CS3600 — Systems and Networks

NORTHEASTERN UNIVERSITY

Lecture 3: Processes

Prof. Alan Mislove (amislove@ccs.neu.edu)

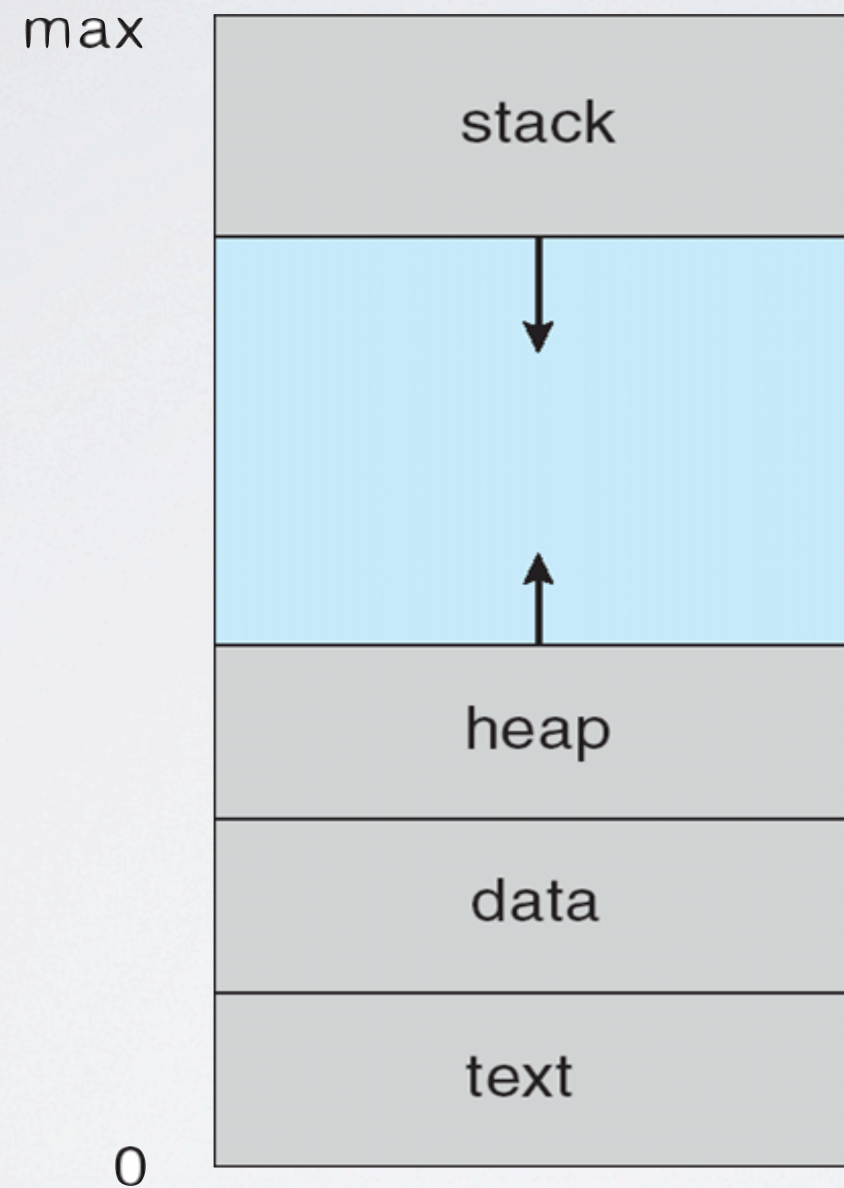
Process Concept

- 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 – a program in execution; process execution must progress in sequential fashion
- A process includes:
  - program counter
  - stack
  - data section

The Process

- Multiple parts
  - The program code, also called **text section**
  - Current activity including **program counter**, processor registers
  - **Stack** containing temporary data
    - Function parameters, return addresses, local variables
  - **Data section** containing global variables (r/o and r/w)
  - **Heap** containing memory dynamically allocated during run time
- Program is passive entity, process is active
  - Program becomes process when executable file 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 in Memory



