CS420: Operating Systems

Processes

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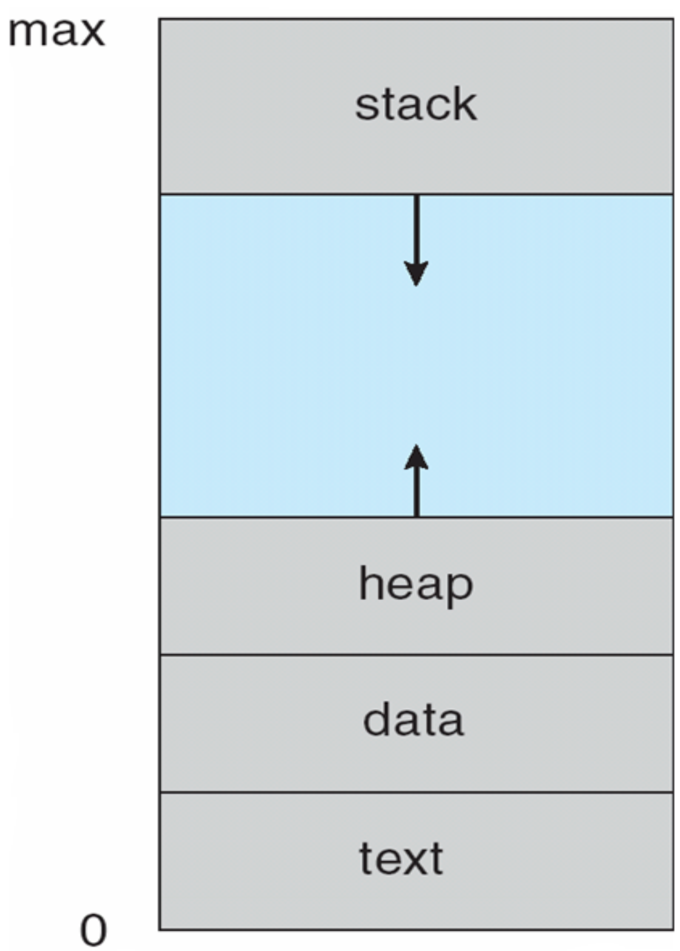
Process Concept

- **Process – a program in execution; process execution must progress in sequential fashion**
- **Textbook uses the terms job and process almost interchangeably**
- **A process includes:**
  - program counter
  - stack
  - data section

The Process

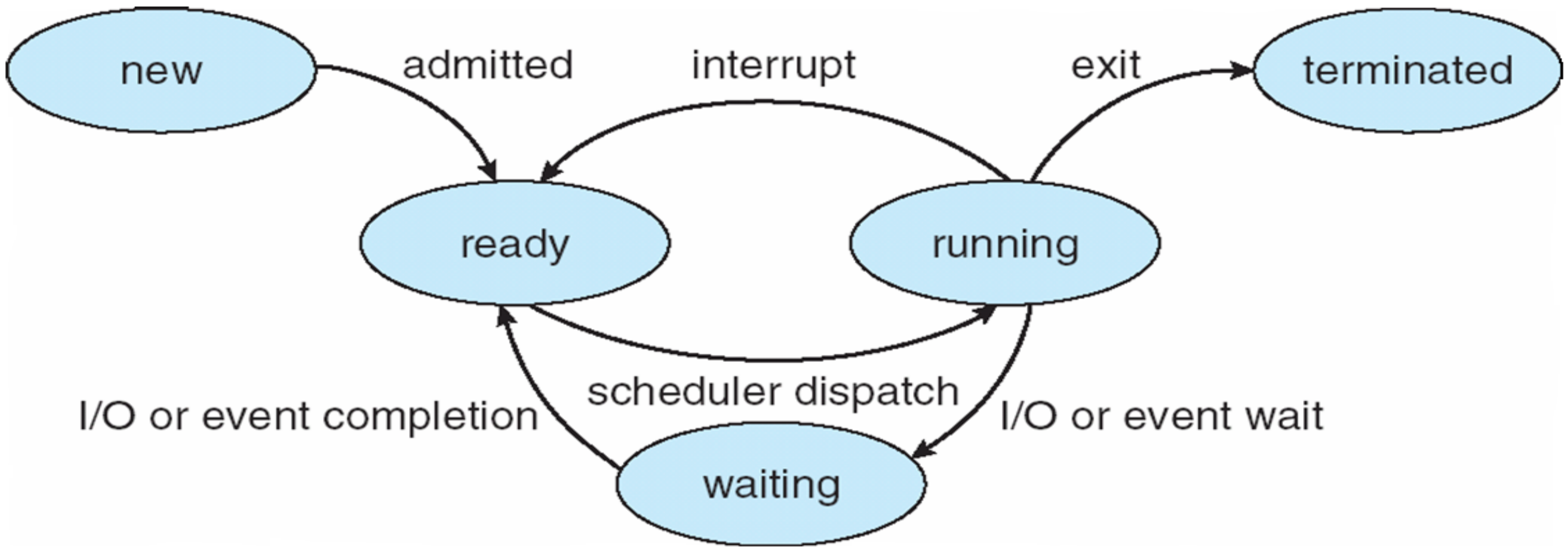
- **Multiple parts**
  - The program code, also called text section
  - Program counter & processor registers
  - Stack containing temporary data
    - Function parameters, return addresses, local variables
  - Data section containing constants and global variables
  - Heap containing memory dynamically allocated during run time
- **A program is passive entity, process is active**
  - Program becomes process when executable file loaded into memory
- **One program can consist of several processes**
- **Multiple processes of the same type may run concurrently**
  - Consider multiple users executing the same program
  - Each has its own memory space



