ENSC 351

Processes & Threads

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Slides for course derived from
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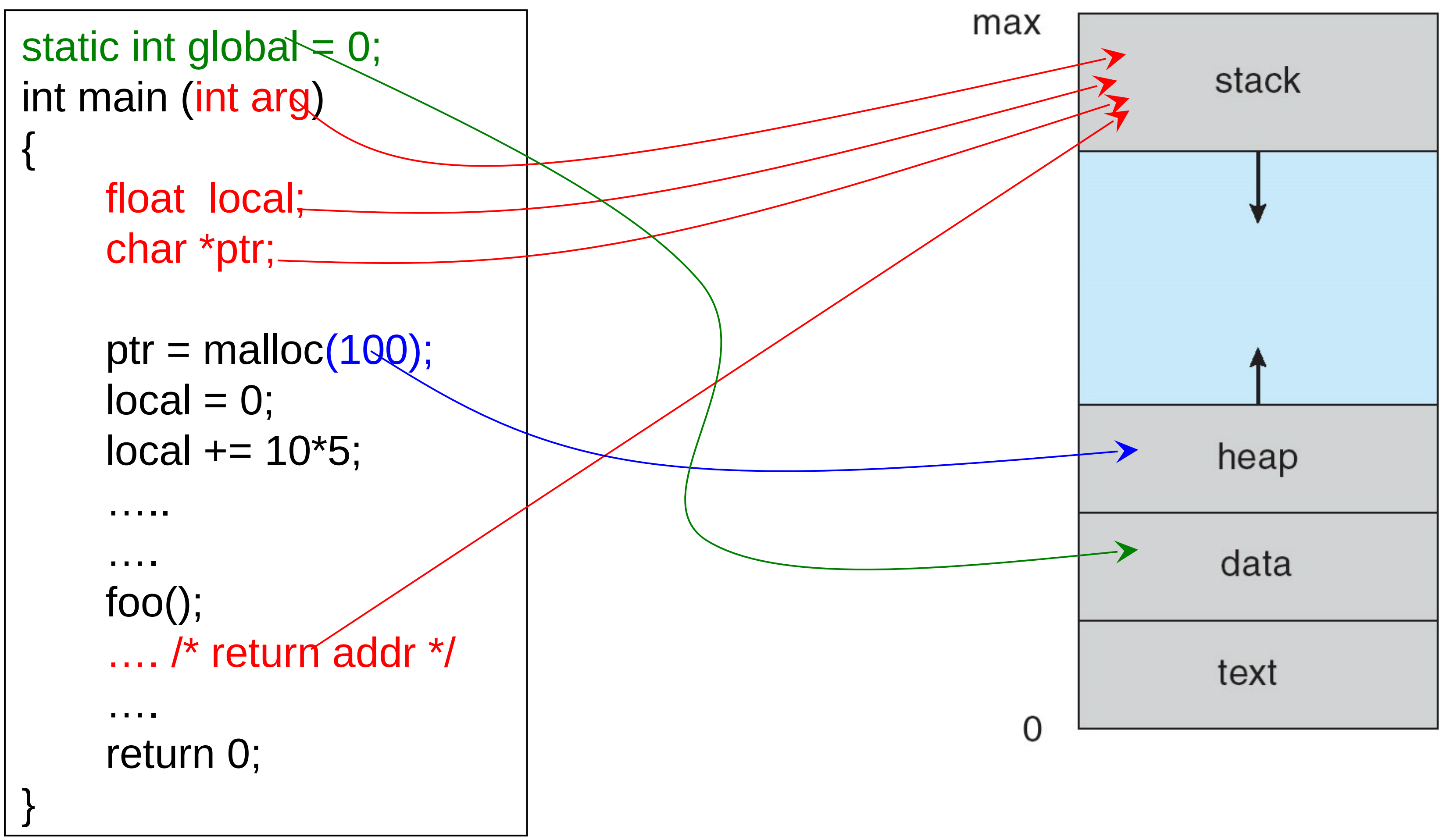
Objectives

- Understand
    - Process concept
    - Process scheduling
    - Creating and terminating processes
    - Interprocess communication
    - Threads vs Processes

Process Concept

- Process is..
    - Process execution must progress in sequential fashion
    - A program may exist on the hard drive, but is not a process until being executed (usually from memory)
- Note:
    - Terms.. are interchangeable
- A process includes:
    - program counter
    - stack pointer
    - data section (memory)
    - code section (memory)