Storage of variables

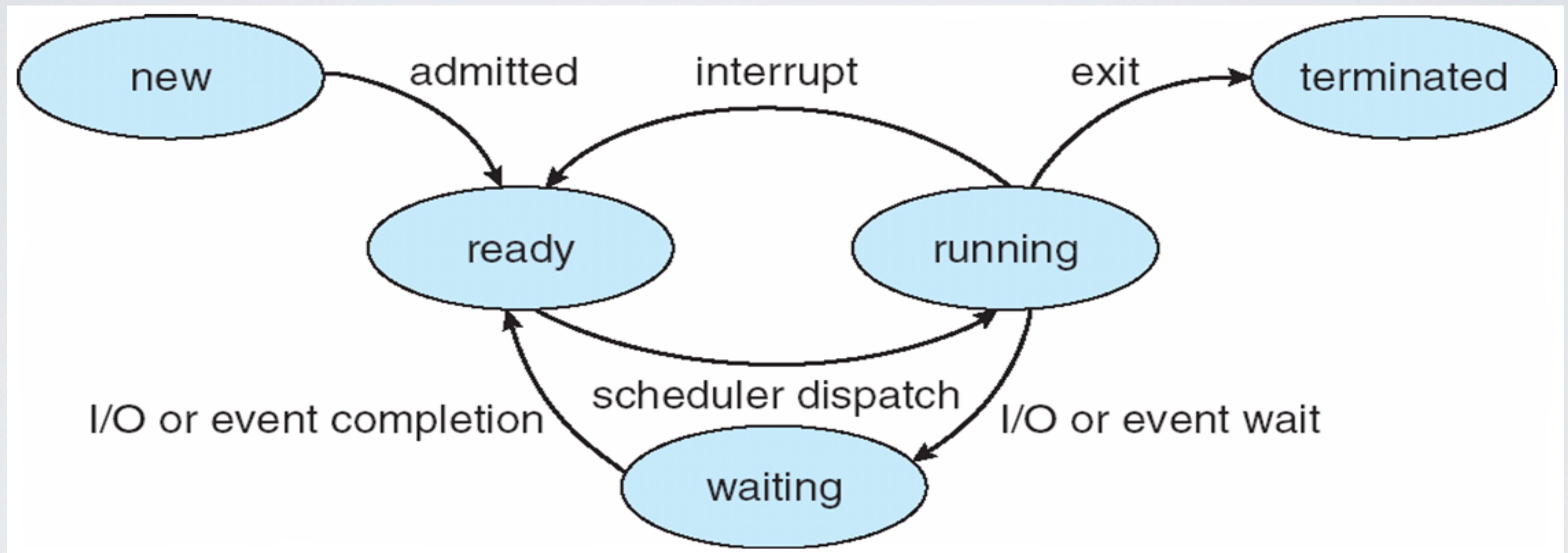
```
#include <stdio.h>

int int1 = 1;
char *str1 = “hello”;
const char *str2 = “const”;

int main(int argc, char** argv) {
  int int2 = 0;
  char *str3 = “inner”;
  char *str4 = (char *) malloc(10*sizeof(char));
  printf(“%s -- %s\n”, message, foo);
  return 0;
}
```

- Where are int1, int2, str1--4, and the char*s stored?