A Process in Memory

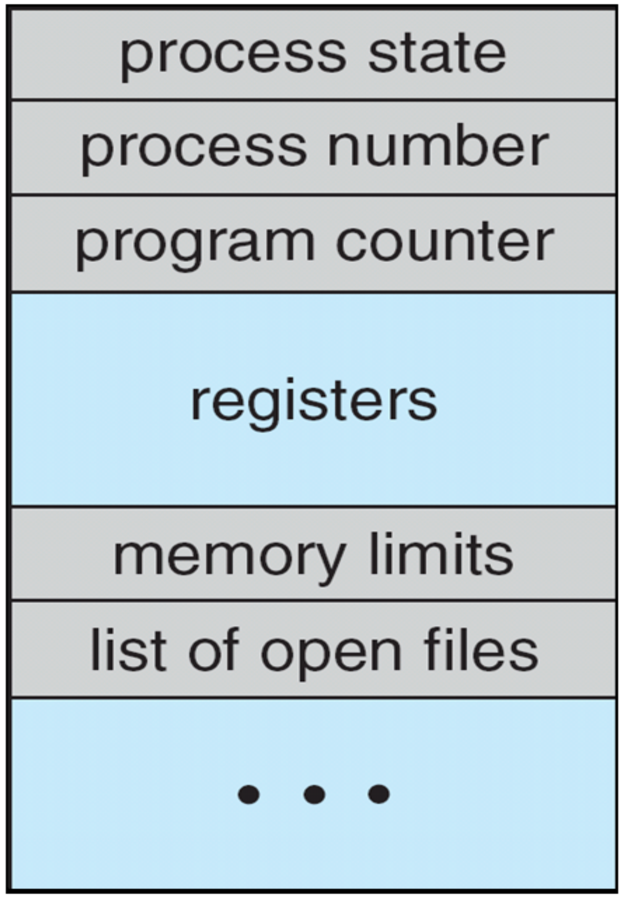
Process State

- **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

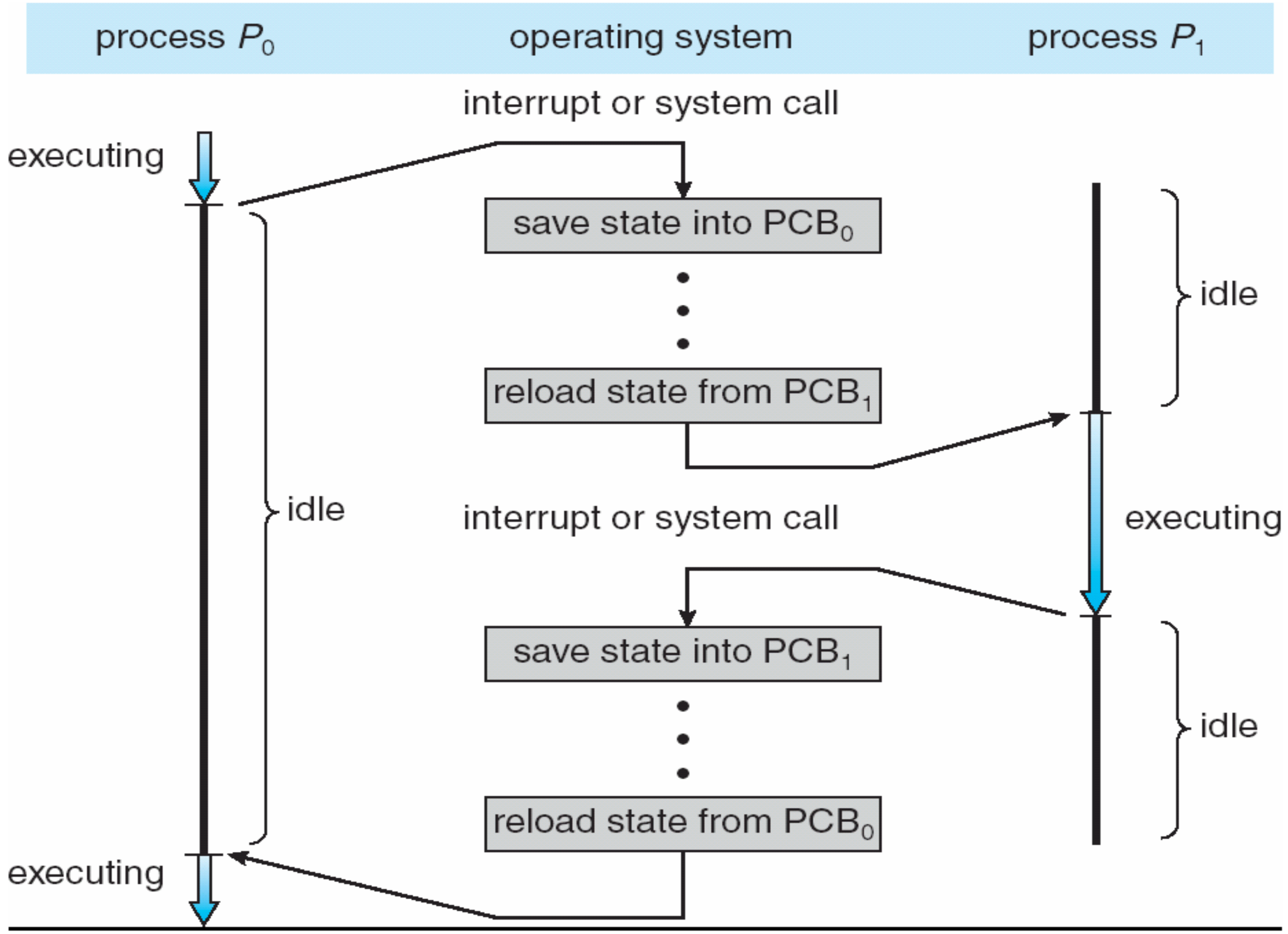


Process Control Block (PCB)

- **Each process is represented in the operating system by a process control block (PCB)**
- **The process control block contains information associated with each process including:**
  - Process state
  - Program counter
  - CPU registers
  - CPU scheduling information
  - Memory-management information
  - Accounting information
  - I/O status information

