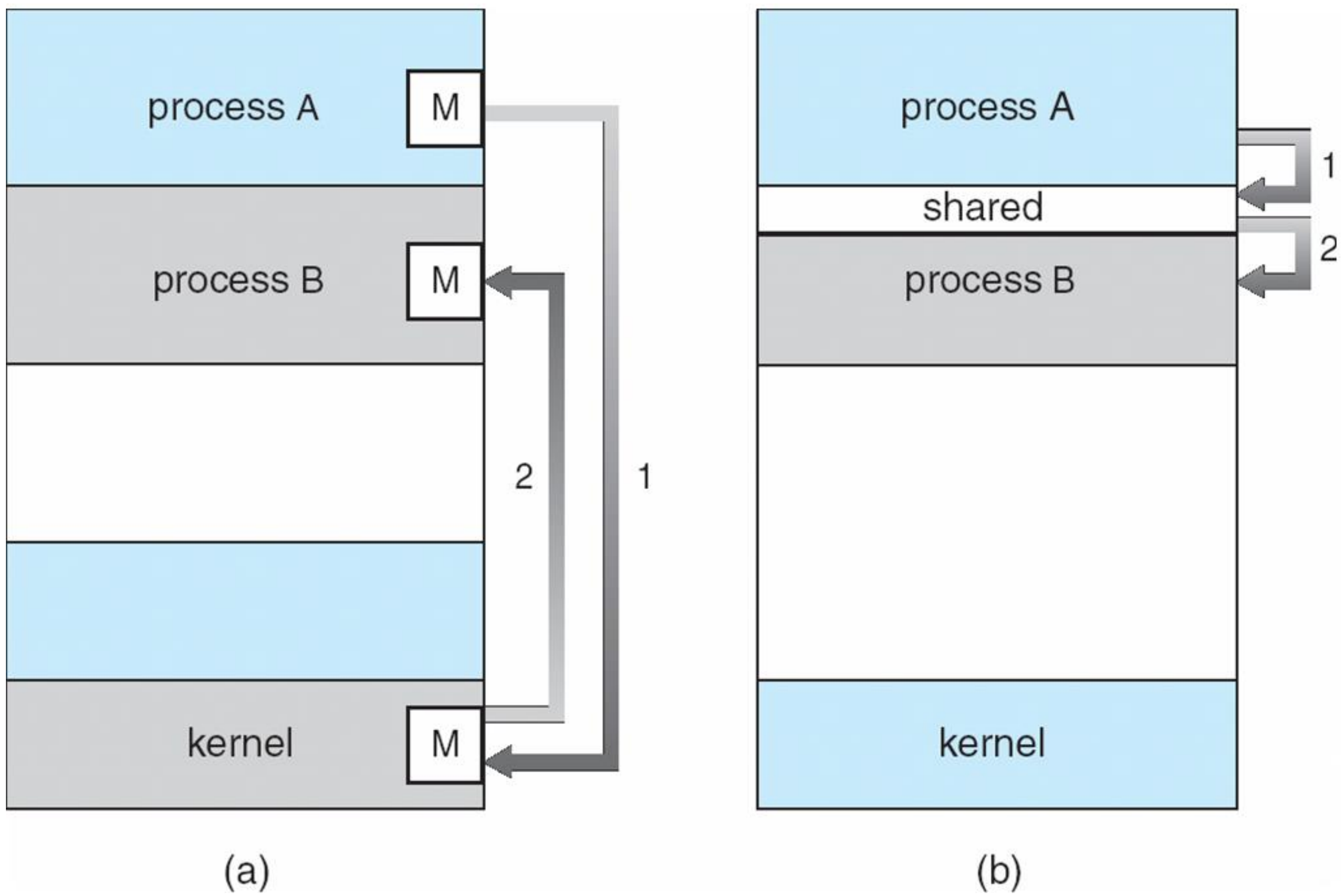
Process Management (II)

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 **inter-process communication** (**IPC**)

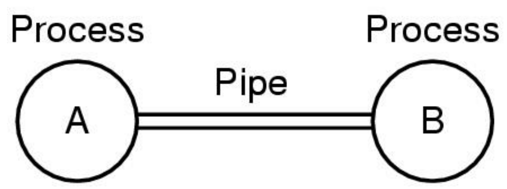
Communications Models



Message Passing Shared Memory

Example of Message Passing: Unix Pipes

- Pipe sets up communication channel between two (related) processes.

