CS370 Operating Systems

Colorado State University

Yashwant K Malaiya

Fall 21 Lecture 4

OS Structures/Processes

Slides based on

- Text by Silberschatz, Galvin, Gagne
- Various sources

FAQ

- Bash commands: see Self Exercise 1
- API vs system call User programs in a high level language use APIs, APIs are wrappers for system calls that call system routines. Example Linux x-86 system call code.
- Why do we need API (application programing interface)? So that we don't have to write the code in assembly. Example
- Who came up with API standard POSIX? Committees of experts.

CS370 OS   Ch3   Processes

- Process Concept: a program in execution
- Process Scheduling
- Processes creation and termination
- Interprocess Communication using shared memory and message passing

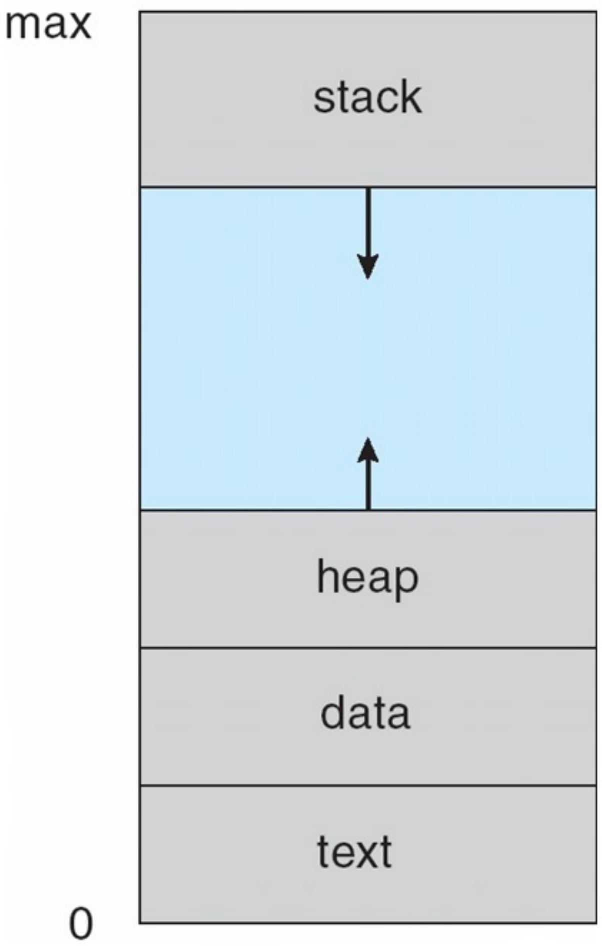
Process Concept

- 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. Includes
  - 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

Process Concept (Cont.)

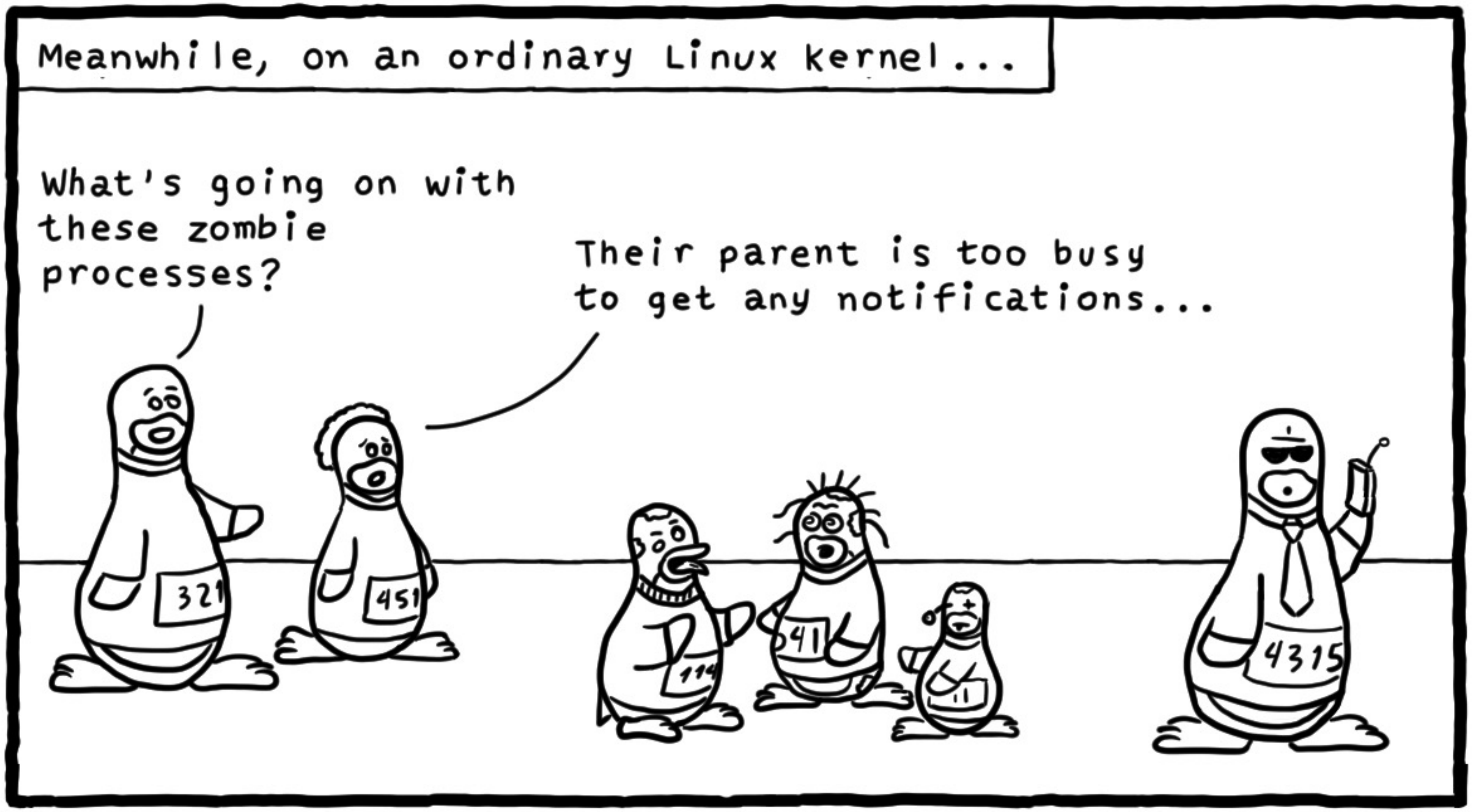
- Program is ***passive*** entity stored on disk (**executable file**), process is ***active***
  - Program becomes process when executable file loaded into memory
- Execution of program started via GUI mouse clicks, command line entry of its name, etc
- One program can be several processes
  - Consider multiple users executing the same program

