CST 347 – Real Time OS

Lecture 04 – Processes

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Definitions

- Concurrency
  - The appearance that threads are running simultaneously even though there is a single CPU.
- Context
  - The “processor” state of a block of executing code. This includes all registers required to uniquely identify this chain of execution.
- Process
  - A group of instructions along with the context defining the execution “state (s)” of those instructions.

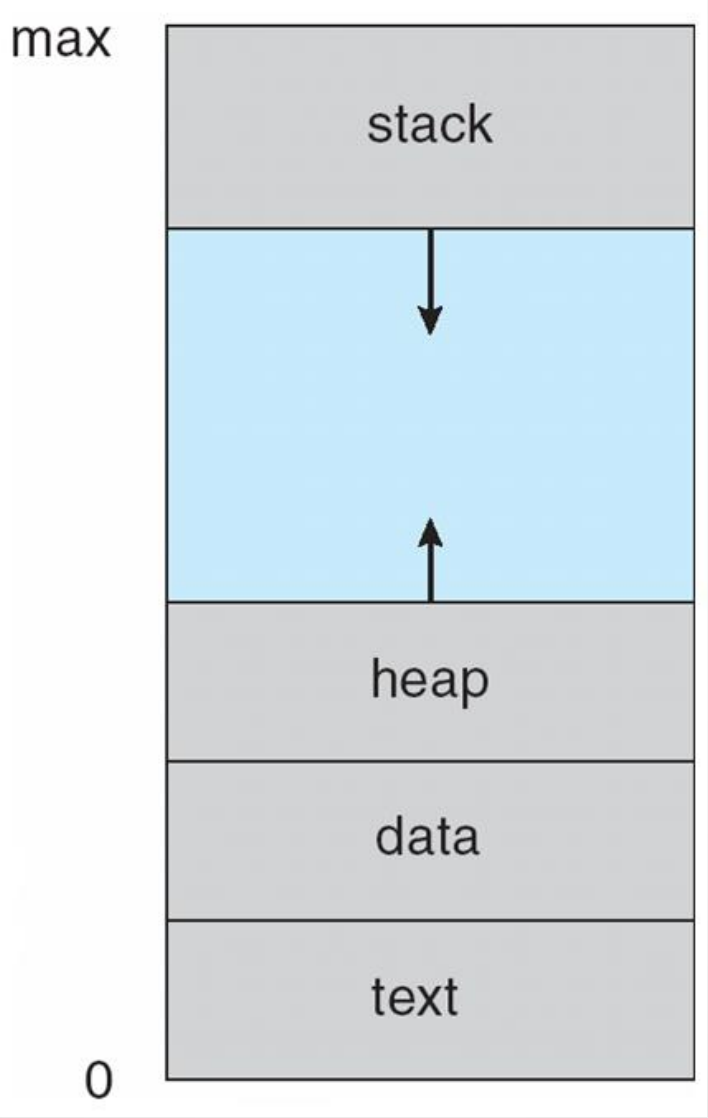
Objectives

- To introduce the notion of a process
  - A program in execution, which forms the basis of all computation
- To describe the various features of processes, including scheduling, creation and termination, and communication

Process Concept

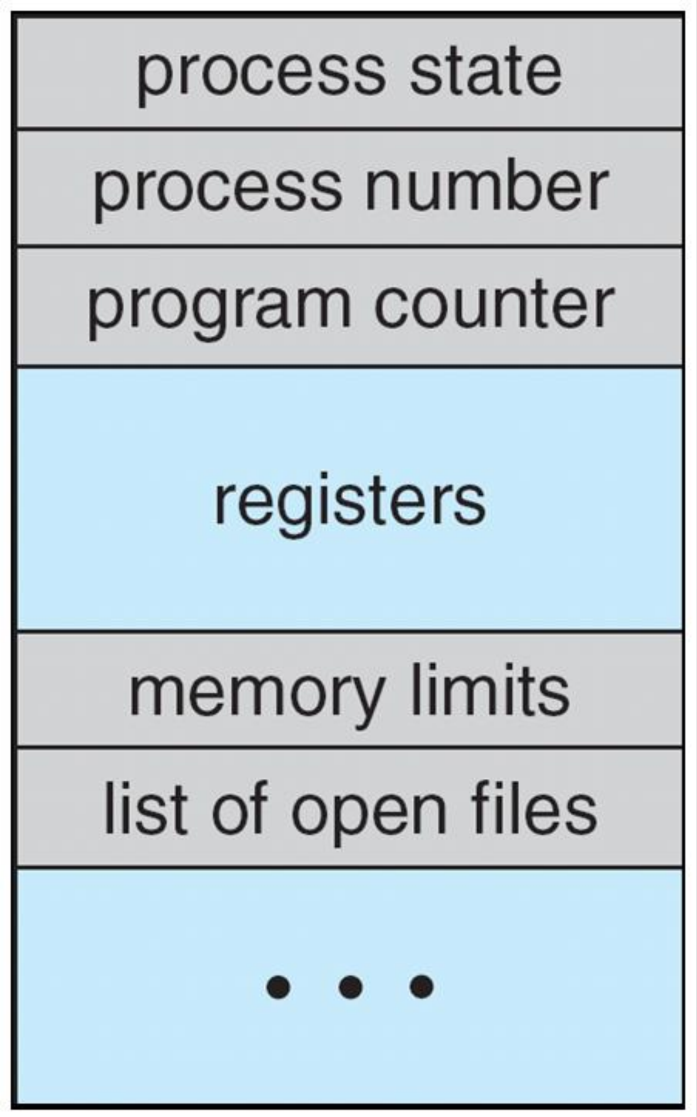
- An operating system executes a variety of programs:
  - Batch system – jobs
  - Time-shared systems – user programs or tasks
- Process – a program in execution; process execution must progress in sequential fashion
  - Multiple parts
    - The program code, also called text section
    - Current activity including program counter, processor registers
    - Stack containing temporary data
      - Function parameters, return addresses, local variables
    - Data section containing global variables
    - Heap containing memory dynamically allocated during run time
- Program is passive entity stored on disk (executable file), 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



Process Control Block (PCB)

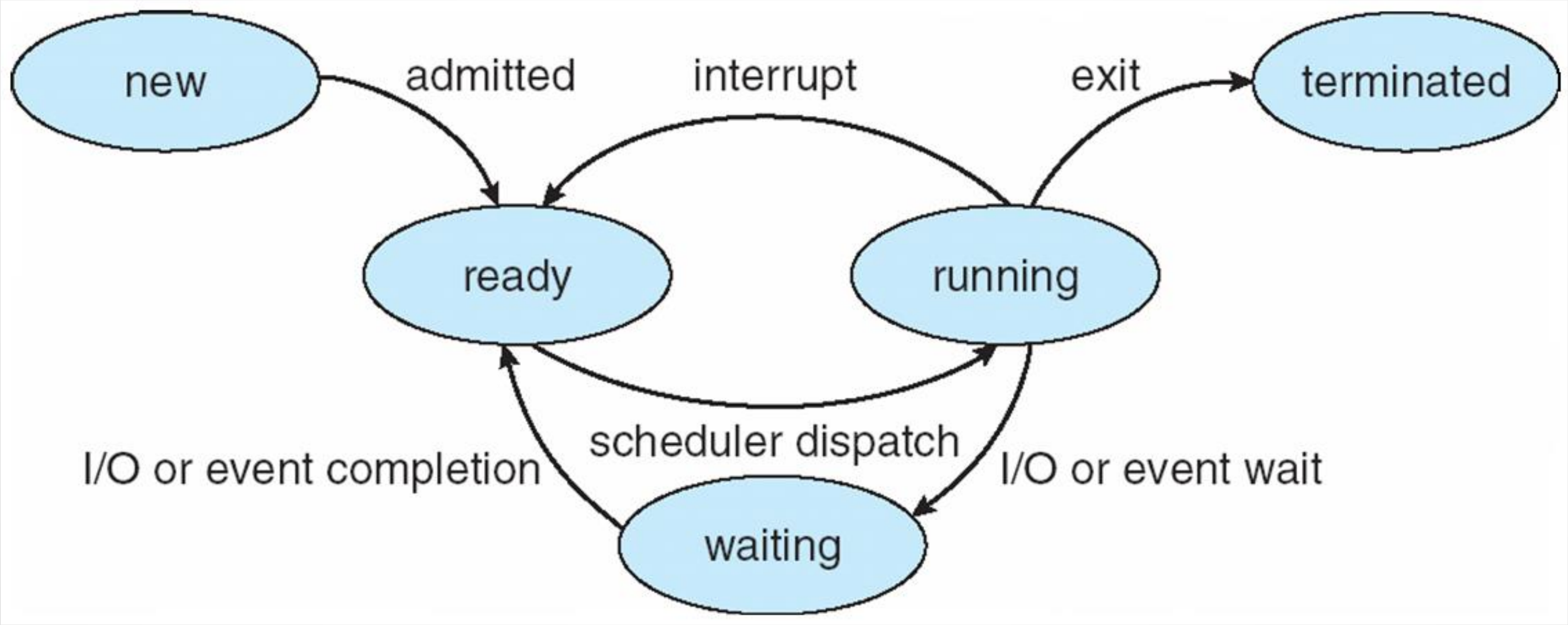
- Information associated with each process (also called task control block)
  - Process state – running, waiting, etc
  - Program counter – location of instruction to next execute
  - CPU registers – contents of all process-centric registers
  - CPU scheduling information- priorities, scheduling queue pointers
  - Memory-management information – memory allocated to the process
  - Accounting information – CPU used, clock time elapsed since start, time limits
  - I/O status information – I/O devices allocated to process, list of open files