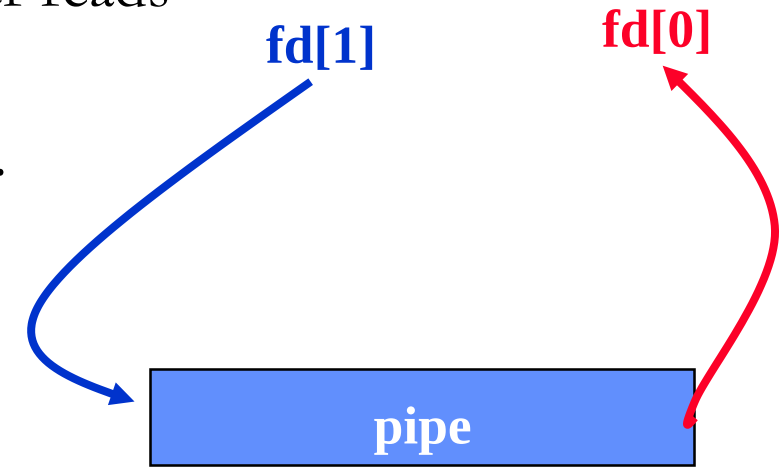


Two processes connected by a pipe

Unix Pipes

- One process writes to the pipe, the other reads from the pipe.
- Similar to reading from/writing to a file.
- System call:

```
int fd[2] ;
pipe(fd) ;
```

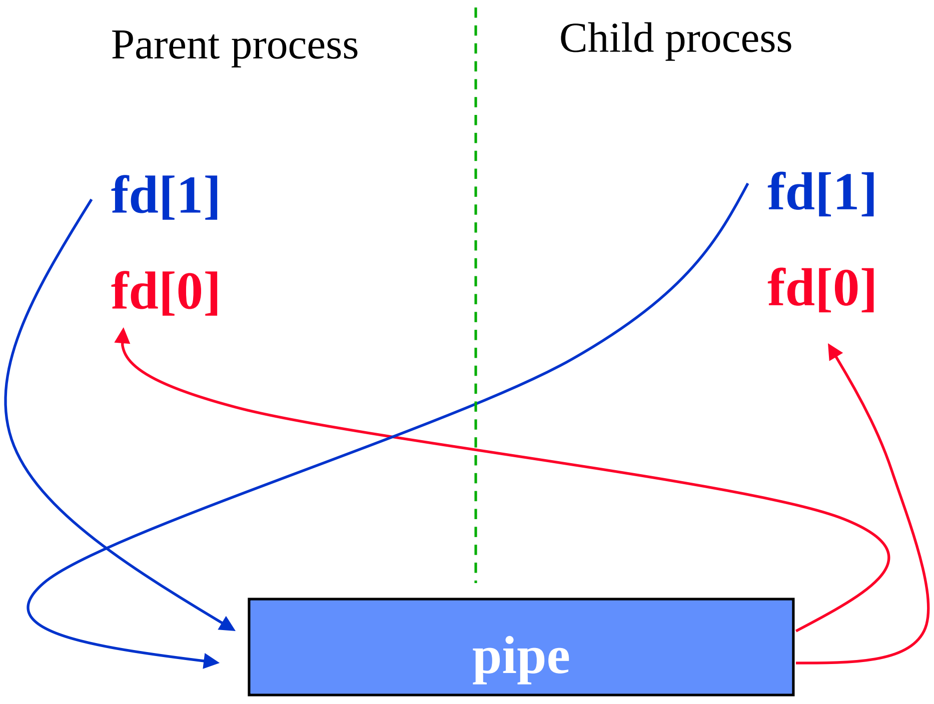


fd[0] now holds descriptor to read from pipe

fd[1] now holds descriptor to write into pipe

A Simple Example

```
#include <unistd.h>
#include <fcntl.h>
#include <stdio.h>
char *message = "This is a message!!!" ;
main()
{  char buf[1024] ;
   int fd[2];
   pipe(fd);    /*create pipe*/
   if (fork() != 0) { /* I am the parent */
      write(fd[1], message, strlen (message) + 1) ;
      }
   else { /*Child code */
      read(fd[0], buf, 1024) ;
      printf("Got this from parent!!: %s\n", buf) ;
      }
}
```