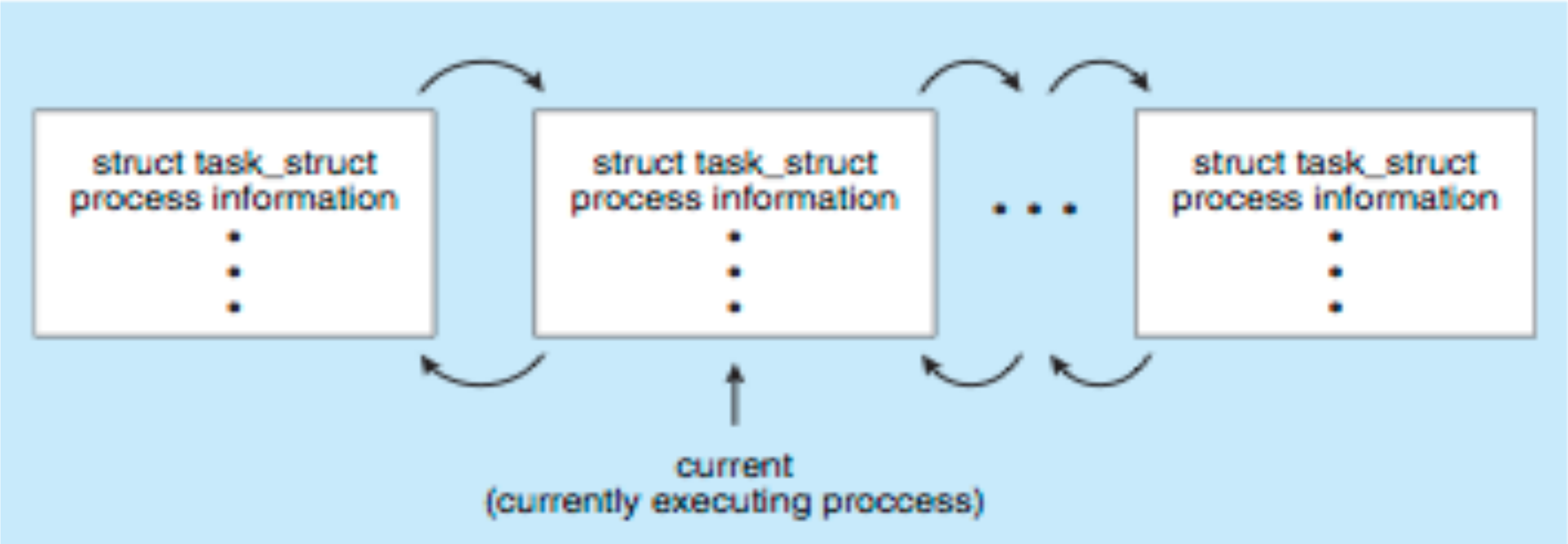


CPU Switch From Process to Process



Process Representation in Linux

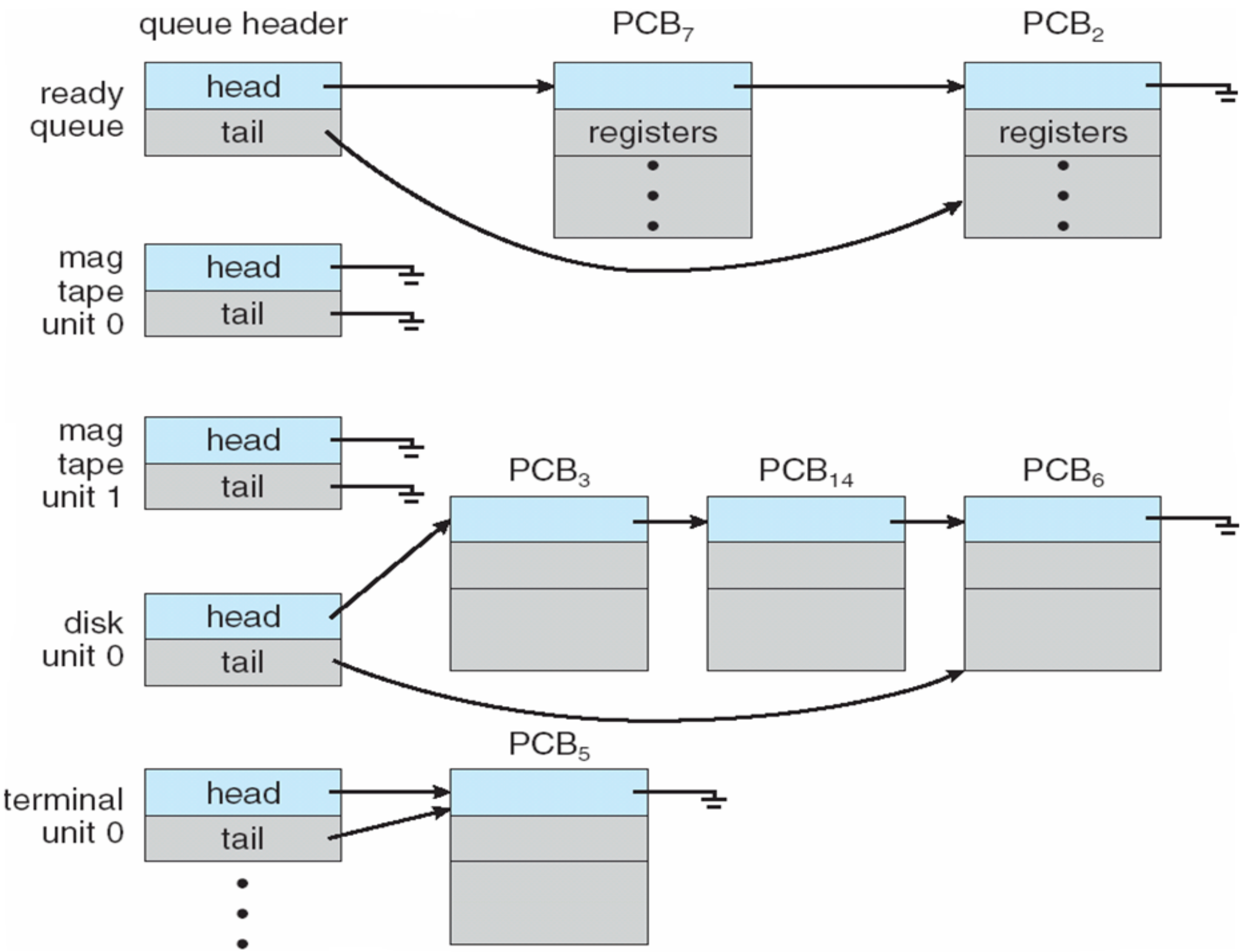
```
struct task_struct
{
  pid t pid;                         /* process identifier */
  long state;                        /* state of the process */
  unsigned int time_slice;           /* scheduling information */
  struct task_struct *parent;        /* this process's parent */
  struct list_head children;         /* this process's children */
  struct files_struct *files;        /* list of open files */
  struct mm_struct *mm;              /* address space of process */
}
```