Process State

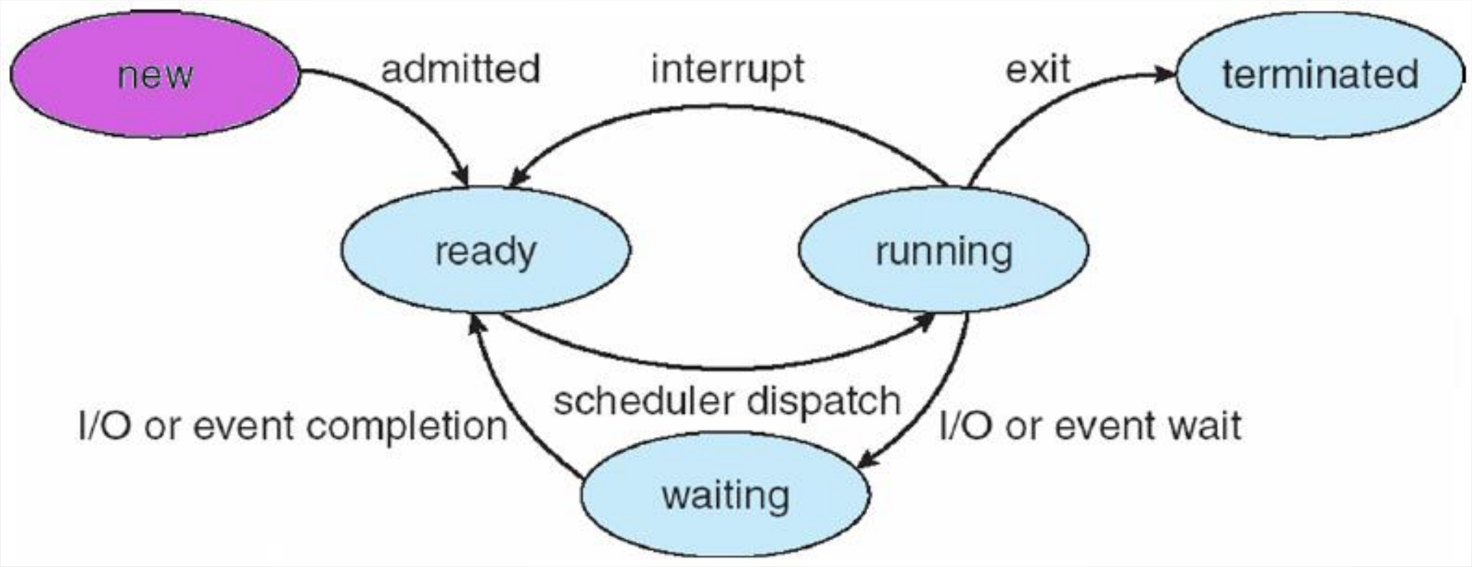
- As a process executes, it changes **state**
  - **new**: The process is being created
  - **running**: Instructions are being executed
  - **waiting**: The process is waiting for some event to occur
  - **ready**: The process is waiting to be assigned to a processor
  - **terminated**: The process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

Diagram of Process State



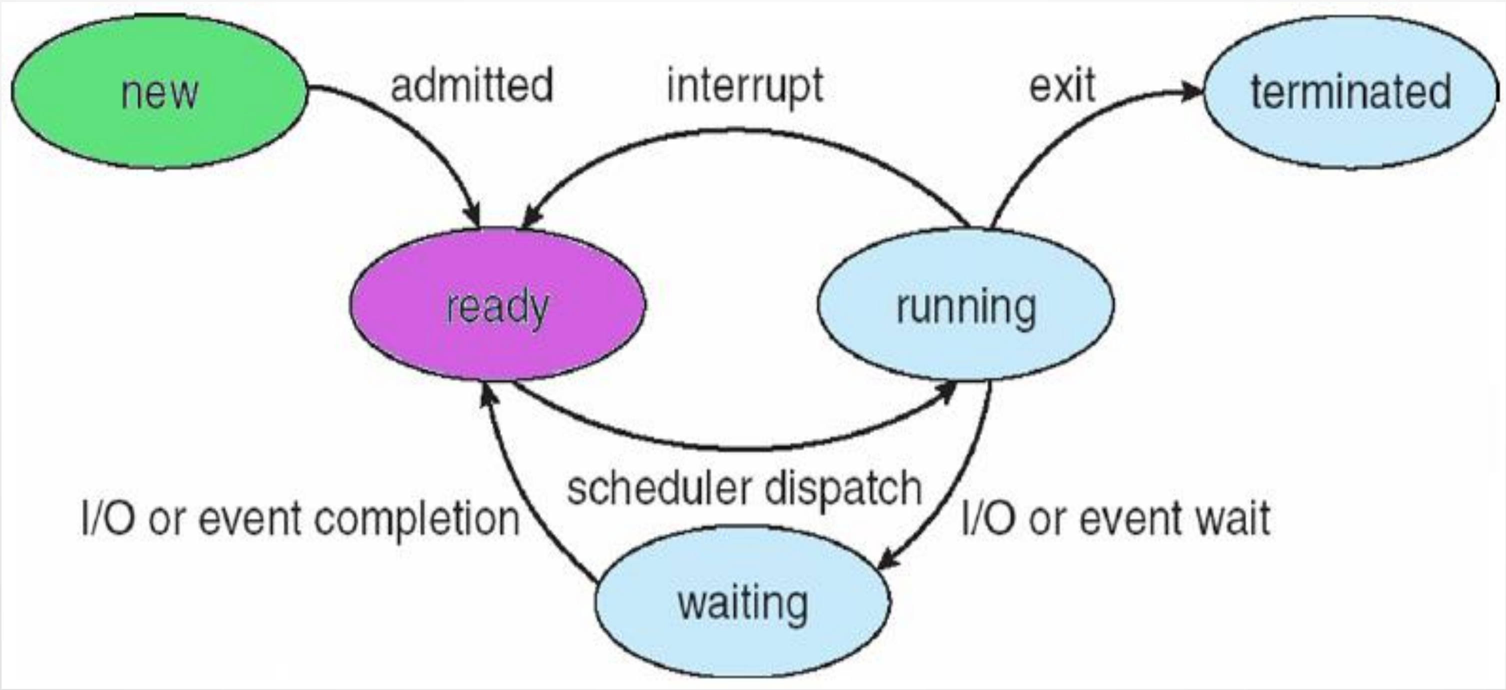
Process State Transition

- Process Creation
  - Scheduler creates the Process Control Block and places it in the new list
    - Create process data segment.
    - Create process code segment.
    - Load op codes from disk into memory
    - Build run-time stack.