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
- Read in pipe is blocking

Limitations of Pipes

- Processes using a pipe must come from a common ancestor
  - e.g., parent and child; siblings
- Pipes are not permanent
  - disappearing when the process terminates

Named Pipes (Called FIFO in UNIX)

- Similar to pipes, but with some advantages
  - A FIFO can be created separately from the processes that will use it
  - FIFOs look like files
    - Having an owner, size, access permissions
    - Permanent until deleted with rm

Creating a FIFO

- Using unix command line (calling system program):

  $mkfifo <FIFO-NAME>

  e.g., $mkfifo fifo1

- Using C program

  ```
  #include <sys/types.h>
  #include <sys/stat.h>
  int mkfifo(const chair *pathname, mode_t mode);
  ```

  - pathname: path-name of the FIFO
  - mode: permission. It could be any combination of S_IRUSR (owner read), S_IWUSR (owner write), S_IRGRP (owner's group read), S_IWGRP (group write), S_IROTH (other users read), S_IWOTH (other write)

  e.g., mkfifo("fifo1", S_IRUSR|S_IWUSR); //create FIFO fifo1 for owner's processes' communication

Open an Existing FIFO

```
#include <sys/types.h>
#include <sys/stat.h>
#include <fcntl.h>
int open( const chair *pathname, mode_t mode );
```

- pathname: path-name of the FIFO
- open a FIFO to write: open (FIFOName, O_WRONLY);
- open a FIFO to read: open (FIFOName, O_RDONLY);

- After a FIFO has been open, read/write operations can be performed on it like with the pipe.

POSIX Shared Memory

- Process first creates shared memory segment

```
segment_id = shmget(IPC_PRIVATE, size, S_IRUSR |
  S_IWUSR); //a new shared memory segment is created
segment_id = shmget(key, size,
  S_IRUSR|S_IWUSR|IPC_CREAT); //if a SM segment
  associated with key exists, its ID is returned;
  otherwise, a new SM segment is created
```

- Process wanting access to that shared memory must attach to it

```
Shared_memory = (char *) shmat(id, NULL, 0);
```

- Now the process could write to the shared memory

```
sprintf(shared_memory, "Writing to shared memory");
```

- When done a process can detach the shared memory from its address space

```
shmdt(shared_memory);
```

A simple program

```
#include <stdio.h>
#include <sys/shm.h>
#include <sys/stat.h>
int main( ){
    int segment_id;
    char *shared_memory;
    const int size = 4096;
    segment_id = shmget(IPC_PRIVATE, size, S_IRUSR|S_IWUSR);
    shared_memory=(char *)shmat(segment_id, NULL,0);
    sprintf(shared_memory, "Hi there!");
    shmdt(shared_memory);
    shmctl(segment_id,IPC_RMID,NULL); //remove the shared memory block
}
```

A simple program (cont.): Sharing a memory between parent and child processes

```
#include <stdio.h>
#include <sys/shm.h>
#include <sys/stat.h>
int main( ){
    int segment_id;
    char *shared_memory;
    const int size = 4096;
    segment_id = shmget(IPC_PRIVATE, size, S_IRUSR|S_IWUSR);
    shared_memory=(char *)shmat(segment_id, NULL,0);
    if (fork( ) == 0){
        sprintf(shared_memory, "Hi, this is the child!");
        shmdt(shared_memory);
        exit(0);
    }else{
        wait(NULL );
        printf("%s\n", shared_memory);
        shmdt(shared_memory);
        shmctl(segment_id,IPC_RMID,NULL); //remove the shared memory
    } …
```