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

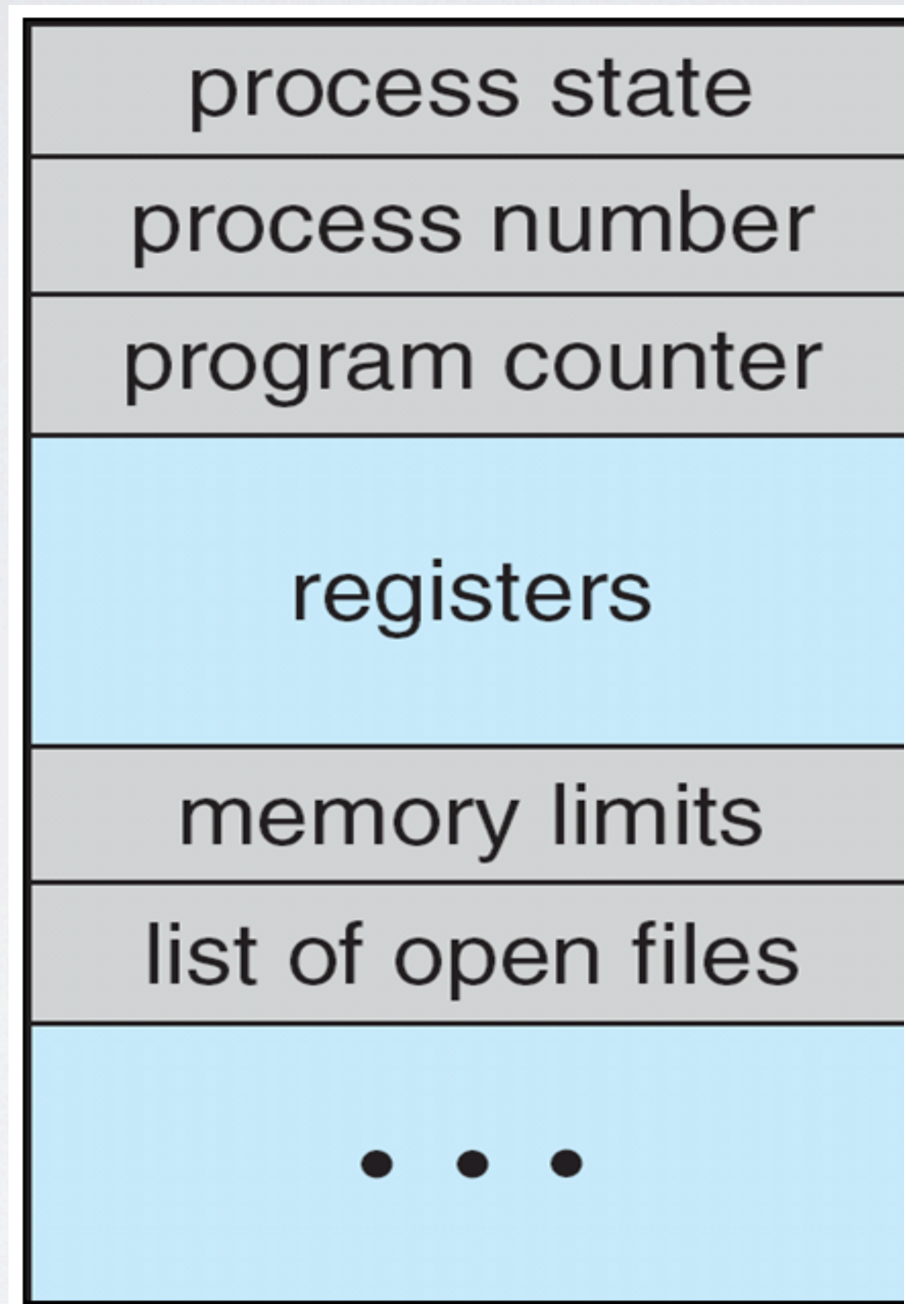
Diagram of Process State



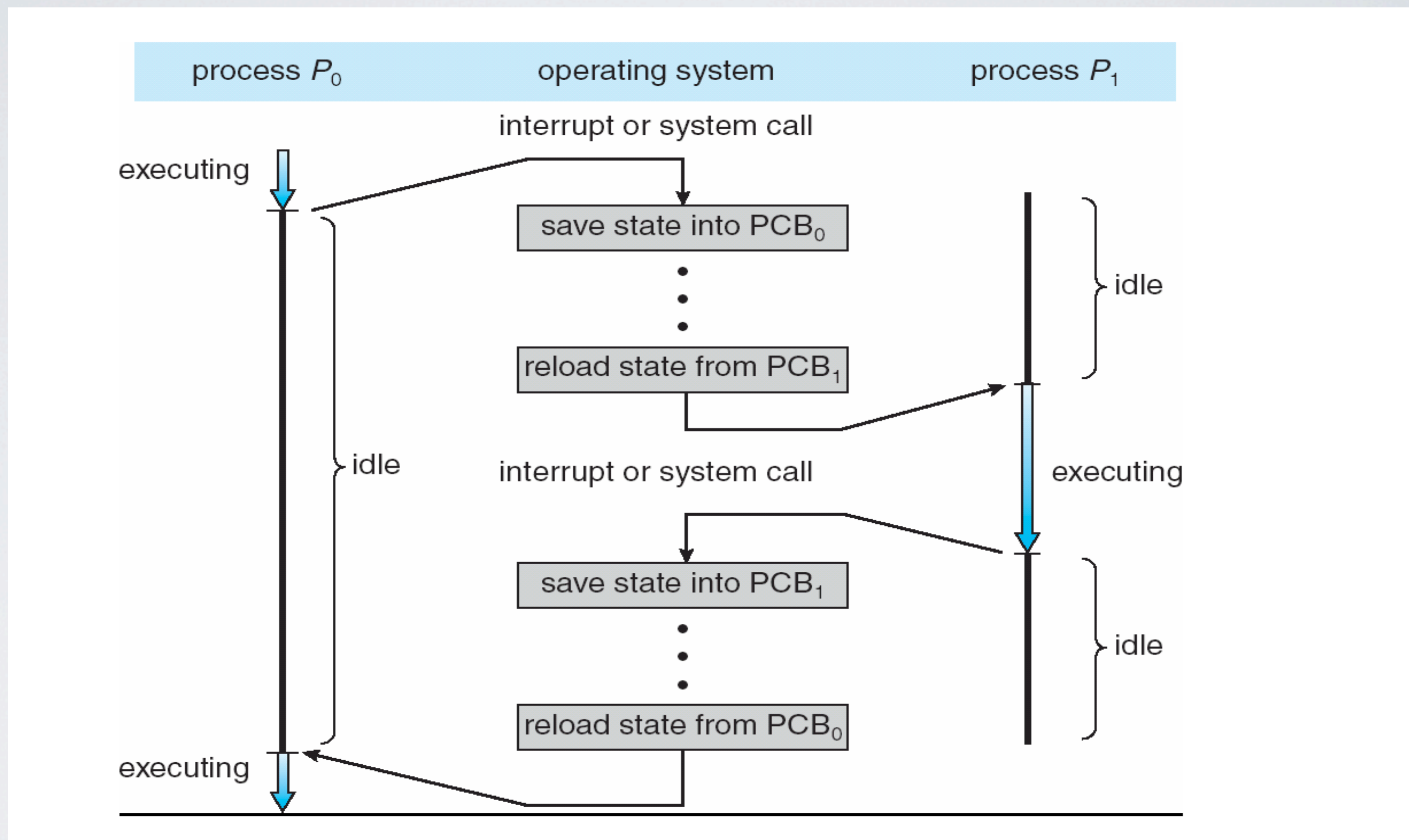
Process Control Block (PCB)