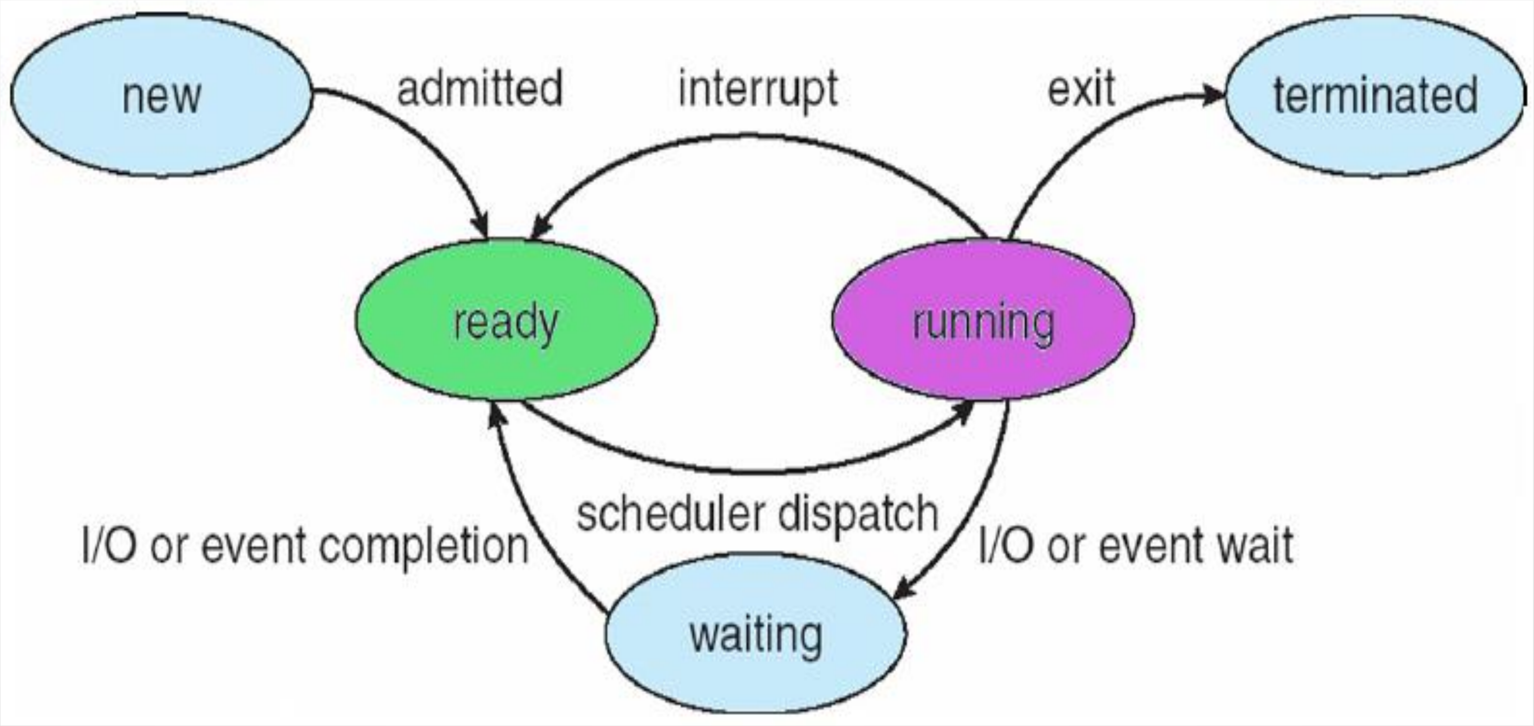
Process State Transition

- Process is admitted by the system and goes to the ready state
  - Process system call is done and ready for execution
  - Process Control Block marked as active



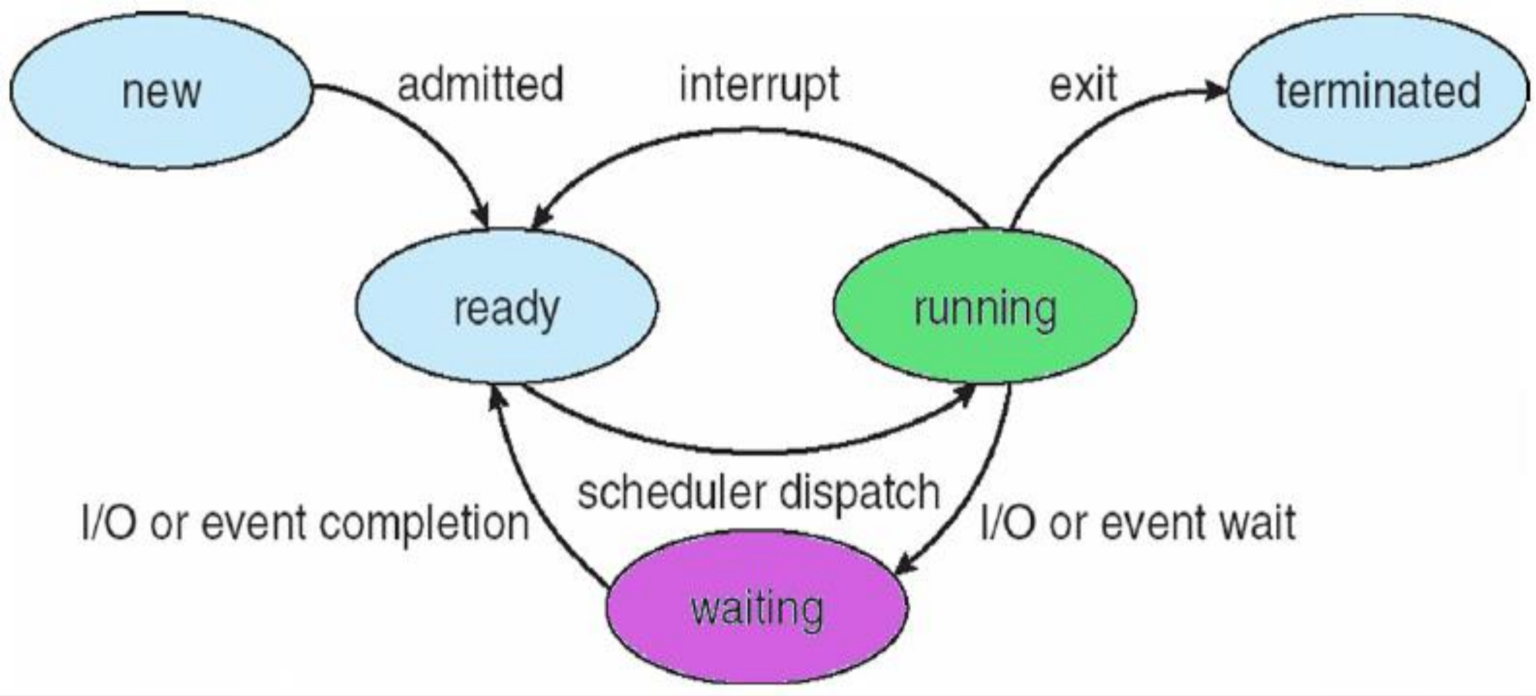
Process State Transition

- Scheduler dispatch
  – Process Control Block is switched into the CPU based on Scheduling algorithm