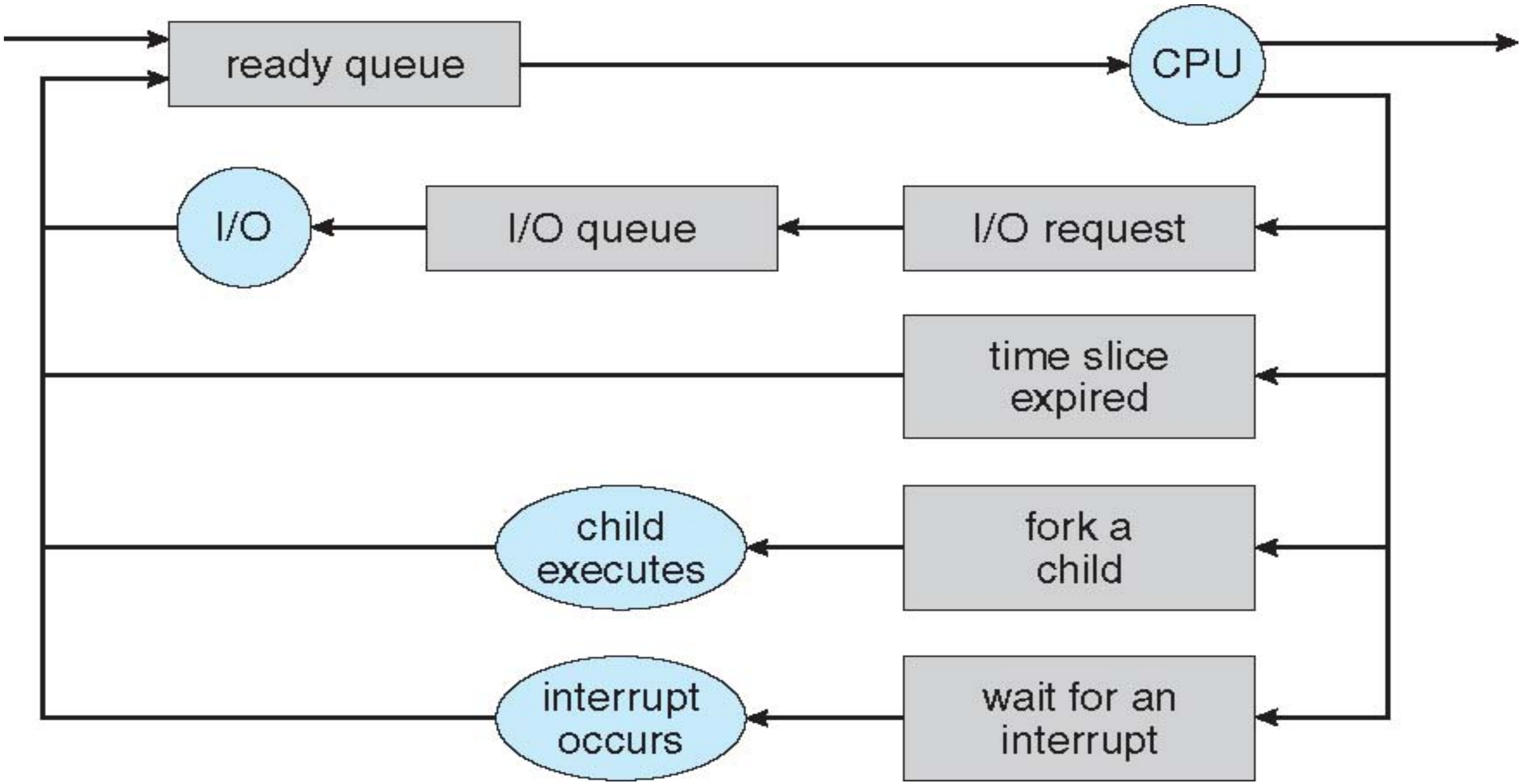
Process Scheduling

- **Want to 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**
  - Long-term scheduler is invoked very infrequently (seconds, minutes) ⇒ (may be slow)
  - The long-term scheduler controls the degree of multiprogramming (i.e. the number of processes in memory)
- **Short-term scheduler (or CPU scheduler) – selects which process should be executed next and allocates CPU**
  - Sometimes the only scheduler in a system
  - Short-term scheduler is invoked very frequently (milliseconds) ⇒ (must be fast)

