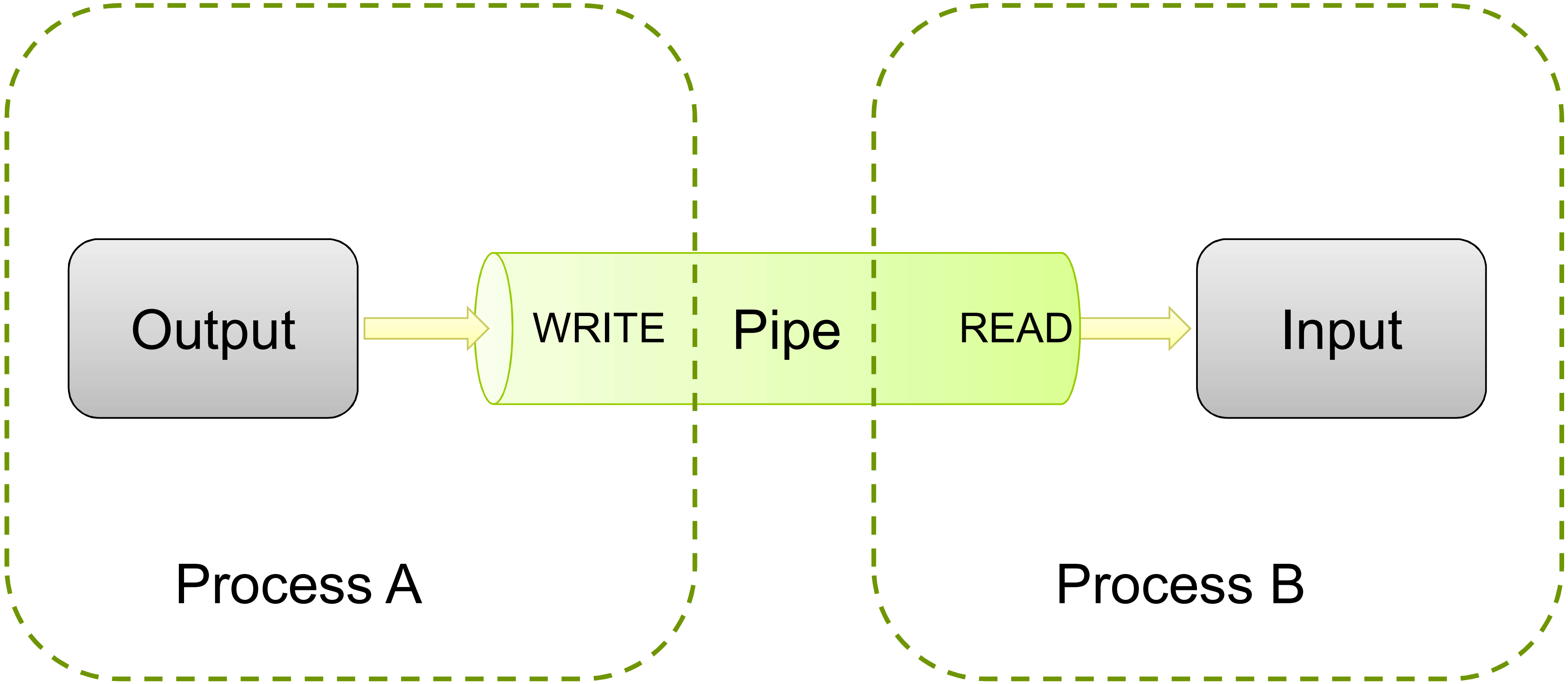
- Weakness:
  - Busy waiting
  - The solution allows only BUFFER_SIZE-1 elements at the same time

- Popquiz:
  - Rewrite the previous processes to allow BUFFER_SIZE items in the buffer at the same time

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 in fact unidirectional
- Require parent-child relationship between communicating processes