Process in Memory

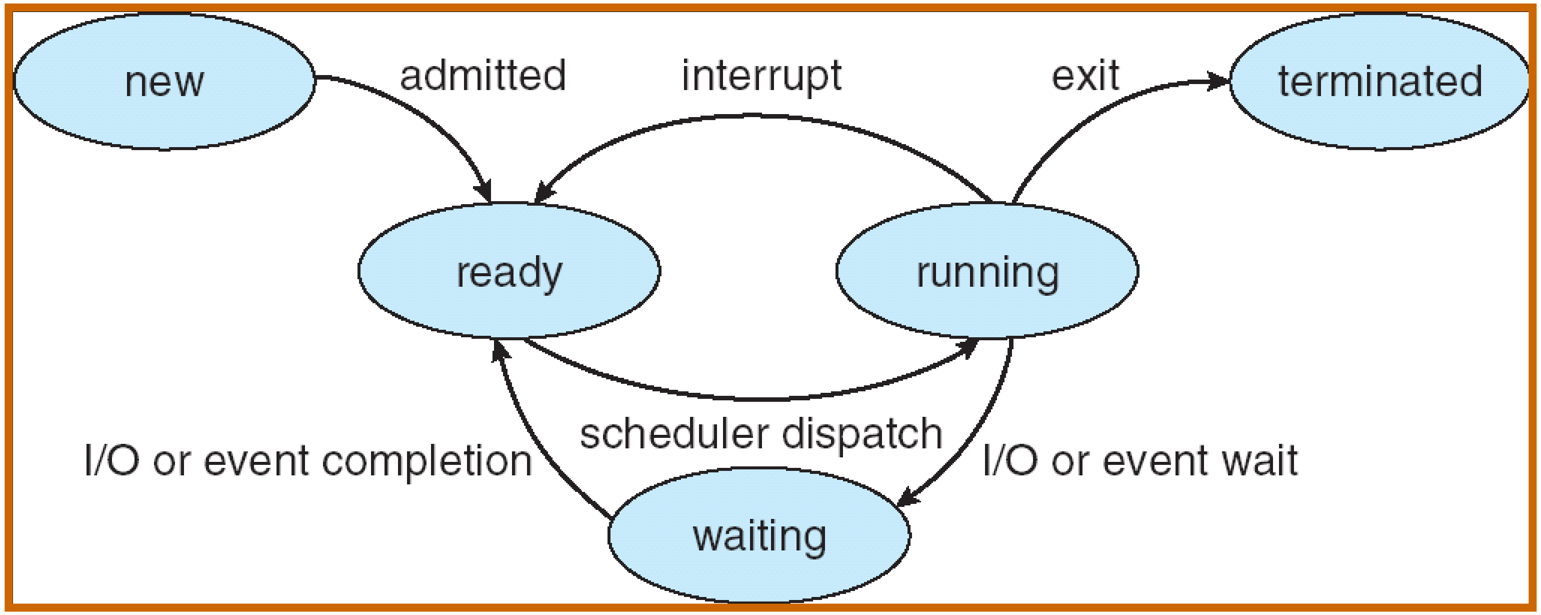


```
static int global = 0;
int main (int arg)
{
        float  local;
        char *ptr;

        ptr = malloc(100);
        local = 0;
        local += 10*5;
        …..
        ….
        foo();
        …. /* return addr */
        ….
        return 0;
}
```

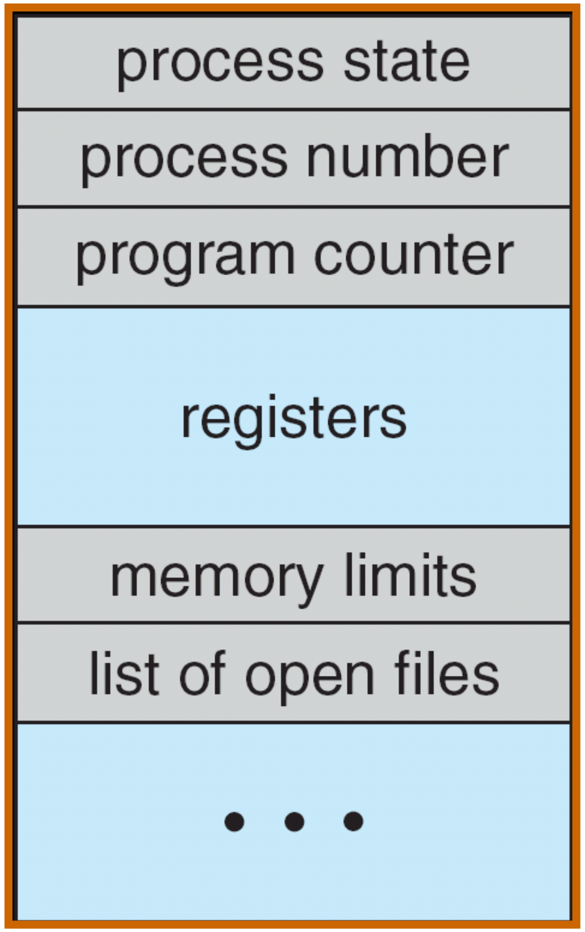
Process State

- As a process executes,..
  - **new**: just created
  - instructions are being executed
  - process is waiting for some event to occur
  - process is waiting for CPU
  - **terminated**: process has finished execution



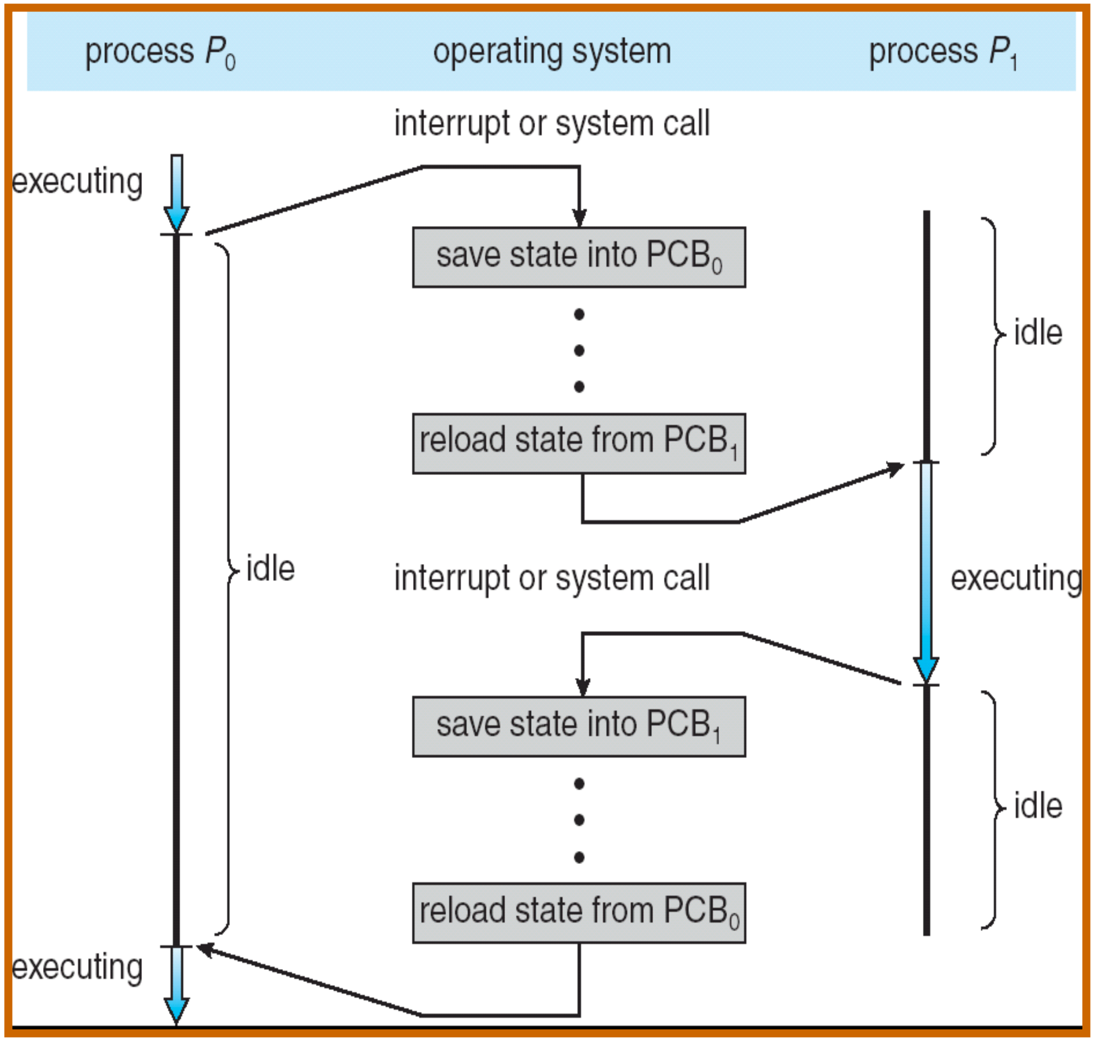
.. (PCB)