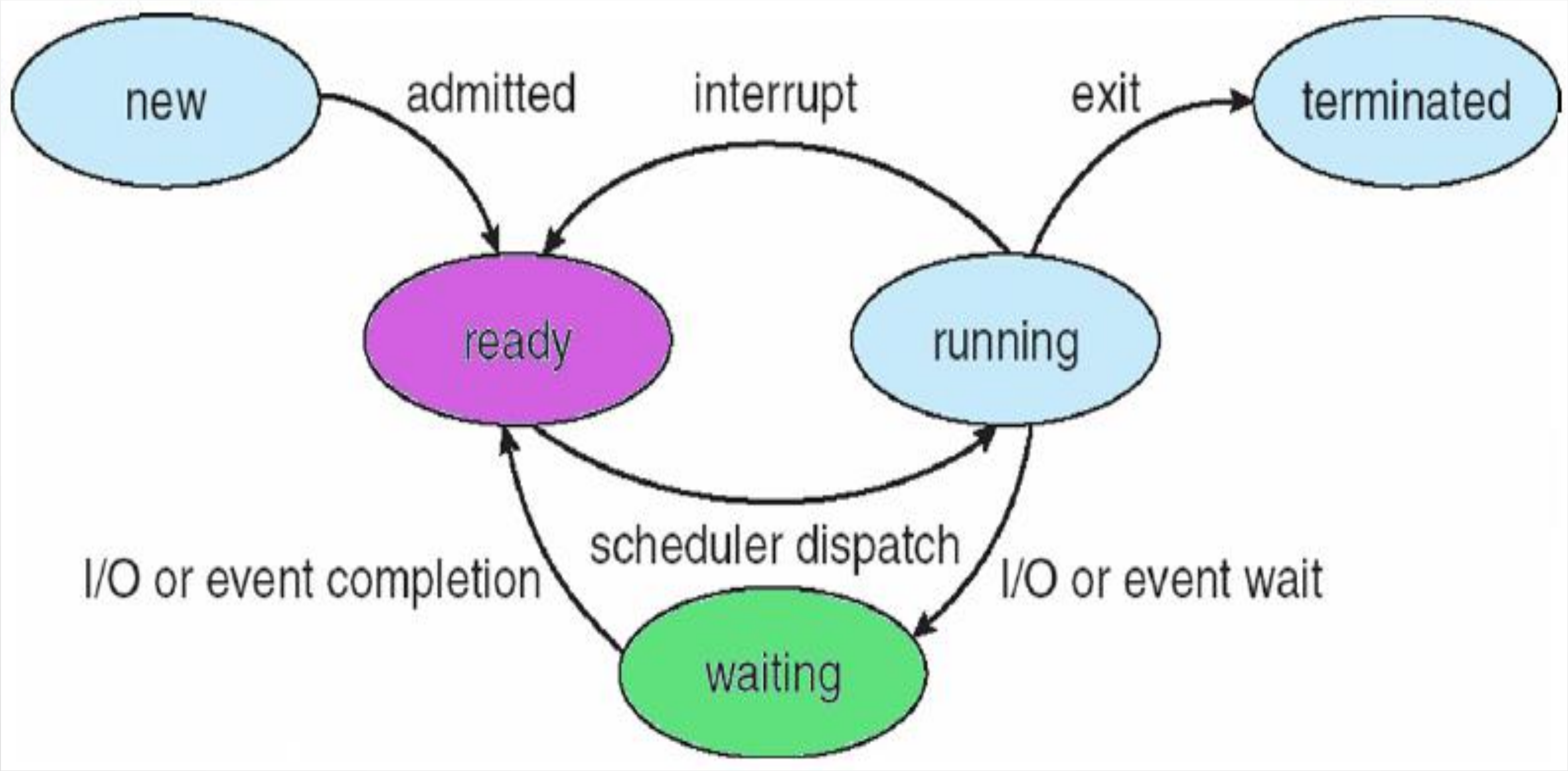
Process State Transition

- IO or event Wait
  - Process requested some unavailable resource
  - Process Control Block is switched out of the CPU and put on waiting list



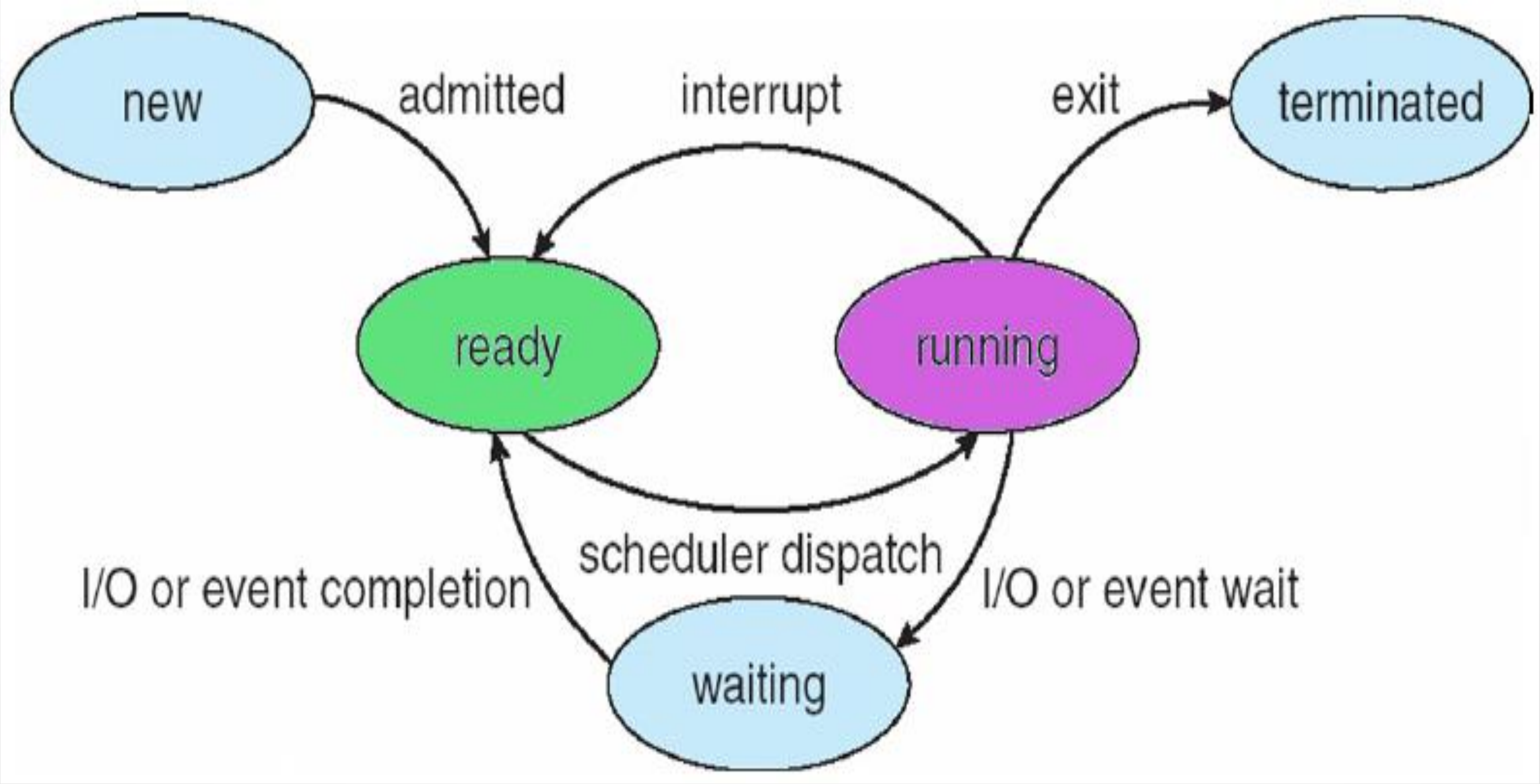
Process State Transition

- Requested resource becomes available
  - Process Control blocked moved from waiting to ready (or active) state