- Kernel keeps information associated with each process
  - Process state
  - Program counter
  - CPU registers
  - CPU scheduling information
  - Memory-management information
  - Accounting information
  - I/O status information
- Stored in a data structure call the Process Control Block (PCB)

Process Control Block (PCB)



CPU Switch From Process to Process



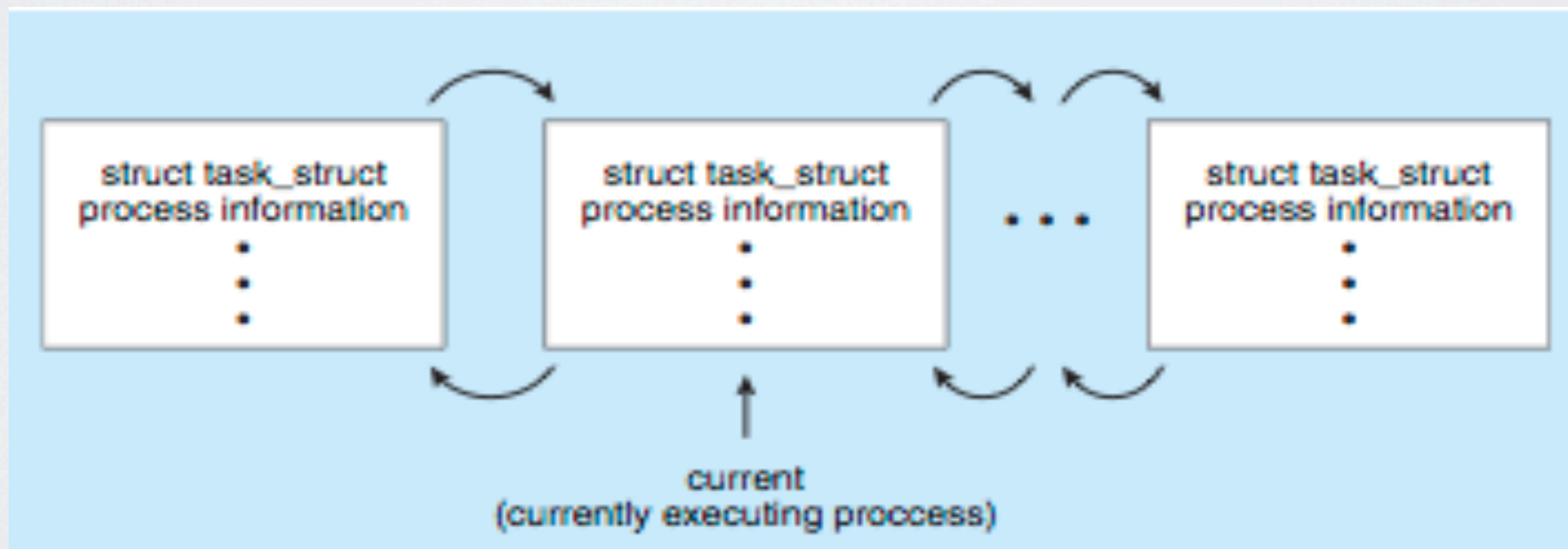
Process Scheduling

- To maximize CPU use, want to 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