- OS maintains info about process in PCB
  - Process state
  - Program counter
  - CPU registers
  - CPU scheduling info
  - Memory-management info
  - Accounting info
  - I/O status info
- PCB used to..
  - E.g., to switch CPU from one process to another
- Typically, a large C structure in kernel
  - Linux: **struct task_struct**



CPU Switch From Process to Process

- When switching from P_0 to P_1 kernel will:
  - Save **state** of P_0 in PCB_0 (in memory)
  - Load **state** of P_1 from PCB_1 into registers
- **State** = values of the..



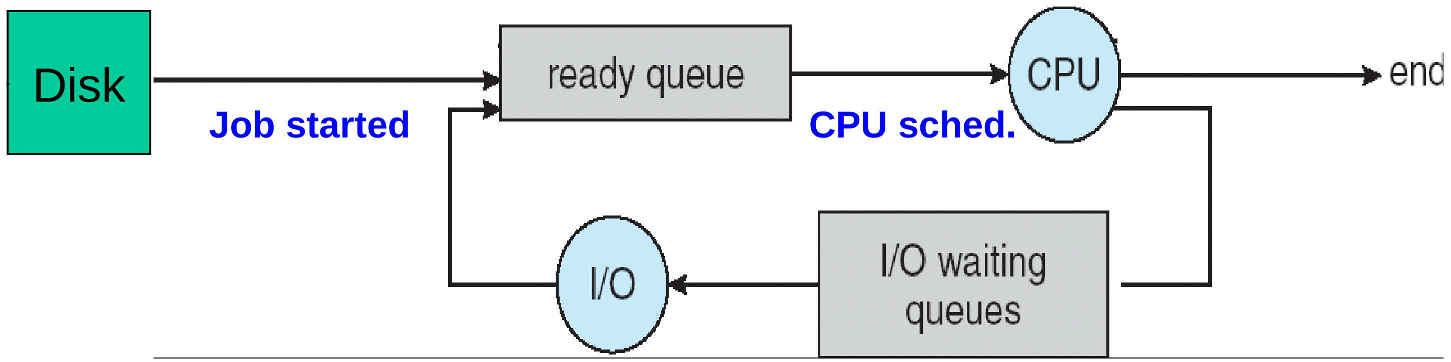
CPU Switch From Process to Process cont'd

- Switching between processes is called a
  ..
- Context-switch time is..
  no useful work is done
- Switching time depends on hardware support
  - Some systems (Sun UltraSPARC) provide multiple register sets ➔ very fast switching (just change a pointer)
  - Typical systems, few milliseconds for switching

Job Types

- Jobs (Processes) can be described as either:
  - ..
    - spends more time doing I/O than computations, many short CPU bursts
    - Often characteristic of interactive programs
    - Example: GUI, word processor, IDE
  - ..
    - spends more time doing computations; long CPU bursts
    - Example: factoring a large prime (cryptography)

Scheduling: The Big Picture (cont'd)