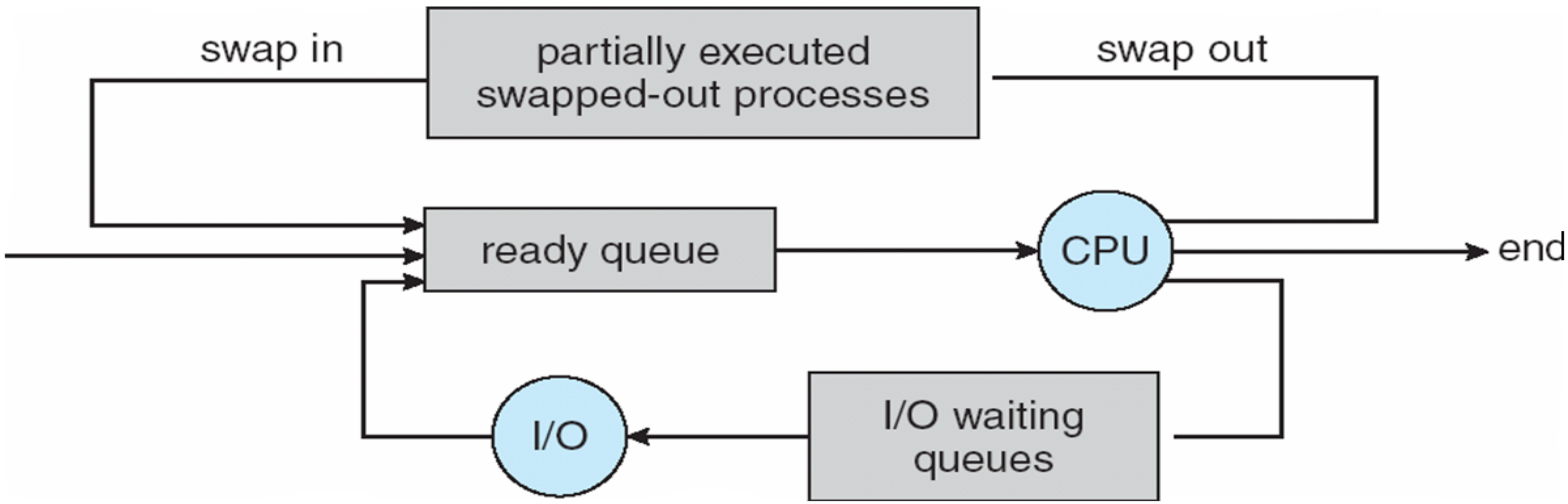
Schedulers (Cont.)

- **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

- **Desirable to achieve a balance of I/O bound processes and CPU-bound processes**

Addition of Medium Term Scheduling

- **Sometimes it is useful to remove processes from memory and return them to memory later**
  - This is called **swapping**



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 (e.g. Intel's hyperthreading)

Process Creation

- **Parent processes create children processes, which, in turn create other processes, forming a tree of processes**
- **Generally, process identified and managed via a process identifier (pid)**
- **Different approaches to resource sharing**
  - Parent and children share all resources
  - Children share subset of parent's resources
  - Parent and child share no resources
- **Different approaches to execution**
  - Parent and children execute concurrently
  - Parent waits until children terminate

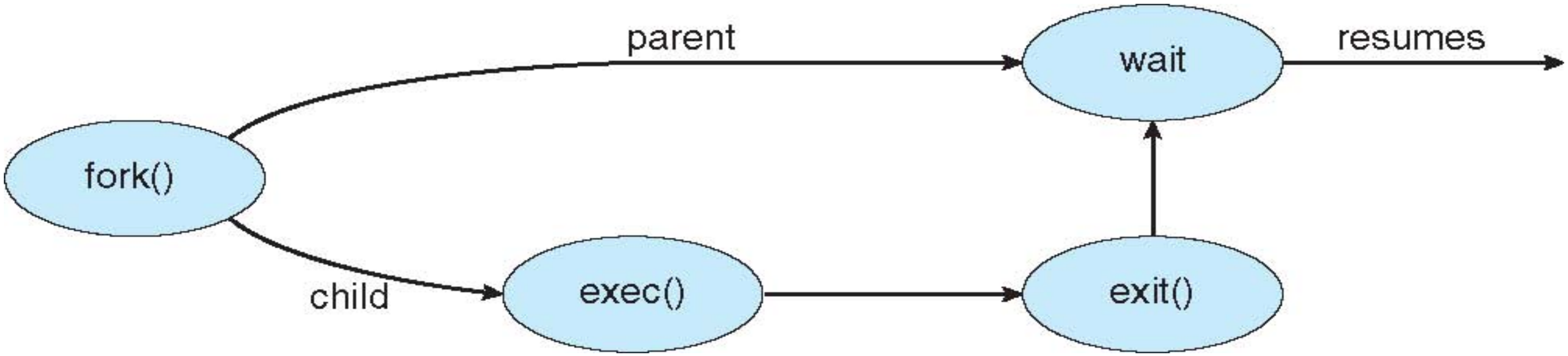
Process Creation (Cont.)