Ordinary Pipe



Using Pipe – Part 1

- First, create a pipe and check for errors

```
int mypipe[2];
if (pipe(mypipe)) {
    fprintf (stderr, "Pipe failed.\n");
    return -1;
}
```

mypipe[0]	read-end
mypipe[1]	write-end

- Second, fork your threads
- Third, close the pipes you don't need in that thread
  - reader should close(mypipe[1]);
  - writer should close(mypipe[0]);

Using Pipe – Part 2

- Fourth, the writer should write the data to the pipe
  - write(mypipe[1],&c,1);
- Fifth, the reader reads from the data from the pipe:
  - while (read(mypipe[0],&c,1)>0) {

    //do something, loop will exit when WRITER closes pipe

    }
- Sixth, when writer is done with the pipe, close it
  - close(mypipe[1]); //EOF is sent to reader
- Seventh, when reader receives EOF from closed pipe, close the pipe and exit your polling loop
  - close(mypipe[0]); //all pipes should be closed now

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

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; The processes need to know only each other's identity to communicate
  - A link is associated with exactly one pair of communicating processes
  - Between each pair there exists exactly one link

Indirect Communication

- Messages are directed to and received from mailboxes (also referred to as ports)
  - Each mailbox has a unique id
  - Processes can communicate only if they share a mailbox
- Primitives are defined as:

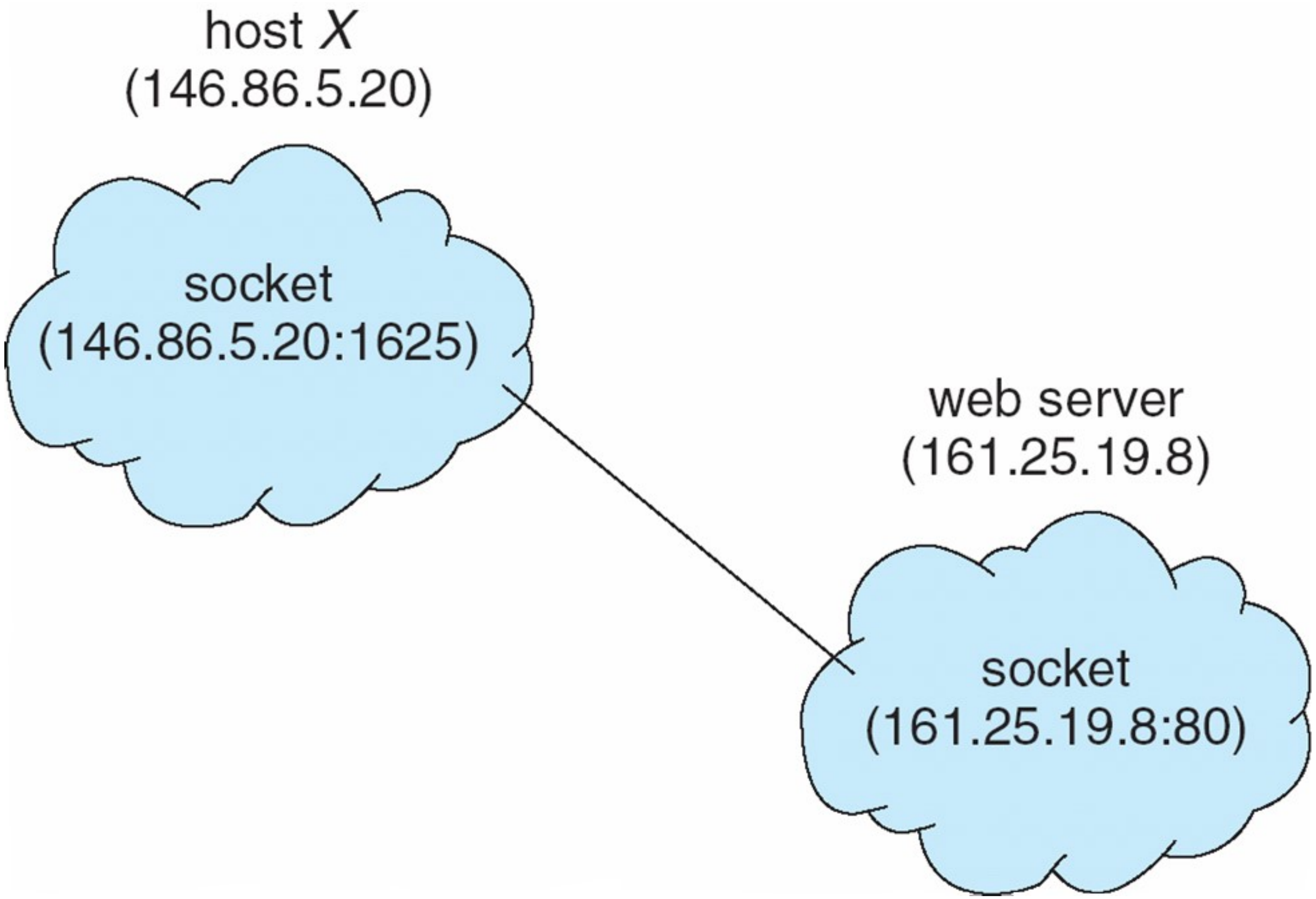
  send(*A, message*) – send a message to mailbox A