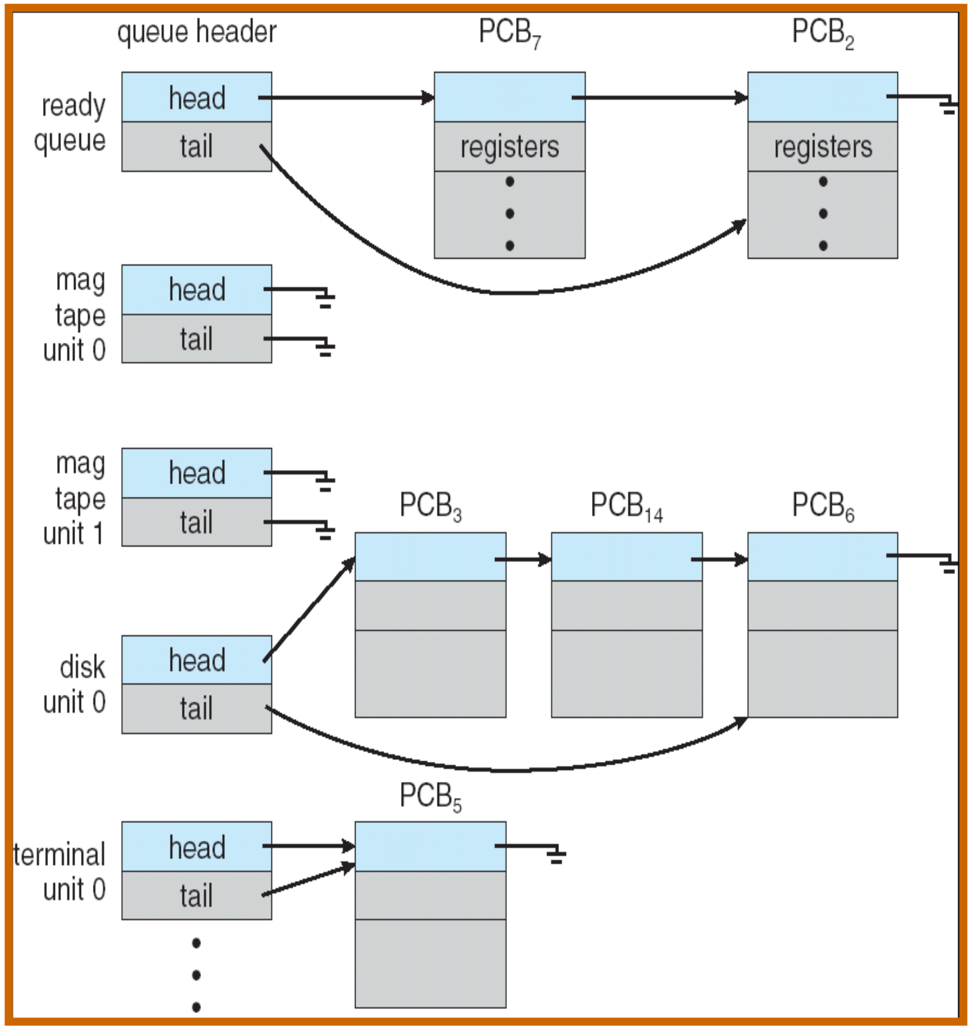


Schedulers (cont’d)

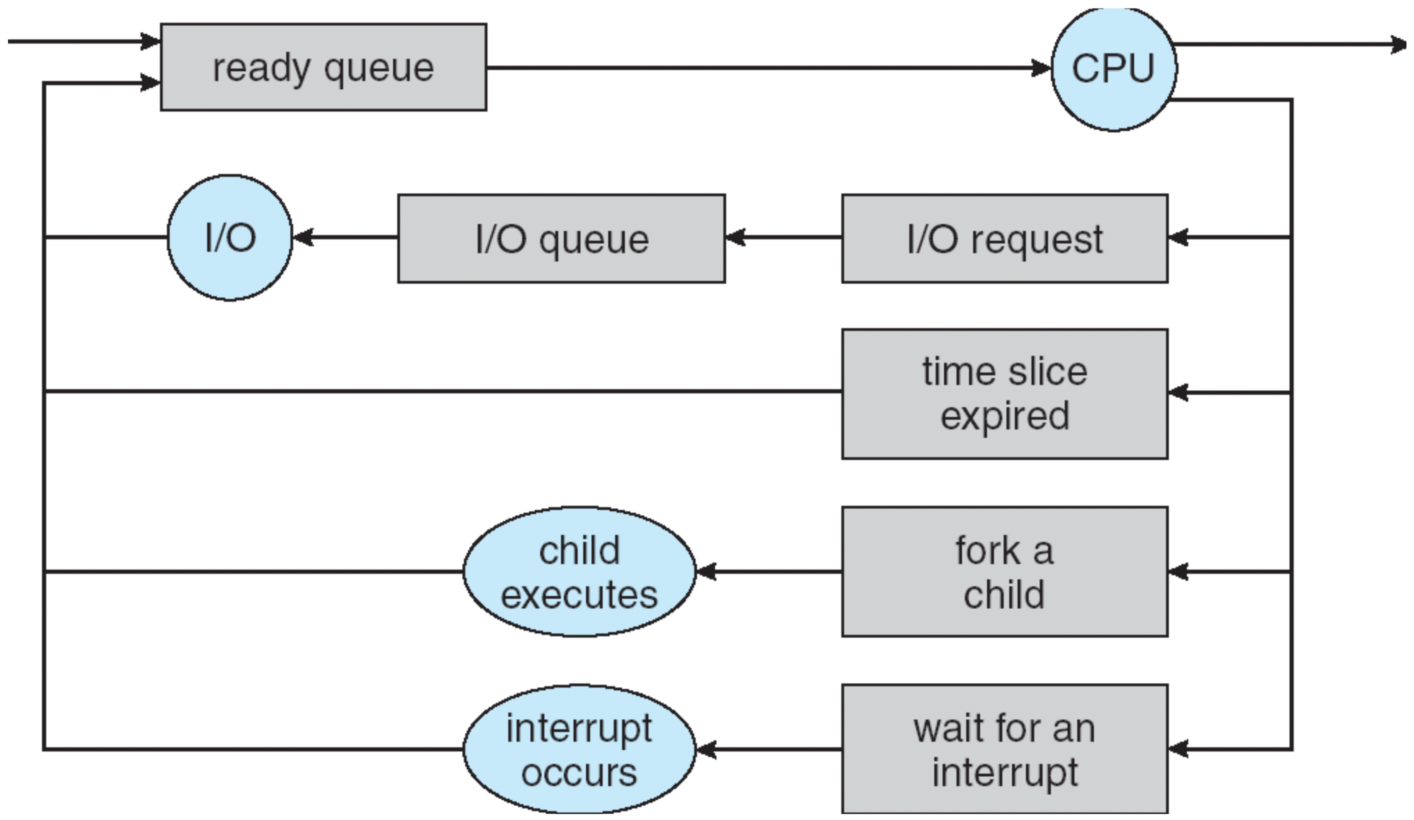
- **Short-term scheduler** (or CPU scheduler)
  - selects which process should be..
    and allocates CPU to it
  - Short-term scheduler is invoked..
    (milliseconds)
    - So must..