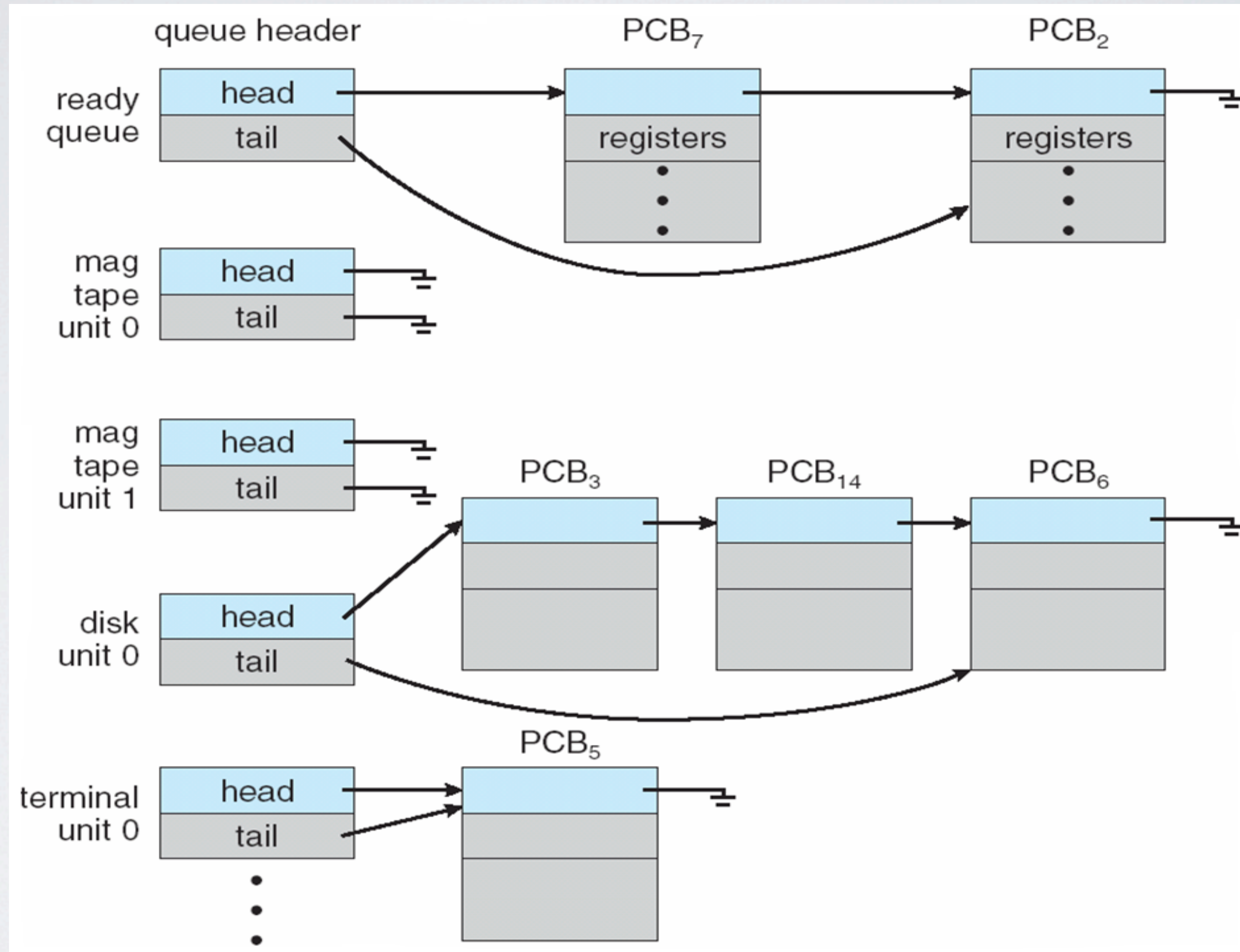
Process Representation in Linux

- Represented by the C structure

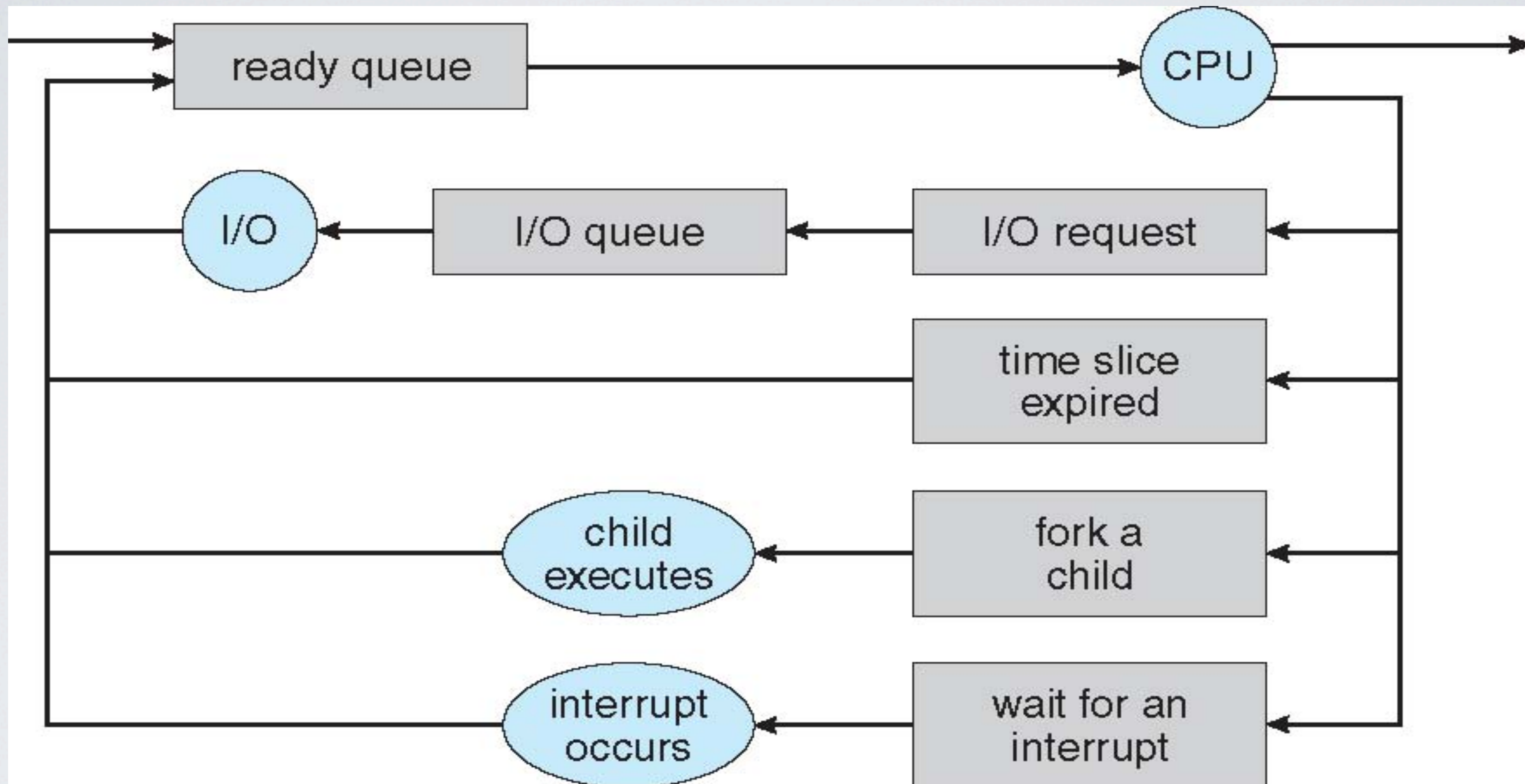
```
struct task_struct {
  pid t pid; /* process identifier */
  long state; /* state of the process */
  unsigned int time slice /* scheduling information */
  struct task struct *parent; /* this process's parent */
  struct list head children; /* this process's children */
  struct files struct *files; /* list of open files */
  struct mm struct *mm; /* address space of this process */
}
```