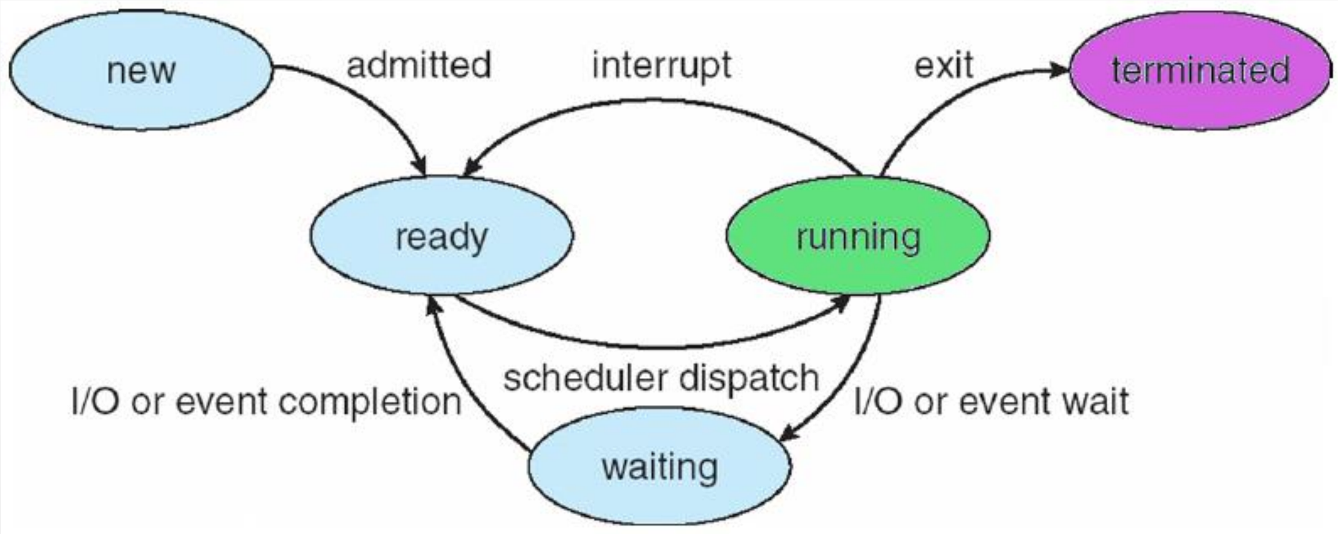
Process State Transition

- Process continues to run based on scheduling algorithm

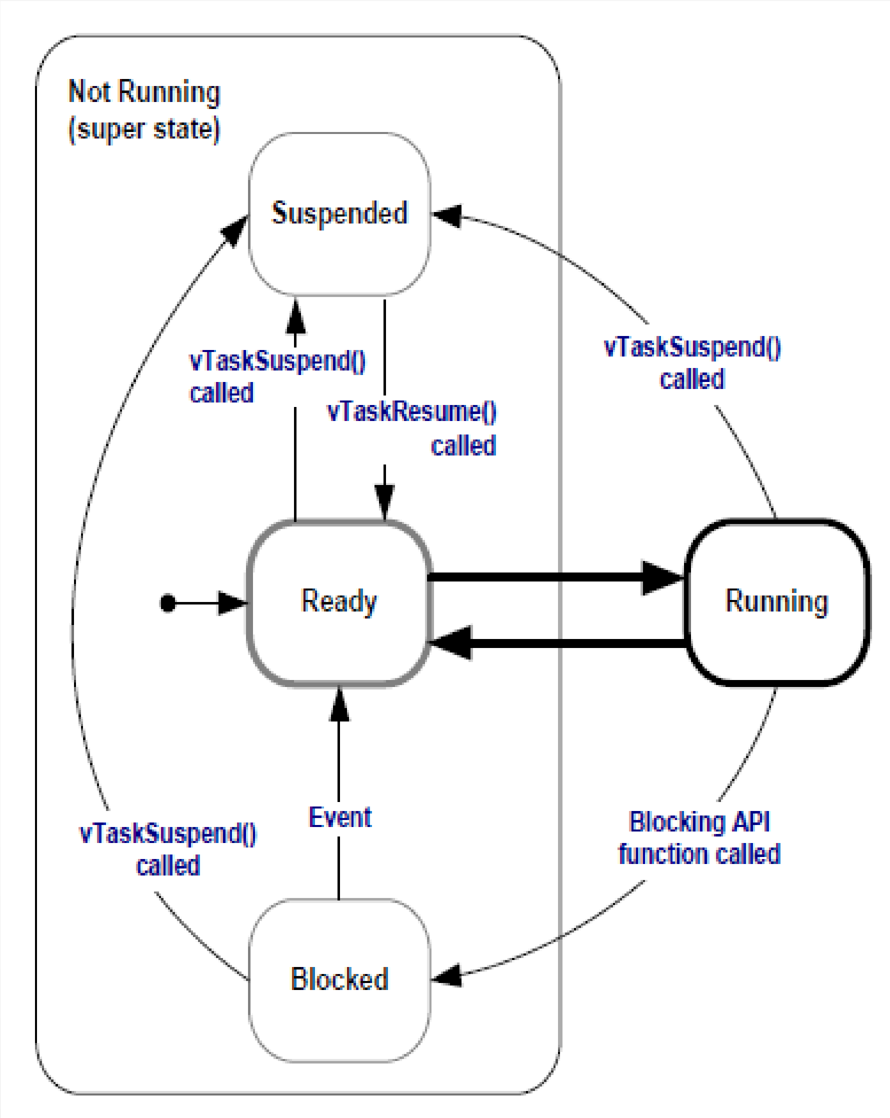


Process State Transition

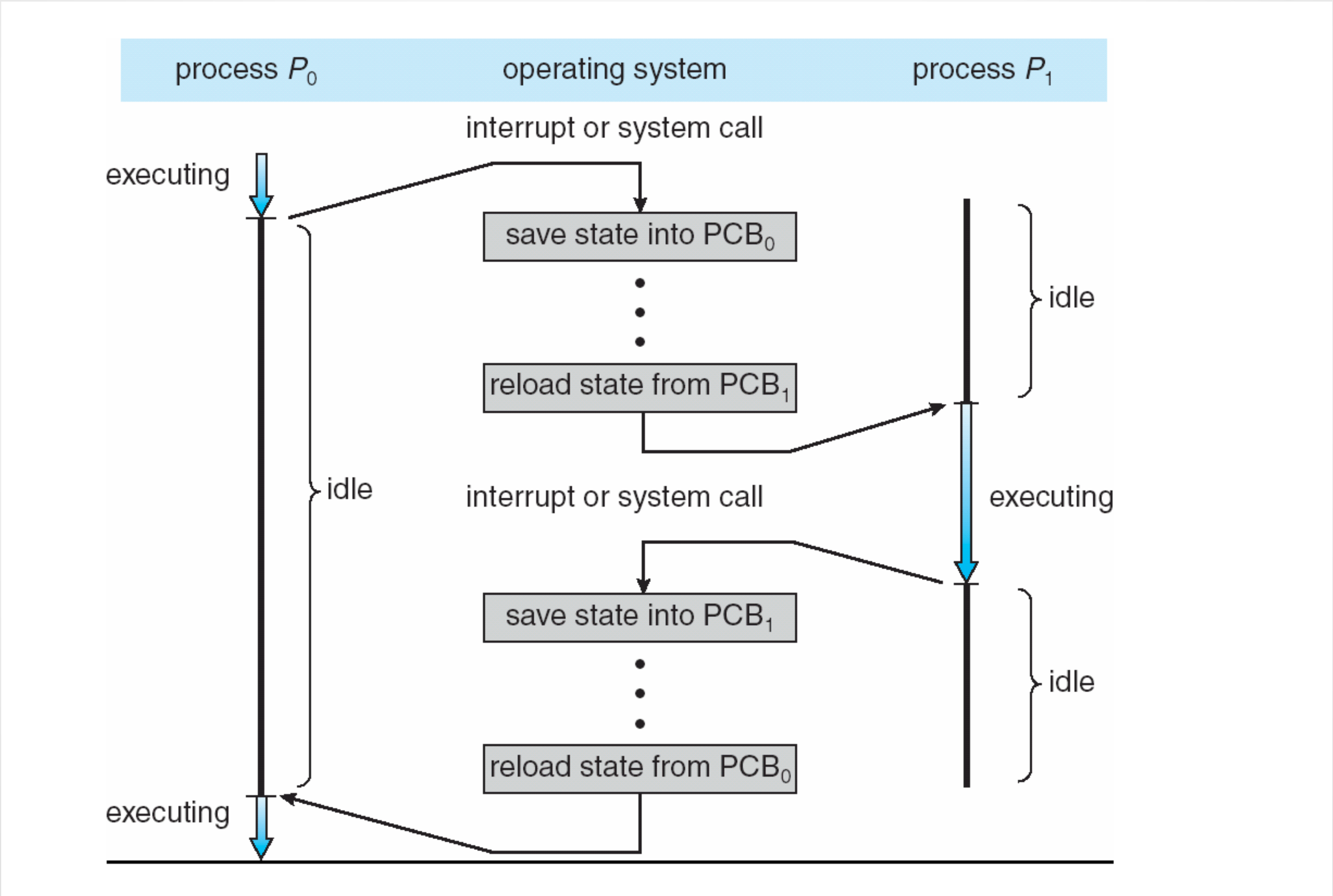
- Process Completes or is terminated by another process
  - Process Resources are returned to OS
  - Process Memory Segment is cleaned up
  - Process Runtime stack is cleaned up