- **Address space options**
  - 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' memory space with a new program

Process Creation

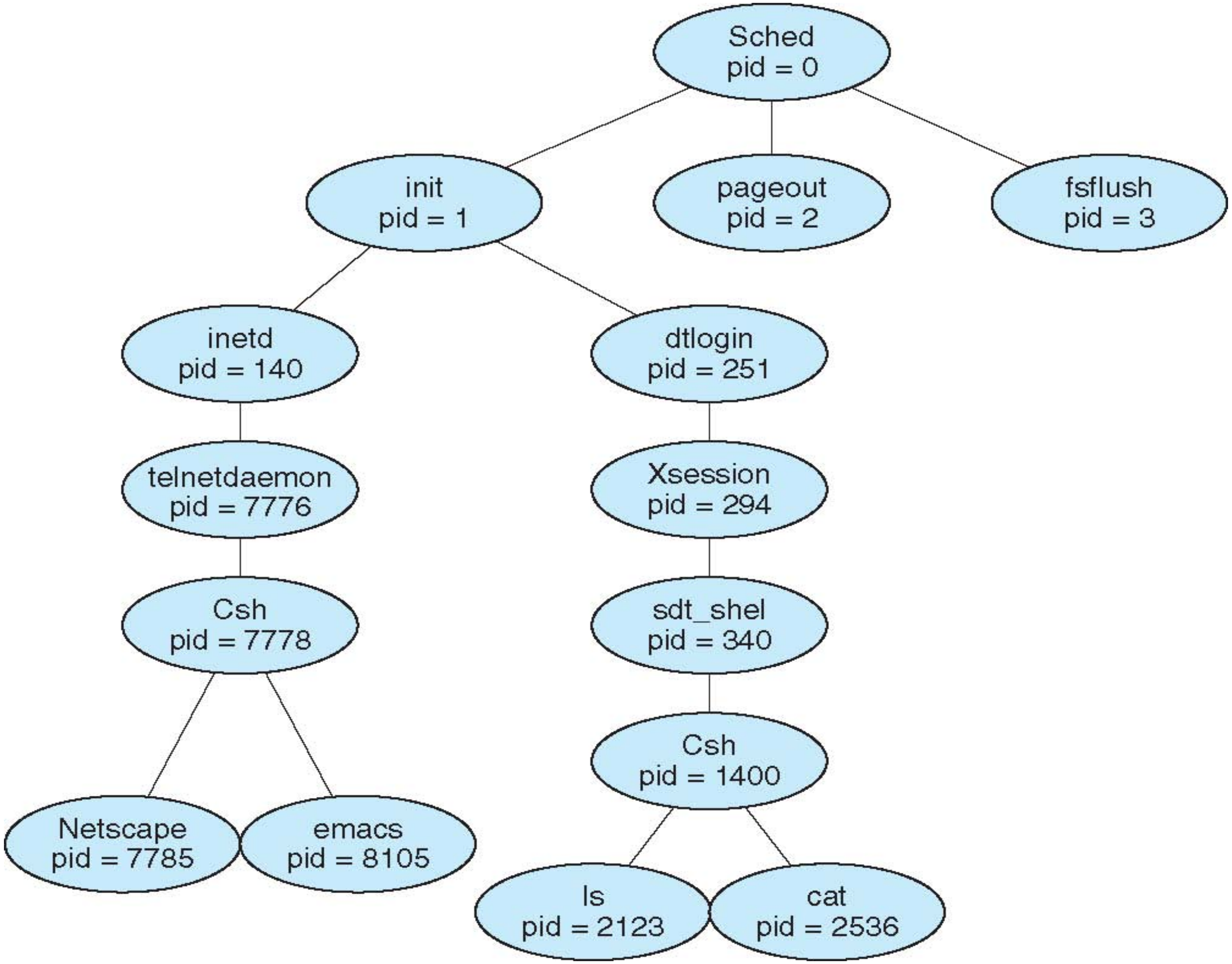
- **Parent waits for child to exit before resuming**



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 Options

- **Process executes last statement and asks the operating system to delete it (exit)**
  - Termination code output 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