Ready Queue And Various I/O Device Queues



Representation of Process Scheduling



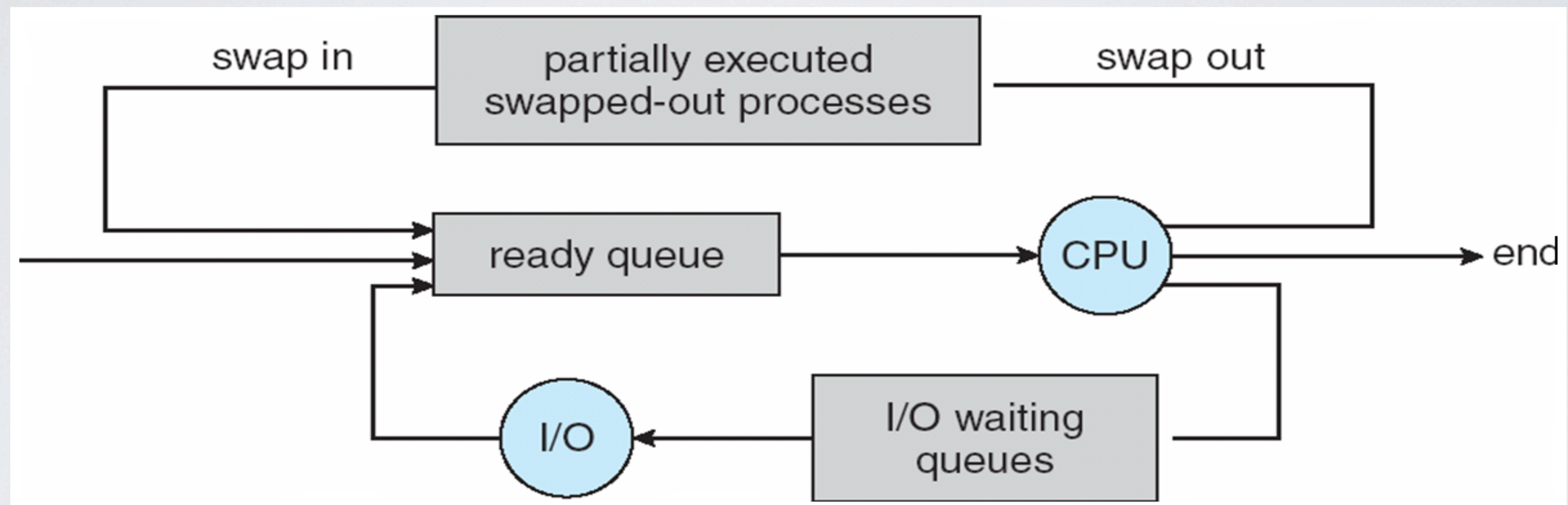
Schedulers

- **Long-term scheduler** (or job scheduler) – selects which processes should be brought into memory and put on 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

Addition of Medium Term Scheduling



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 via a **context switch**.
- **Context** of a process represented in the PCB
- Context-switch time is overhead; the system does no useful work while switching
  - The more complex the OS and the PCB -> longer the context switch
- Time dependent on hardware support
  - Some hardware provides multiple sets of registers per CPU -> multiple contexts loaded at once

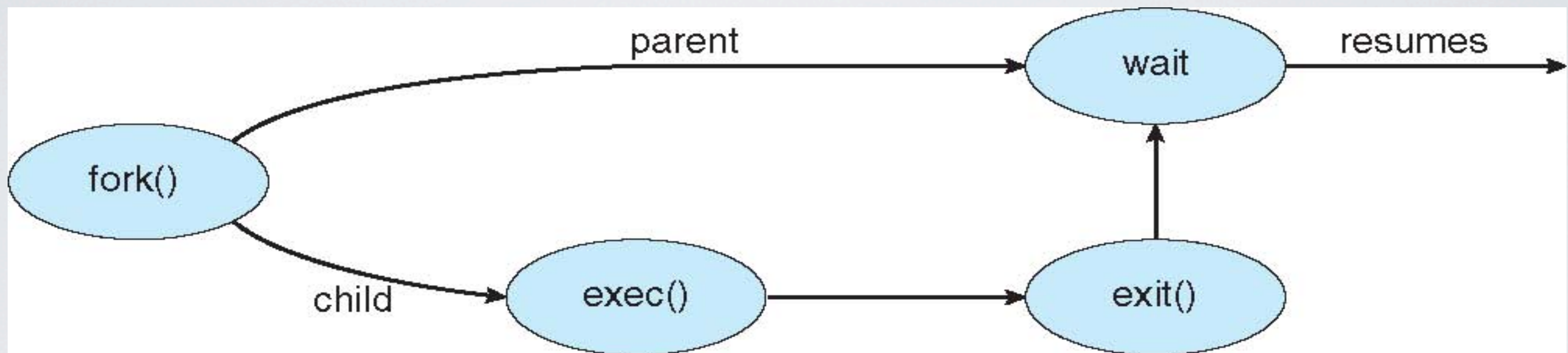
Process Creation

- **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**)
- 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
    - How to tell apart new (child) and old (parent) process?
  - **exec** system call used after a **fork** to replace the process' memory space with a new program