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

Sockets

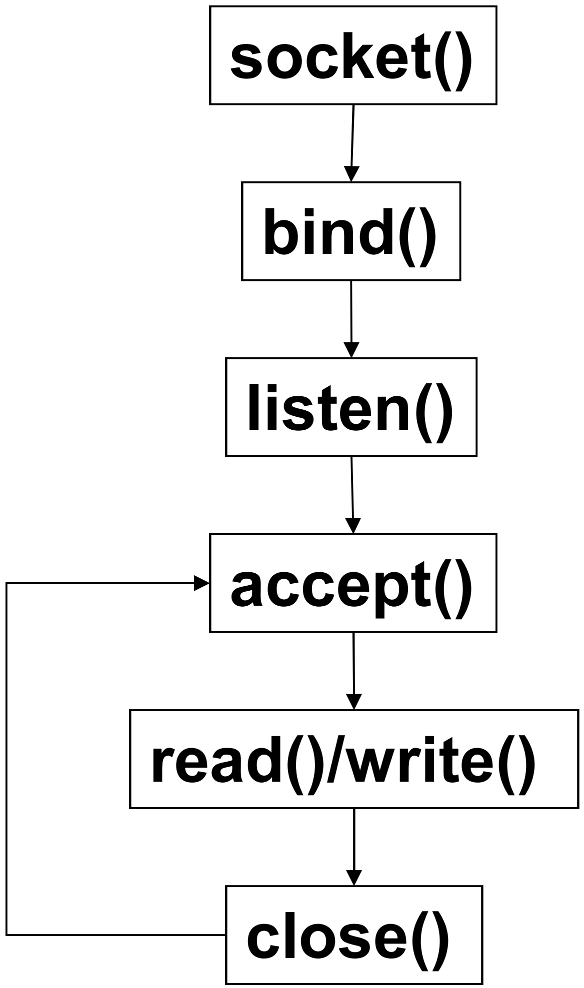
- A **socket** is defined as an *endpoint for communication*
- Concatenation of IP address and port
- The socket **161.25.19.8:1625** refers to port **1625** on host **161.25.19.8**
- Communication consists between a pair of sockets