Scheduling Queues

- Processes migrate among various queues
- ..
  set of all processes in the system
- ..
  set of all processes residing in main memory, ready and waiting to execute
- ..
  set of processes waiting for a specific I/O device

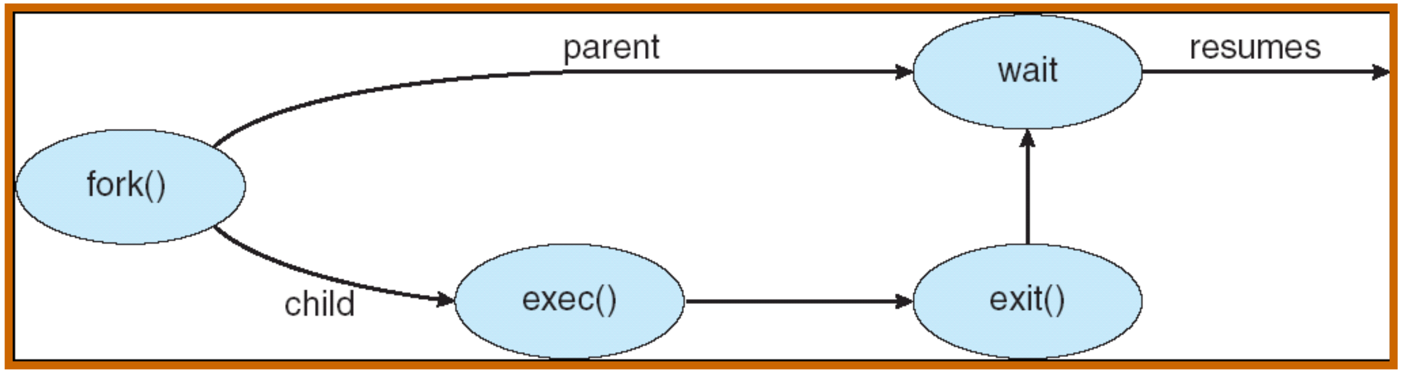


Process Lifetime



Process Creation: Unix Example

- Process creates another process (child) by using **fork** system call
  - Child is..
  - Typically, child loads another program into its address space using **exec** system call
  - Parent waits for its children to terminate



C Program Forking Separate Process

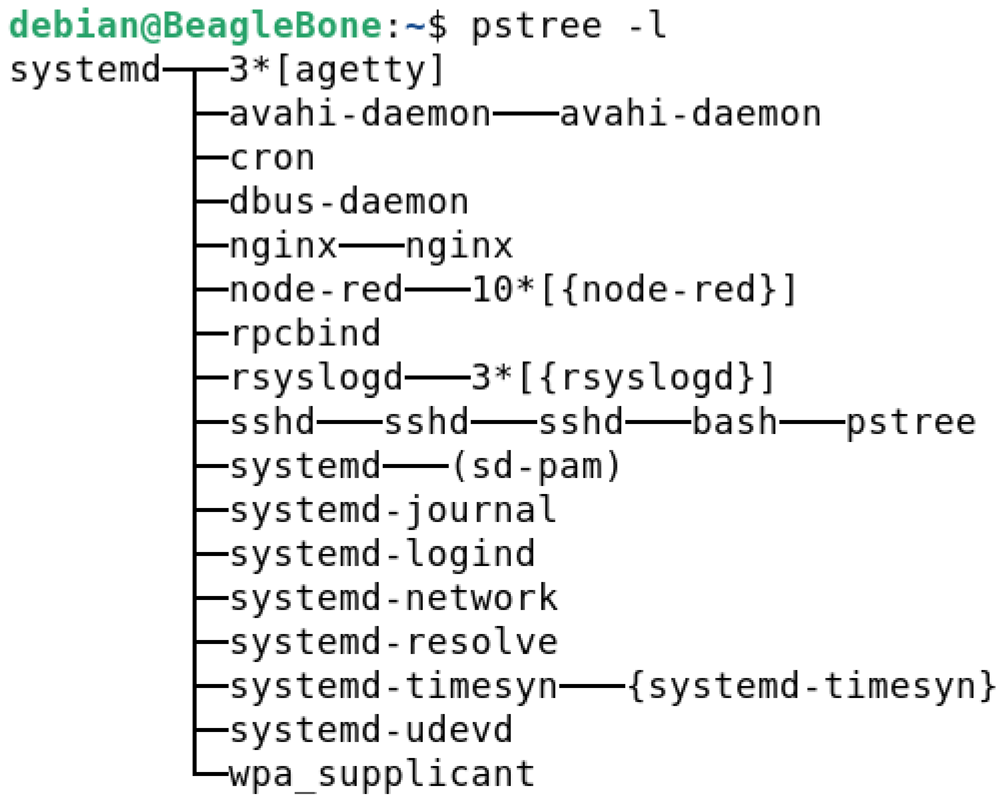
```
int main()
{
   /* fork another process */
   pid_t  pid = fork();

   if (pid < 0) { /* error occurred */
        fprintf (stderr, "fork Failed");
        exit(-1);
   }
   else if (pid == 0) { /* child process */
        execlp ("/bin/ls", "ls", NULL);
   }
   else {             /* parent process */
        /* parent will wait for child to complete */
        wait (NULL);
        printf ("Child %d Completed", pid);
        exit(0);
   }
}
```

Fork returns:
< 0:
0:
> 0:

Replace child with new program.