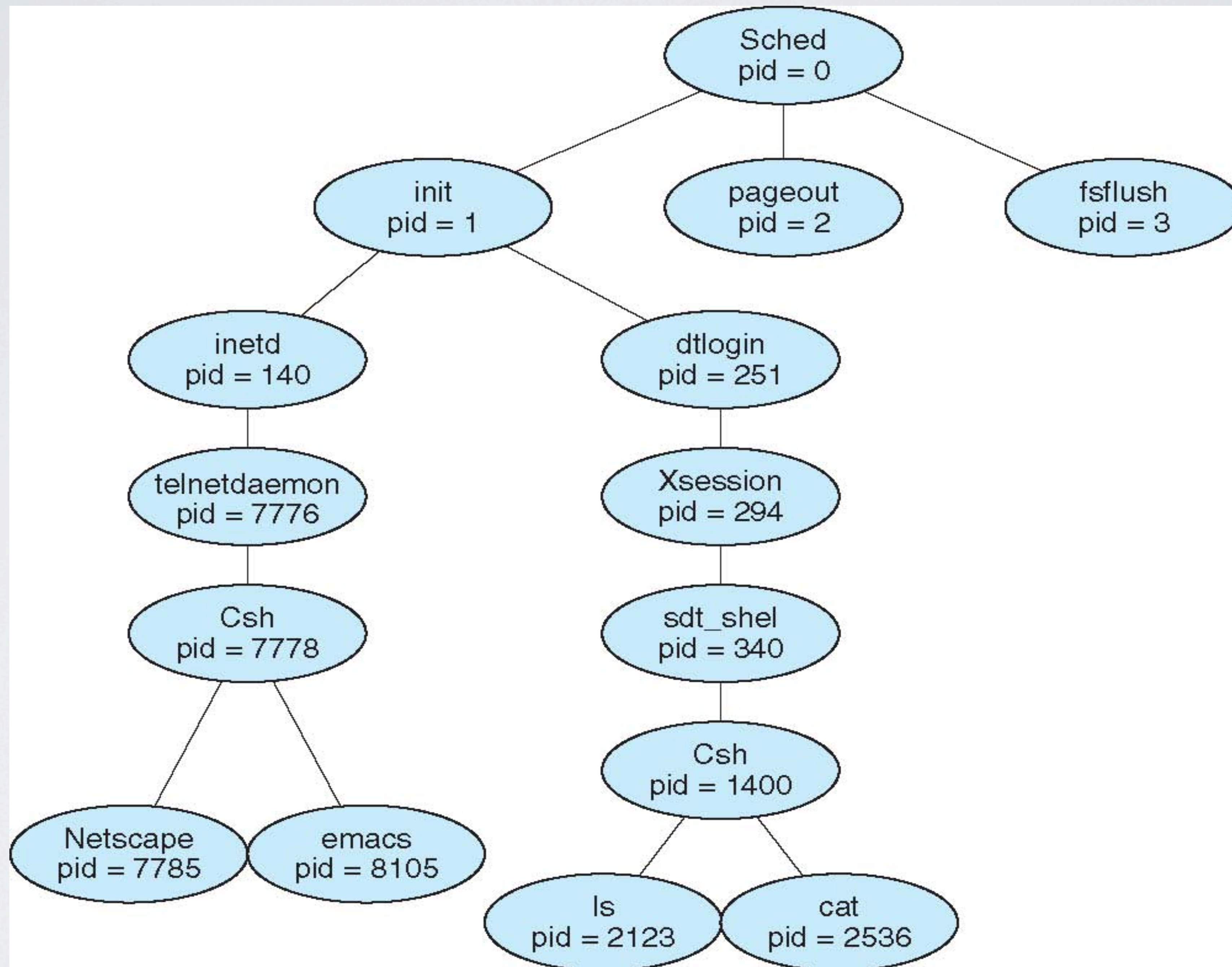
Process Creation



C Program Forking Separate Process

```
#include <sys/types.h>
#include <studio.h>
#include <unistd.h>
int main()
{
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 */
         execlp("/bin/ls", "ls", NULL);
    }
    else { /* parent process */
         /* parent will wait for the child */
         wait (NULL);
         printf ("Child Complete");
    }
    return 0;
}
```

A Tree of Processes 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 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**

Process I/O

- Open files with
  - int open(char *path, int flags)
  - flags allow process to specify read, write, truncate, append
  - returned int is file descriptor
    - Use in subsequent file I/O methods
    - File descriptors are inherited by children
- Other operations
  - int read (int fd, void *buf, int length)
  - int write (int fd, void *buf, int length)
  - int lseek (int fd, off_t pos)
  - int close(int fd)
- Special descriptors exist
  - 0 (stdin), 1 (stdout), 2 (stderr) -- normally attached to terminal