FreeRTOS Task State



CPU Switch From Process to Process



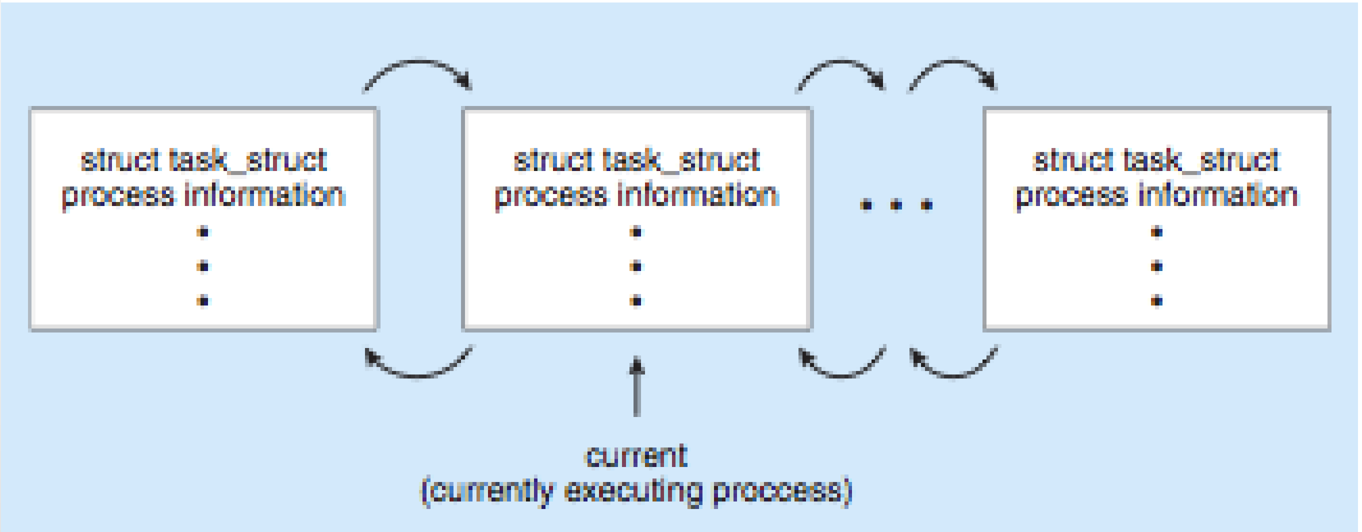
Threads

- So far, A process has a single thread of execution
- Consider having multiple program counters per process
  - Multiple locations can execute at once
    - Multiple threads of control → **threads**
- Must then have storage for thread details, multiple program counters in PCB
- We'll talk more about threads next lecture

Process Representation in Linux

- Represented by the C structure

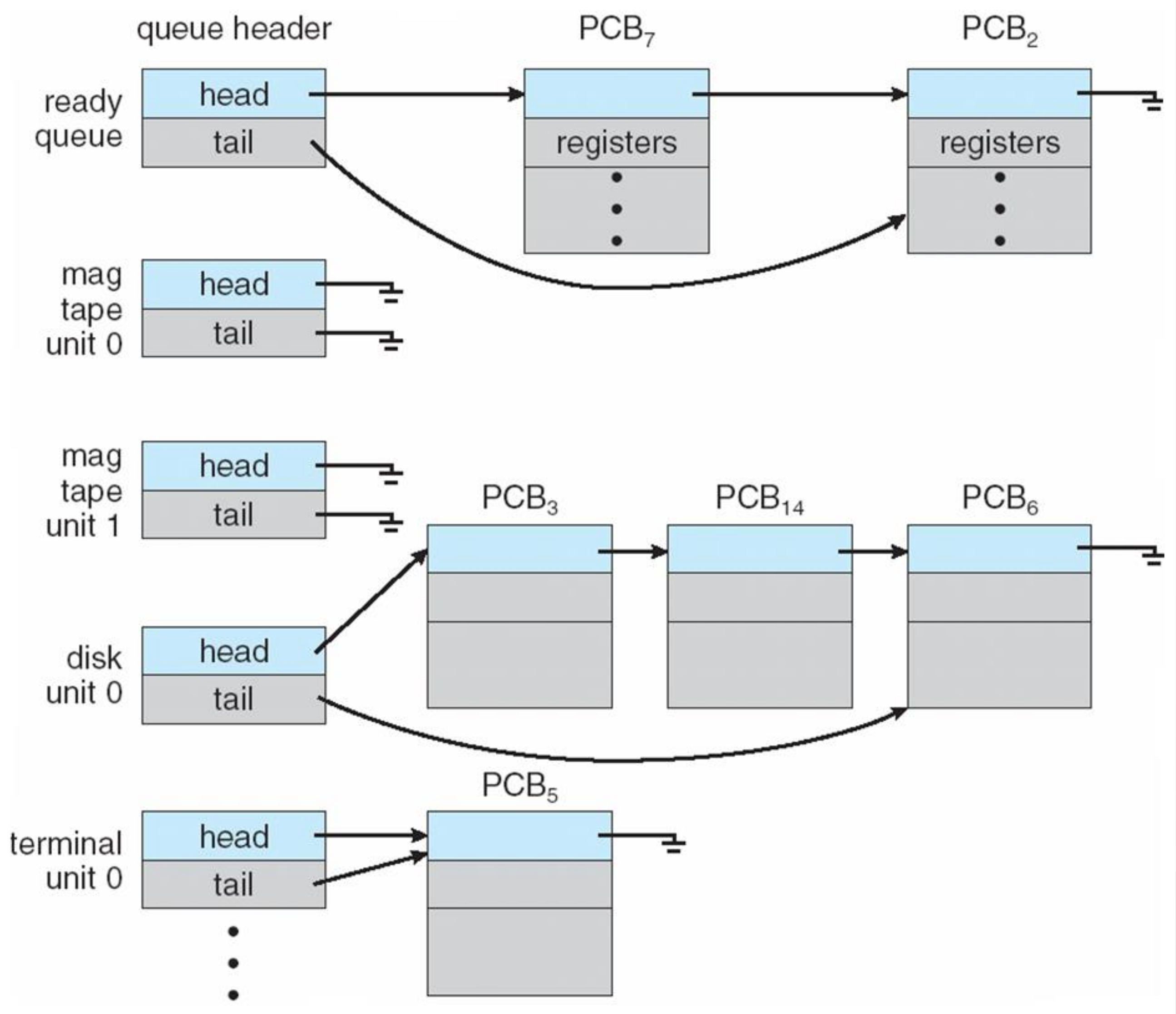
```
struct task_struct
{  pid_t pid;                    /* process identifier */
     long state;                 /* state of the process */
unsigned int time_slice;         /* scheduling information */
struct task_struct *parent;      /* this process's parent */
struct list_head children;       /* this process's children */
struct files_struct *files;      /* list of open files */
struct mm_struct *mm;            /* address space of this process */
}
```