Another example: Sharing a memory between two processes

```
#define KEY 9876
int main( ){
    int segment_id;
    char *shared_memory;
    const int size = 4096;
    segment_id = shmget(KEY, size, S_IRUSR|S_IWUSR|IPC_CREAT);
    shared_memory=(char *)shmat(segment_id, NULL,0);
    sprintf(shared_memory, “Hi, this is the child!”);
    shmdt(shared_memory); }
```

```
#define KEY 9876
int main( ){
    int segment_id;
    char *shared_memory;
    const int size = 4096;
    segment_id = shmget(KEY, size, S_IRUSR|S_IWUSR|IPC_CREAT);
    shared_memory=(char *)shmat(segment_id, NULL,0);
    printf(“%s\n”, shared_memory);
    shmdt(shared_memory);}
```

Unix/Linux Signals

Signals are software interrupts

- Examples: A user hitting ctrl+c; a process sending a signal to kill another process.

In Linux, signals are defined at /usr/include/bits/signum.h, and every signal has a name that begins with characters SIG:

- SIGINT : when a user presses ctrl+c.
- SIGKILL
- SIGUSR1, SIGUSR2: you are free to define what they mean

Unix/Linux Signals

How to send a signal to a process?

- System program kill

  example: >kill -9 1000   //kill process with ID 1000

- System call kill

```
#include <sys/types.h>
#include <signal.h>
int kill(pid_t pid, int sig);
```

Unix/Linux Signals

How to handle a signal in a process?

- Define a handler function
- Make system call signal to link the function with a signal

Unix/Linux Signals

```
#include <stdio.h>
#include <signal.h>
#include <unistd.h>

void sig_handler(int signo){
    if(signo == SIGINT) printf("received SIGINT\n");
}
int main(void){
    if(signal(SIGINT, sig_handler)==SIG_ERR)
        printf("Cannot catch SIGINT\n");
    while(1) sleep(1);
}
```

Quiz

```
#include <stdio.h>
#include <sys/shm.h>
#include <sys/stat.h>
int main( ){
    int i;
    for(i=0;i<2;i++) fork();
}
```

How many processes are created while the above program is executed?

Thread (I)