Socket Communication



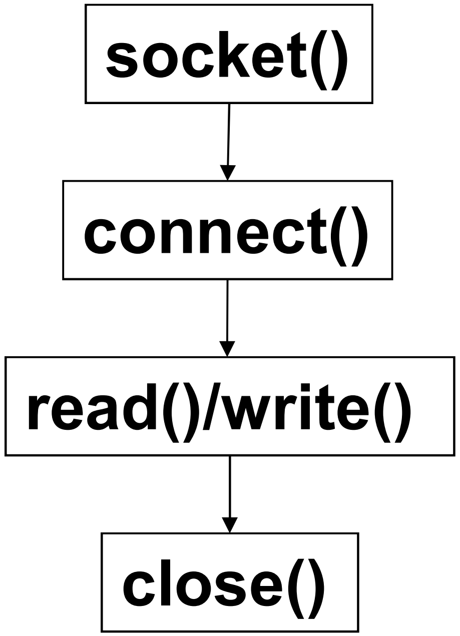
Steps to Create Server Side

1. Create a socket with the socket() system call
2. Bind the socket to an address using the bind() system call.
3. Listen for connections with the listen() system call
4. Accept a connection with the accept() system call (This call typically blocks until a client connects with the server)
5. Send and receive data with read() and write() system calls
6. Close connection with close() system call