Tree of processes on BeagleBone Green



```
debian@BeagleBone:~$ pstree -l
systemd─┬─3*[agetty]
        ├─avahi-daemon───avahi-daemon
        ├─cron
        ├─dbus-daemon
        ├─nginx───nginx
        ├─node-red───10*[{node-red}]
        ├─rpcbind
        ├─rsyslogd───3*[{rsyslogd}]
        ├─sshd───sshd───sshd───bash───pstree
        ├─systemd───(sd-pam)
        ├─systemd-journal
        ├─systemd-logind
        ├─systemd-network
        ├─systemd-resolve
        ├─systemd-timesyn───{systemd-timesyn}
        ├─systemd-udevd
        └─wpa_supplicant
```

Process Termination (Linux)

- Normal termination:..
  Asks OS to delete the current process (itself)
  - Last statement a process executes
  - Process' resources are de-allocated by OS
  - Exit code (int) available to parent process via..
- Abnormal termination:..
- Terminate child process:..
  - Useful if:
    - Child has exceeded allocated resources
    - Task assigned to child is no longer required

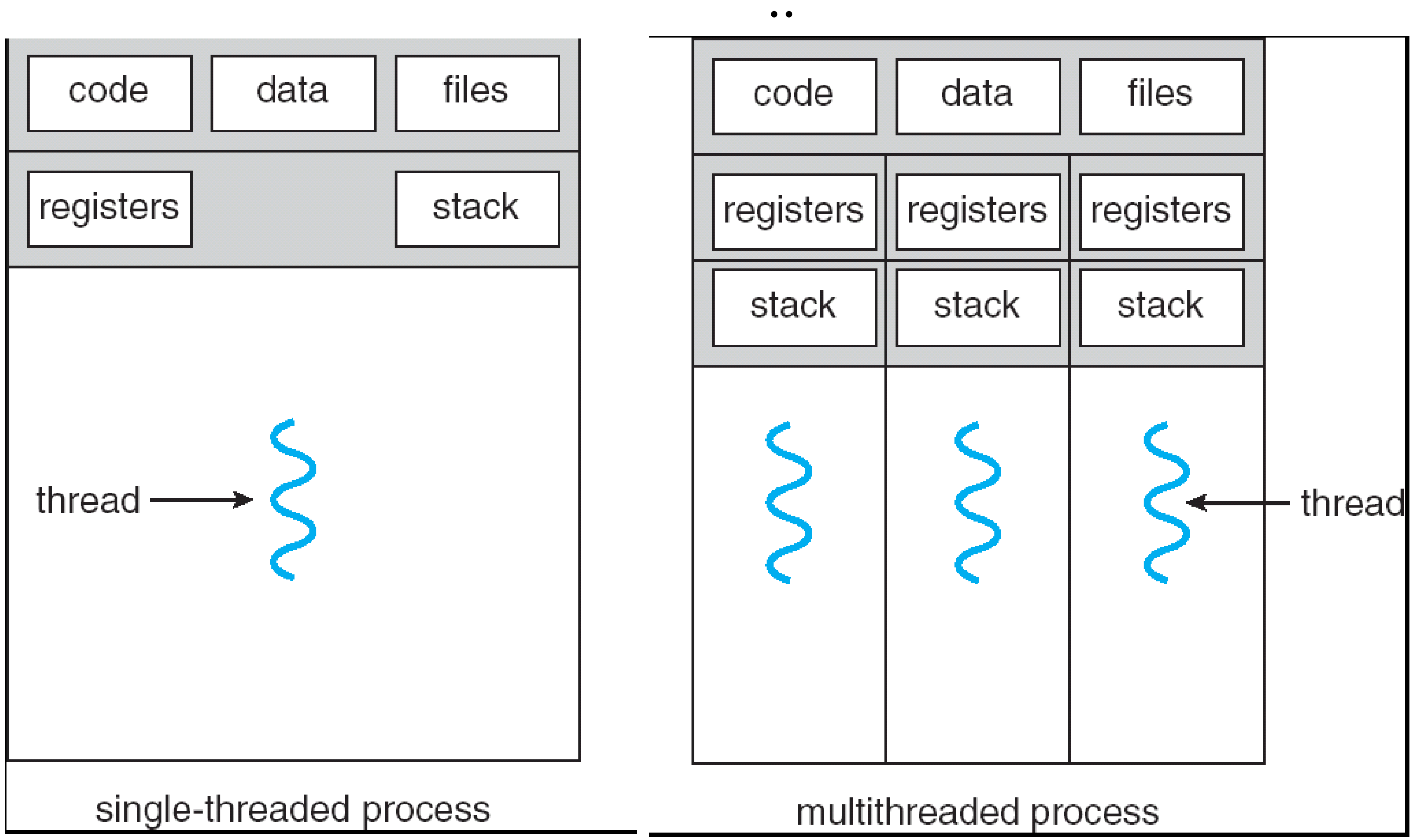
Threads

Thread Definitions

- Thread is a basic unit of CPU utilization
  - A sequence of instructions enclosed in a function which..
- Process is a program in execution
  - A process is composed of..
- Each thread has a thread control block (TCB)
  - Program counter
  - Register set, and
  - Stack
- Threads of the same process share
  - Code section
  - Data section
  - OS resources such as open files and signals

Threads of a process..

Single and Multithreaded Processes



Why Multithreading?

- **Responsiveness:** one thread for
  ..
- **Resource Sharing:** similar requests handled by the same code and use same files/resources
- **Economy:** threads are much cheaper to create/delete than..
- **Utilization of multiprocessors:** single threaded-process can NOT make use of multiple processors
- Examples of multithreaded applications?
  - Web browsers: parallel downloads
  - Web servers: handle multiple concurrent clients
  - Word processors: spell check in the background
  - …. Many others …