Process Scheduling

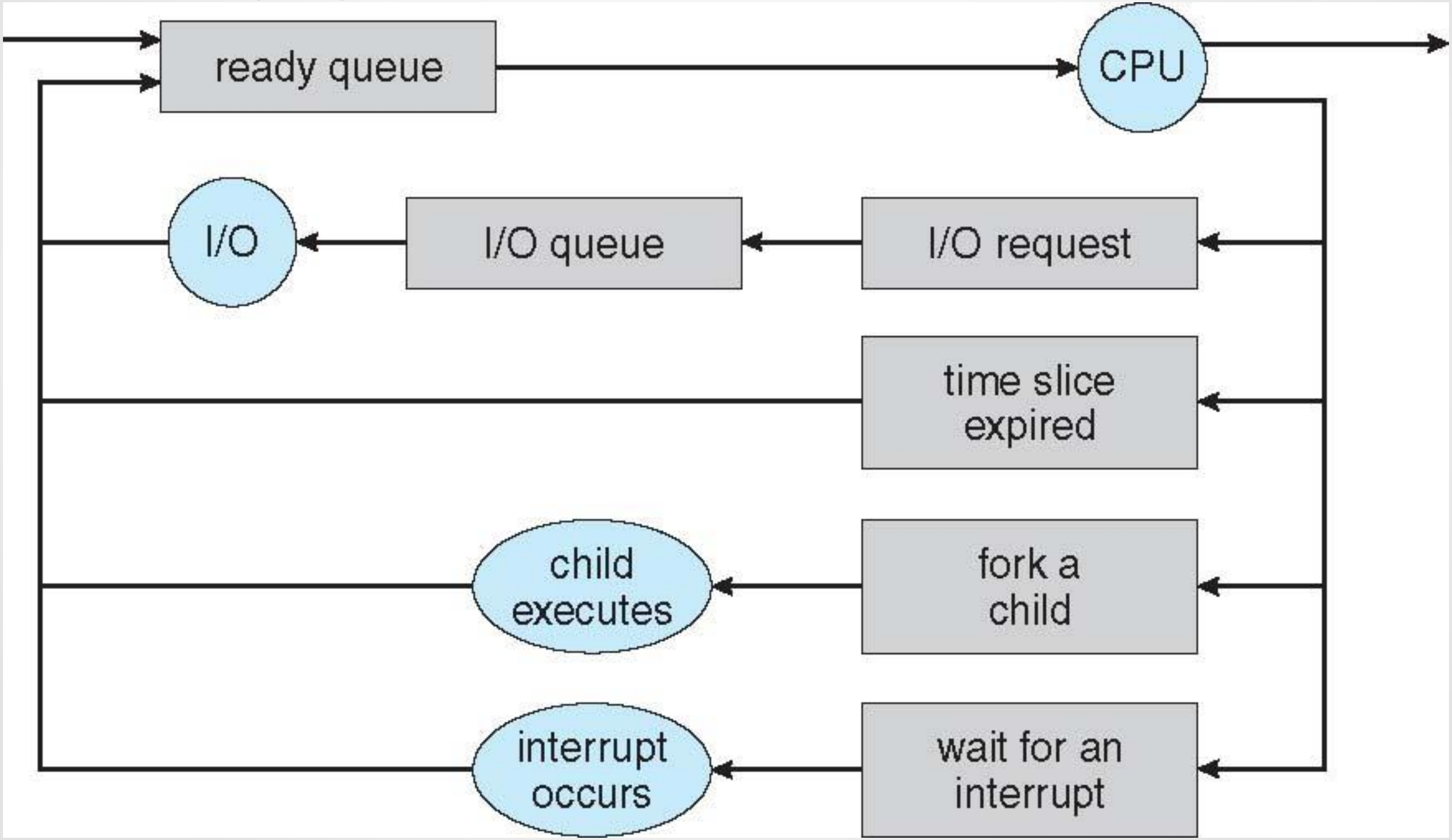
- Maximize CPU use, quickly switch processes onto CPU for time sharing
- **Process scheduler** selects among available processes for next execution on CPU
- Maintains **scheduling queues** of processes
  - **Job queue** – set of all processes in the system
  - **Ready queue** – set of all processes residing 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

- **Queuing diagram** represents queues, resources, flows

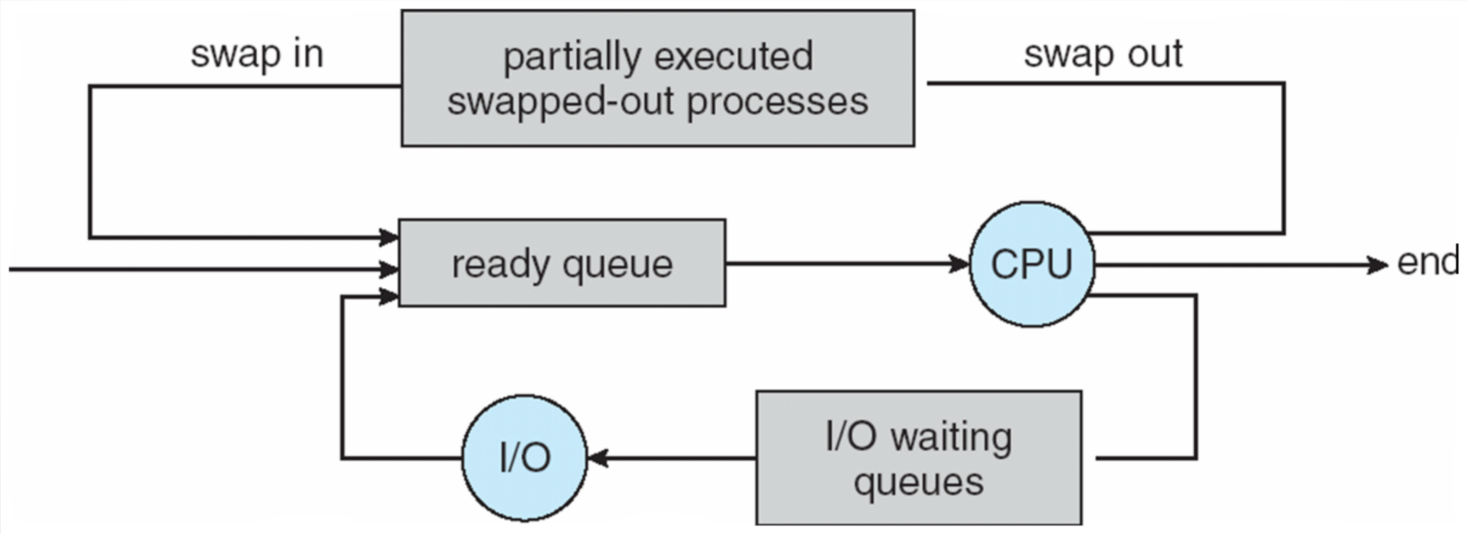


Schedulers

- **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
- 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
- Long-term scheduler strives for good ***process mix***

Addition of Medium Term Scheduling

- Medium-term scheduler can be added if degree of multiple programming needs to decrease
  - Remove process from memory, store on disk, bring back in from disk to continue execution: swapping



Multitasking in Mobile Systems

- Some systems / early systems allow only one process to run, others suspended
- Due to screen real estate, user interface limits iOS provides for a
  - Single **foreground** process- controlled via user interface
  - Multiple **background** processes– in memory, running, but not on the display, and with limits
  - Limits include single, short task, receiving notification of events, specific long-running tasks like audio playback
- Android runs foreground and background, with fewer limits
  - Background process uses a **service** to perform tasks
  - Service can keep running even if background process is suspended
  - Service has no user interface, small memory use