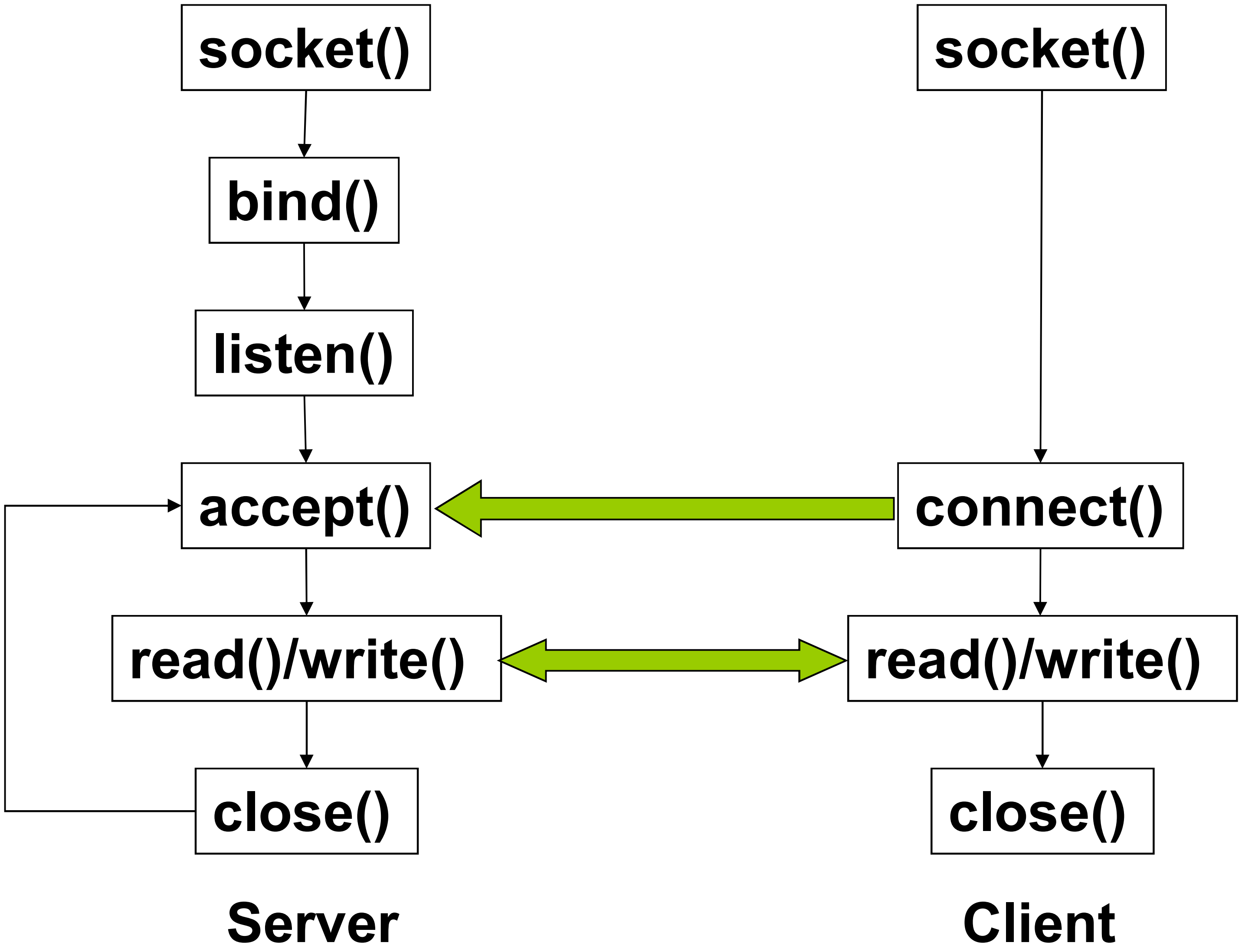


Steps to Create Client Side

1. Create a socket with the socket() system call
2. Connect the socket to the address of the server using the connect() system call
3. Send and receive data with read() and write() system calls.
4. Close the socket with close() system call



Interaction Between Client and Server



Internet Domain Socket

- IP address:
  - 32 bits (IPv4) or 128 bits (IPv6)
  - C/S work on same host: just use localhost
- Port
  - 16 bit unsigned integer
  - Lower numbers are reserved for standard services
- Transport layer protocol: TCP / UDP

Headers

- #include <stdio.h>
- #include <stdlib.h>
- #include <string.h>
- #include <sstream>
- #include <unistd.h>
- #include <sys/types.h>
  - Definitions of a number of data types used in system calls
- #include <sys/socket.h>
  - Definitions of structures needed for sockets
- #include <netinet/in.h>
  - Constants and structures needed for internet domain addresses

Creating Socket

```
int sockfd
sockfd = socket(AF_INET, SOCK_STREAM, 0);
if (sockfd < 0) {
    perror("ERROR opening socket");
    exit(2);
}
```

- AF_INET: address domain
- SOCK_STREAM: stream socket, characters are read in a continuous stream as if from a file or pipe
- 0: protocol. The operating system chooses the most appropriate protocol. It will choose TCP for stream sockets.

Binding Socket

```
struct sockaddr_in serv_addr;
serv_addr.sin_family = AF_INET;
serv_addr.sin_addr.s_addr = htonl(INADDR_ANY);
serv_addr.sin_port = htons(BASIC_SERVER_PORT);
bind(sockfd, (sockaddr*) &serv_addr, sizeof(serv_addr));
    //error check
```

- INADDR_ANY: get IP address of the host automatically
- htonl, htons: data format conversion
- bind(): binds a socket to an address

Listening and Accepting Connection

```
listen(sockfd, 5);
```

- listen(): allows the server to listen on the socket for connections, with a backlog queue of size 5.

```
int client_sockfd;
struct sockaddr_in client_addr;
int len = sizeof(client_addr);
client_sockfd = accept(sockfd, (sockaddr *) &client_addr,
&len);
    //error check
```

- accept(): block process until a client connects to the server. It returns a new socket file descriptor, if the connection is created.

Reading and Writing

```
char buf[1024];
int nread = read(client_sockfd, buf, 1024);
```

read(): reads from the socket

```
write(client_sockfd, buf, len);
```

write(): writes to the socket

```
close(client_sockfd);
```

close(): closes the socket

Connecting A Client to A Server

```
int sockfd;
sockfd = socket(AF_INET, SOCK_STREAM, 0);
    // error check
struct sockaddr_in serv_addr;
struct hostent *host;
serv_addr.sin_family = AF_INET;
host = gethostbyname(argv[1]);
    // error check
memcpy(&serv_addr.sin_addr.s_addr, host->h_addr,
    host->h_length);
serv_addr.sin_port = htons(BASIC_SERVER_PORT);
connect(sockfd, (sockaddr *) &serv_addr, sizeof(serv_addr))
    // error check
```

Homework

- Reading
  - Chapter 3