Cooperating Processes

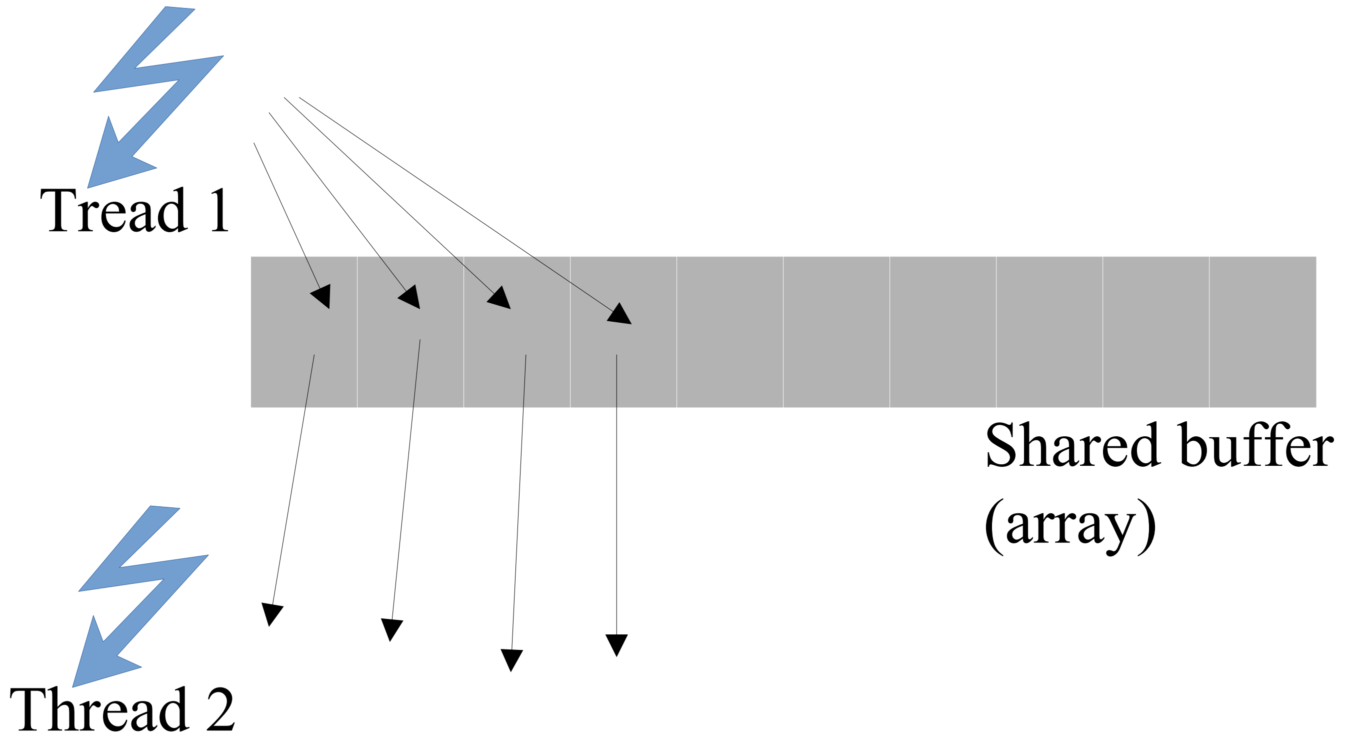
- Cooperating process can affect the execution of each other

- Why processes cooperate?
  - Information sharing
  - Computation speed-up
  - Modularity, Convenience

- Interprocess Communication (IPC) methods
  - Shared memory
  - Message passing

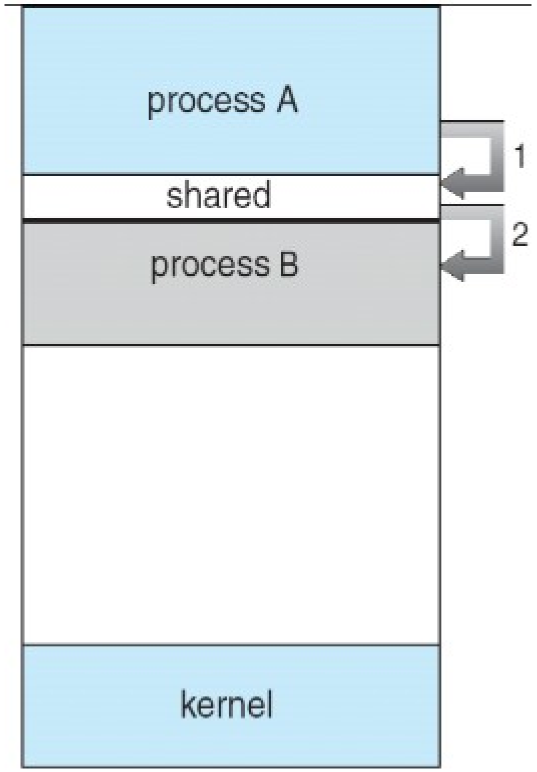
Threads & Shared Memory

- Threads inside a process share a memory space
  - Therefore, they can just use pointers to reference shared memory



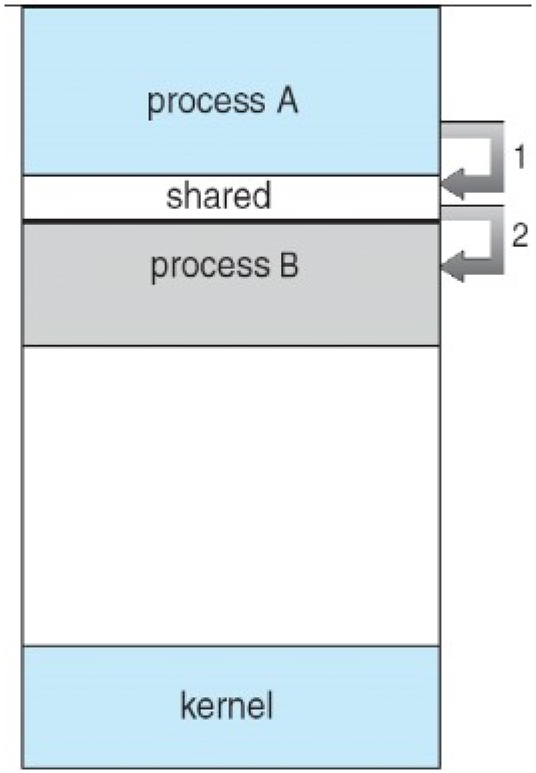
IPC: Shared Memory

- Processes communicate by creating a shared place in memory
  - One process **creates** a shared memory — shmget()
  - Other processes **attach** shared memory to their own address space — shmat()
  - Then, shared memory is treated as regular memory
  - Synchronization is needed to prevent concurrent access to shared memory (conflicts)