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

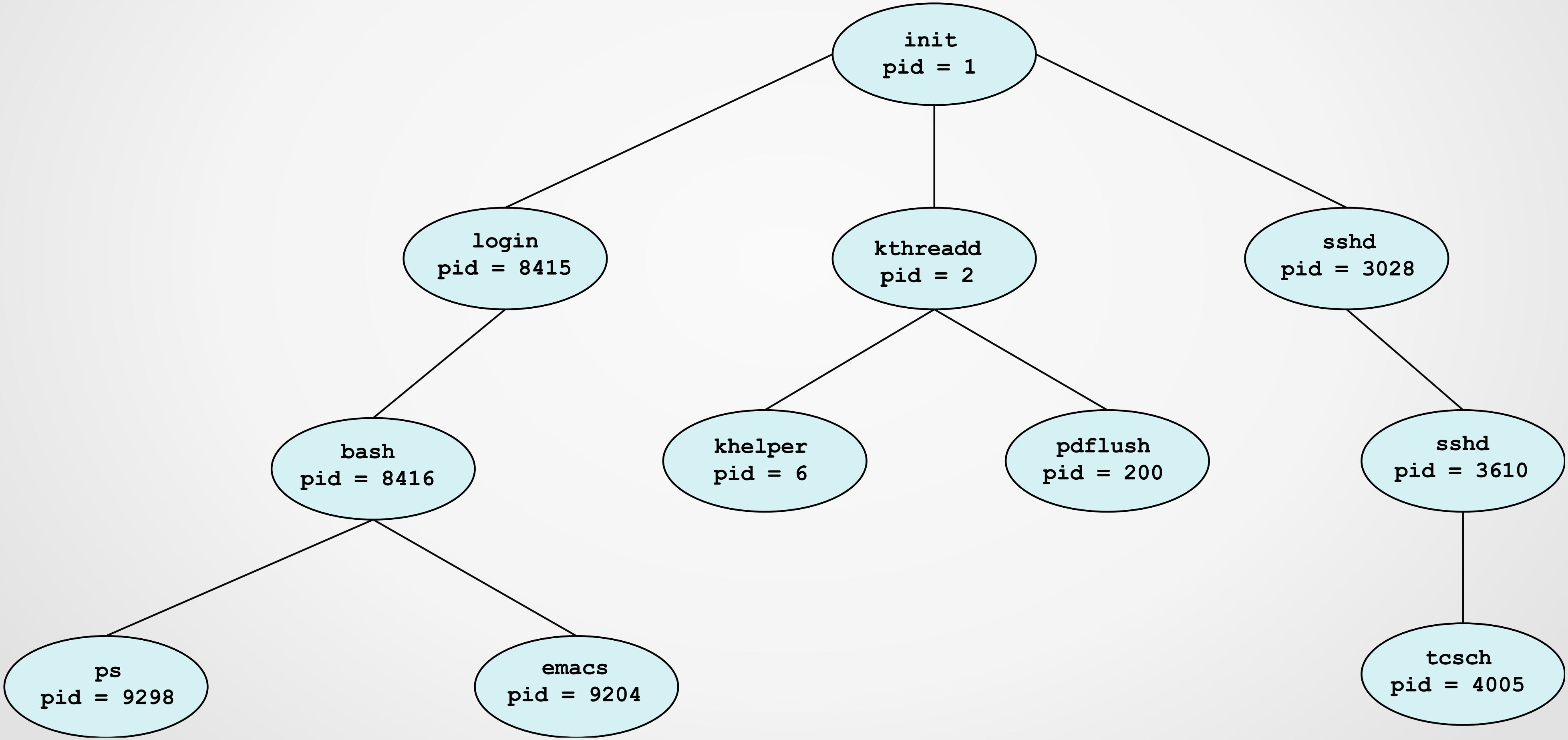
Operations on Processes

- System must provide mechanisms for process creation, termination, and so on as detailed next

Process Creation

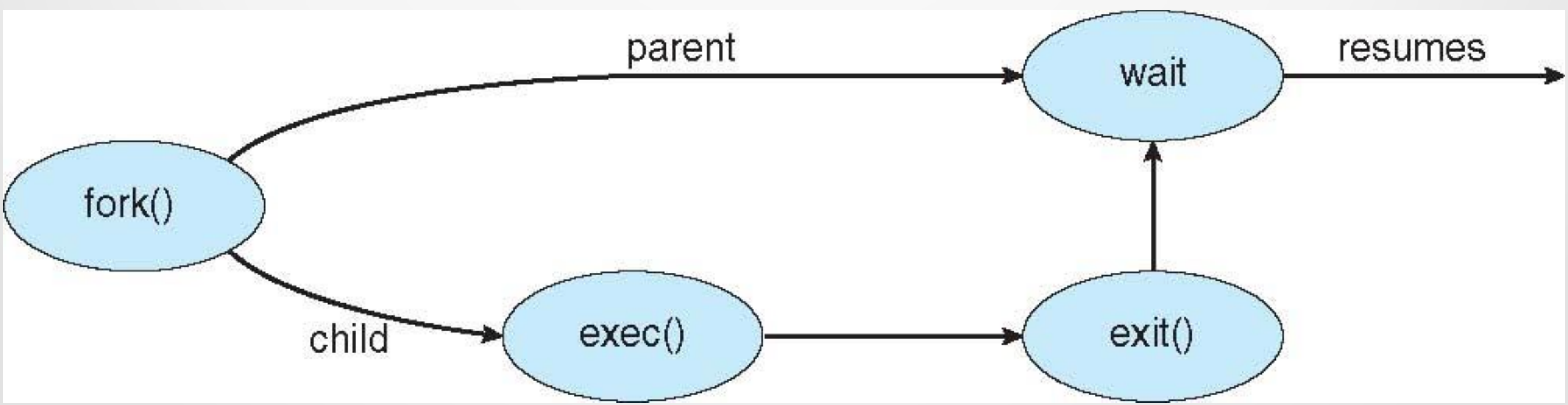
- **Parent** process create **children** processes, which, in turn create other processes, forming a **tree** of processes
- Generally, process identified and managed via a **process identifier** (**pid**)
- Resource sharing options
  - Parent and children share all resources
  - Children share subset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

A Tree of Processes in Linux



Process Creation (Cont.)

- Address space
  - Child duplicate of parent
  - Child has a program loaded into it
- UNIX examples
  - **fork()** system call creates new process



C Program Forking Separate Process

```
#include <sys/types.h>
#include <stdio.h>
#include <unistd.h>

int main()
{
pid_t pid;

    /* fork a child 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 to complete */
       wait(NULL);
       printf("Child Complete");
    }

    return 0;
}
```

Creating a Separate Process via Windows API

```
#include <stdio.h>
#include <windows.h>

int main(VOID)
{
STARTUPINFO si;
PROCESS_INFORMATION pi;

   /* allocate memory */
   ZeroMemory(&si, sizeof(si));
   si.cb = sizeof(si);
   ZeroMemory(&pi, sizeof(pi));

   /* create child process */
   if (!CreateProcess(NULL, /* use command line */
    "C:\\WINDOWS\\system32\\mspaint.exe", /* command */
    NULL, /* don't inherit process handle */
    NULL, /* don't inherit thread handle */
    FALSE, /* disable handle inheritance */
    0, /* no creation flags */
    NULL, /* use parent's environment block */
    NULL, /* use parent's existing directory */
    &si,
    &pi))
   {
     fprintf(stderr, "Create Process Failed");
     return -1;
   }
   /* parent will wait for the child to complete */
   WaitForSingleObject(pi.hProcess, INFINITE);
   printf("Child Complete");

   /* close handles */
   CloseHandle(pi.hProcess);
   CloseHandle(pi.hThread);
}
```

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**
- Wait for termination, returning the pid:

```
pid t pid; int status;

pid = wait(&status);
```

- If no parent waiting, then terminated process is a zombie
- If parent terminated, processes are orphans

Multiprocess Architecture – Chrome Browser

- Many web browsers ran as single process (some still do)
  - If one web site causes trouble, entire browser can hang or crash
- Google Chrome Browser uses multiprocesses with 3 categories:
  - **Browser** process manages user interface, disk and network I/O
  - **Renderer** process renders web pages, deals with HTML, Javascript, new one for each website opened
    - Runs in **sandbox** restricting disk and network I/O, minimizing effect of security exploits
  - **Plug-in** process for each type of plug-in