Kernel Threads

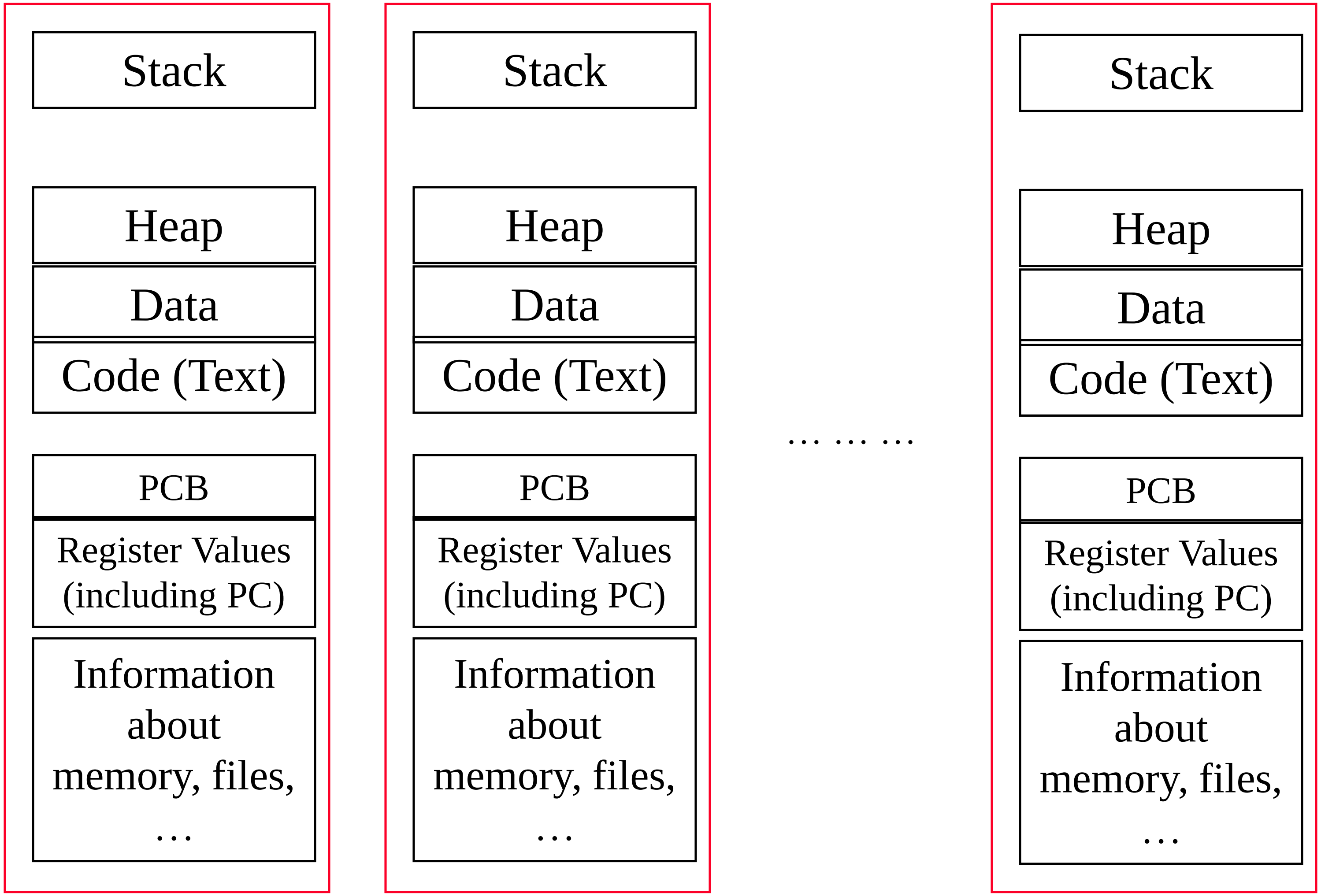
Example of Multi-Process Collaboration

- Finding the lines containing key word “Linux” in all .txt files in the current directory
- Linux command line:

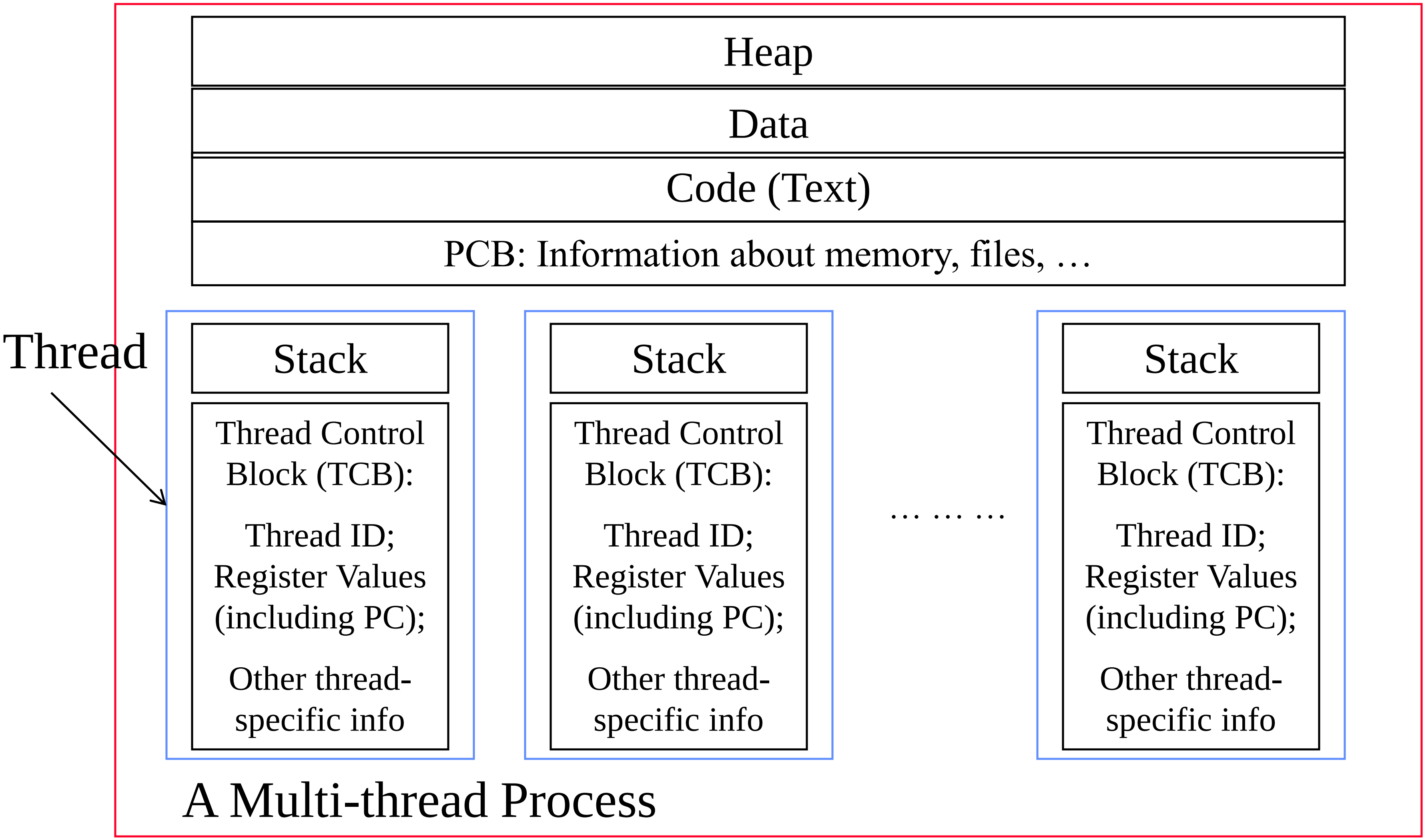
  grep “Linux” *.txt
- Using multi-process collaboration to do the job?

```
…
int numFiles; //total number of files
char fileNames[MAX_NUM_FILES][255]; //array storing the file names
int i;
for(i=0; i<numFiles; i++)
  if (fork( ) == 0){
        FILE *fp = fopen(fileNames[i], “r”);
        … //search for lines containing “Linux” in the file
        exit(0);
  }
```