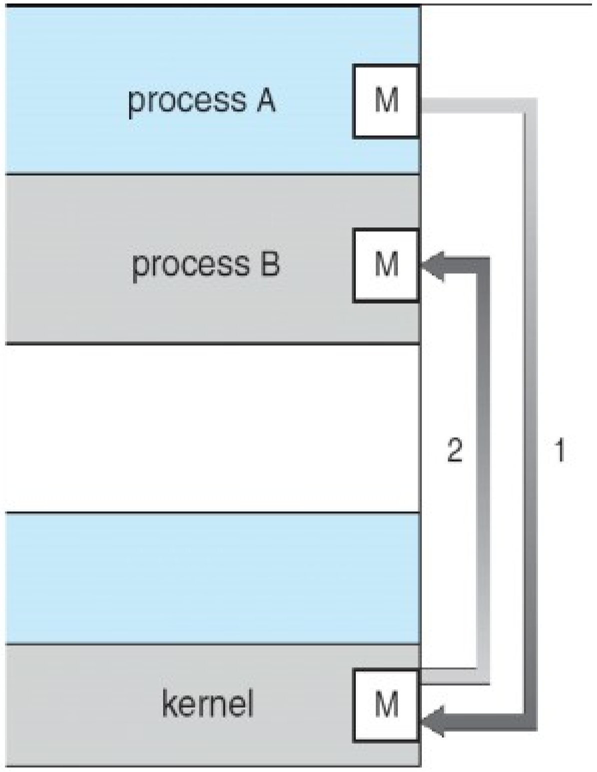
IPC: Shared Memory

- Pros
  - ..
    (use at memory speed)
  - Convenient to programmers
    (just regular memory)
- Cons
  - Need to..
    (tricky for distributed systems)



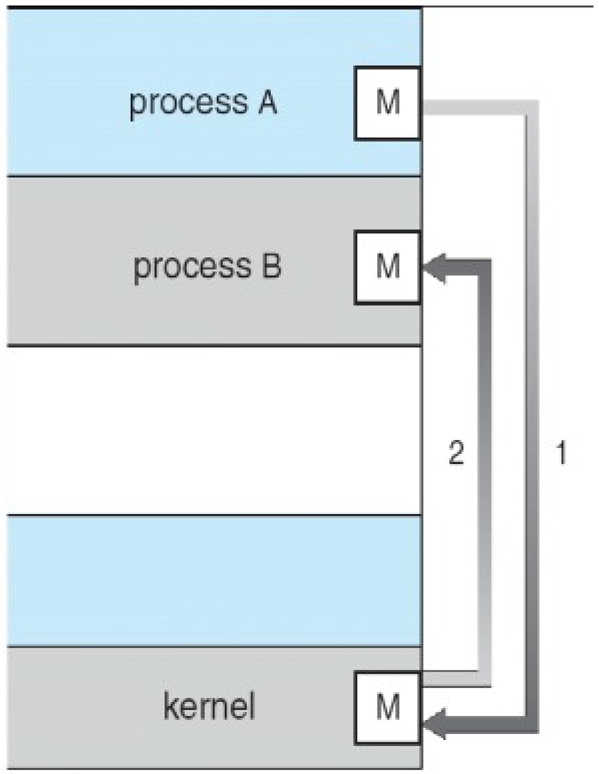
IPC: Message Passing

- If processes (or threads) *P* and *Q* wish to communicate, they need to:
  - establish a communication
  - exchange messages via a pipe:
    - **send** (*message*) – message size fixed or variable
    - **receive** (*message*)



IPC: Message Passing

- Pros
  - No conflict:
    easy to exchange messages
    especially in distributed systems
- Cons
  - Overhead (message headers)
  - ..
    - Sender must prepare messages; receiver must process them.
    - ..
      sender → kernel → receiver
      (several system calls)



IPC: Message Passing (cont'd)

- **Synchronization**: message passing is either
  - **..**
    - **send ()** has sender block until message is received
    - **receive ()** has receiver block until message is available
  - **..**
    - **send ()** has sender send message and continue
    - **receive ()** has receiver receive a valid message or null
- **Buffering:** Queue of messages attached to communication channel
  - **Zero capacity** – Sender must wait for receiver (rendezvous)
  - **Bounded capacity** – Sender must wait if link full
  - **Unbounded capacity** – Sender never waits

Example: Linux Pipes

- Pipe:
  -
  - Good for inter-thread and inter-process communication.
- Needed Functions:
  - pipe() to create file descriptors for read and write ends of pipe.
  - fdopen() to open the pipe (from descriptor)
  - fprintf() to write (or other functions)
  - fgets() to read [blocking] (or other functions)
  - close() to close the file descriptor.

Example: Linux Pipes code

```
int fds[2];                        // File descriptors for two ends of pipe
pipe (fds);                        // Create a pipe.

// Writer: Convert the write file descriptor to a FILE object
FILE* streamW = fdopen (fds[1], "w");
fprintf (streamW, "Hello World of Pipes!\n");
fflush (streamW);
close (fds[1]);
```

This possibly in different process/thread:

```
// Reader: Convert read file descriptor to a FILE object.
FILE* streamR = fdopen (fds[0], "r");

// Read until end of the stream.
char buffer[1024];
while (!feof (streamR) && !ferror (streamR)
        && fgets (buffer, sizeof (buffer), streamR) != NULL) {
        printf("%s", buffer);
}
close (fds[0]);
```

demo_pipe.c

Summary

- A process is a program in execution
  - OS maintains process info in PCB
  - Process State diagram
  - Creating and terminating processes (fork)
- Process scheduling
  - Long-, short-, and medium-term schedulers
  - Scheduling queues
- Interprocess communication
  - Shared memory
  - Message passing
- Threads
  - Share memory between threads of a process
  - Each thread executes independently