Multi-Process



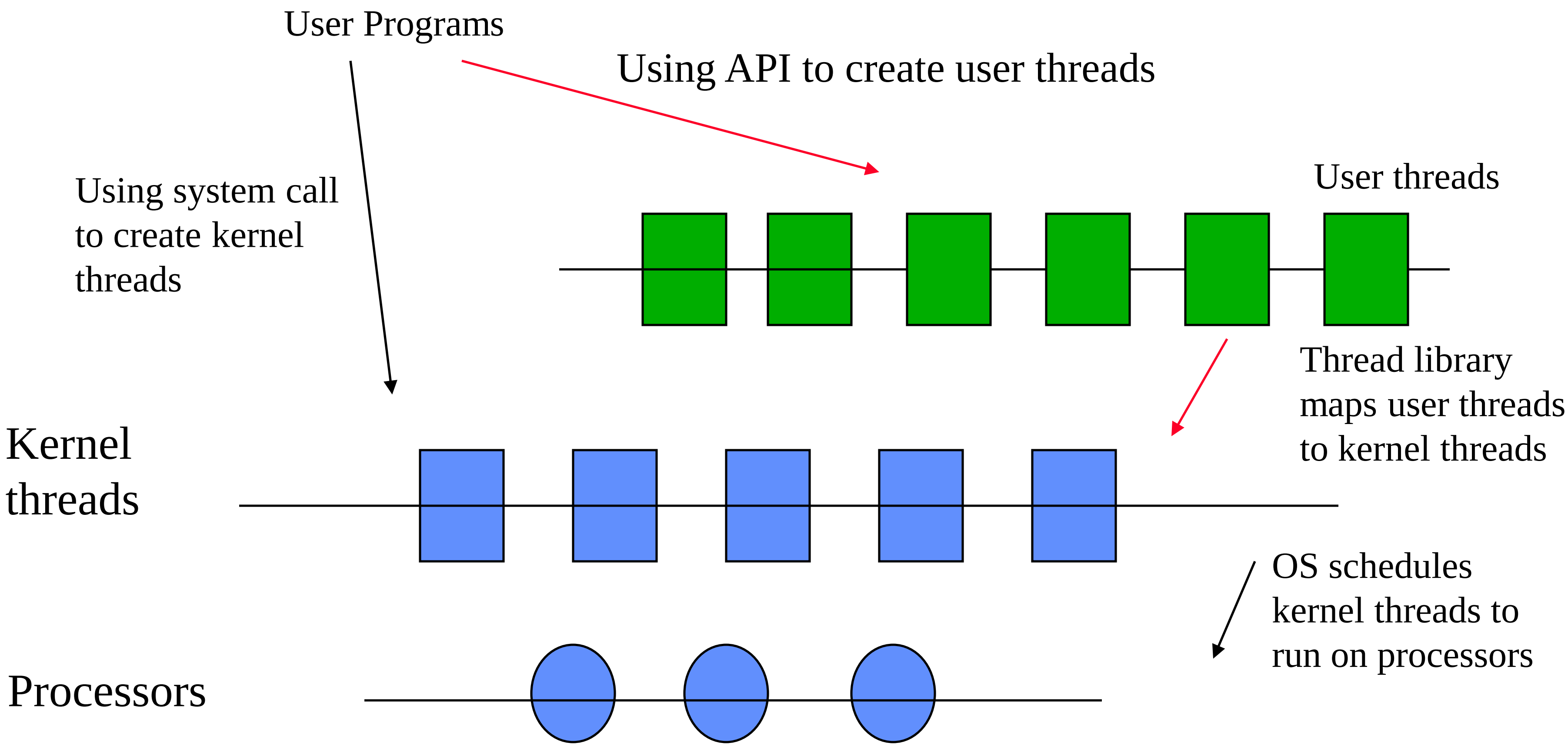
A Process with Multiple Threads



Benefits

- Responsiveness (similar to multi-process)
  - Allowing a program to continue running even if part of it is blocked
  - Allowing a program to perform multiple tasks concurrently
- Resource sharing
  - Threads of the same process share the memory and resources
- Economy
  - Allocating memory and resources for process creation is costly.
- Scalability (similar to multi-process)
  - A single-thread process can only run on one processor regardless how many are available; multi-threaded process can increase parallelism on a multi-processor machine.

Threads in a Computer System



Kernel Threads

- Directly created/managed/scheduled by the OS kernel
- Virtually all contemporary OSes support kernel threads

Linux Kernel Threads

- Linux refers to them as *tasks* rather than *threads*
- Thread creation is done through **clone()** system call

```
#define _GNU_SOURCE
#include <sched.h>
int clone(int (*fn)(void *), void *child_stack, int flags, void *arg);
```

flag	meaning
CLONE_FS	File-system information is shared.
CLONE_VM	The same memory space is shared.
CLONE_SIGHAND	Signal handlers are shared.
CLONE_FILES	The set of open files is shared.

Example

```
#include _GNU_SOURCE
#include <stdio.h>
#include <sched.h>
#include <unistd.h>
#include <stdlib.h>
#include <fcntl.h>

int variable, fd;
int do_something(); //function to be executed by the new task (thread)
```

Example

```
int main( ) {
void *child_stack;
char tempch;
variable = 9;
fd = open("test.file", O_RDONLY);
child_stack = (void *)malloc(16384); child_stack += 16383;
printf("The variable was %d\n", variable);
clone(do_something, child_stack, CLONE_VM|CLONE_FILES, NULL); /*A*/
sleep(1);
printf("The variable is now %d\n", variable);
if (read(fd, &tempch, 1) < 1) {
        perror("File Read Error"); exit(1);}
        printf("Parent could read from the file\n");}
}
```

Example

```
int do_something() {
  char tempch;
  variable = 42;
  if (read(fd, &tempch, 1) < 1) {
    perror("File Read Error");
    _exit(1);
  }
  printf("Child could read from the file\n");
  close(fd);
  _exit(0);
}
```

Example

1. What is the output of the program?

2. What if Line A is changed to:

clone(do_something, child_stack, CLONE_VM, NULL);

or

clone(do_something, child_stack, CLONE_FILES, NULL);

or

Clone(do_something, child_stack, 0, NULL);