Process in Memory



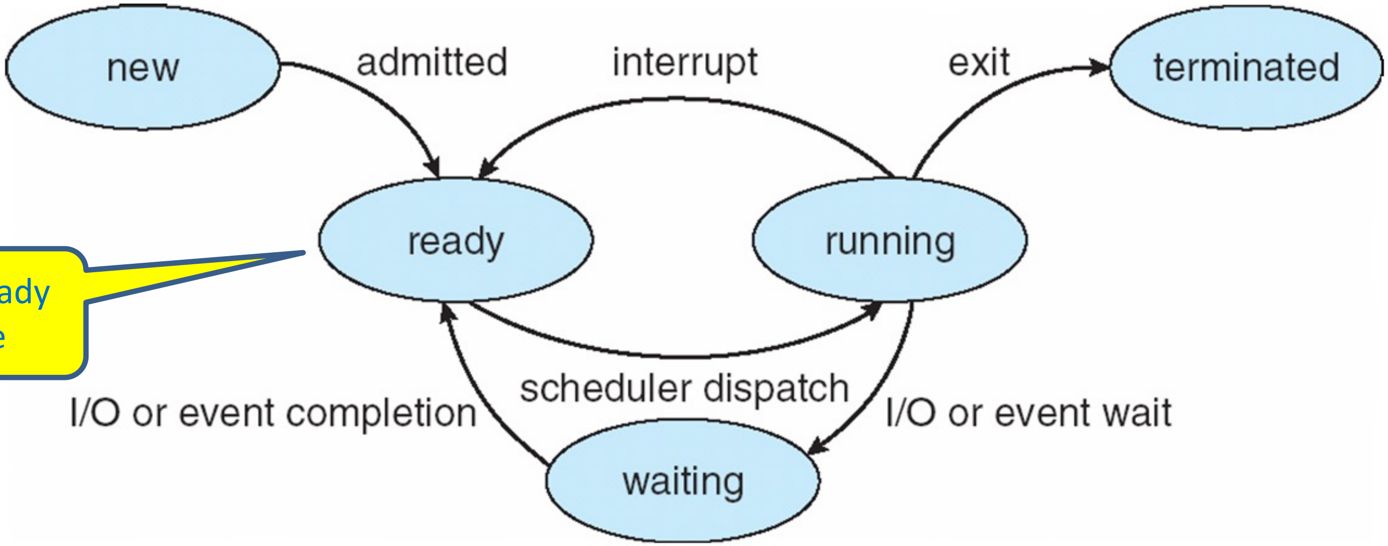
Process State

- 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


Meanwhile, on an ordinary Linux kernel...
What's going on with these zombie processes?
Their parent is too busy to get any notifications...
321
451
114
541
11
4315

Daniel Stori {turnoff.us}

Diagram of Process State



In the Ready Queue

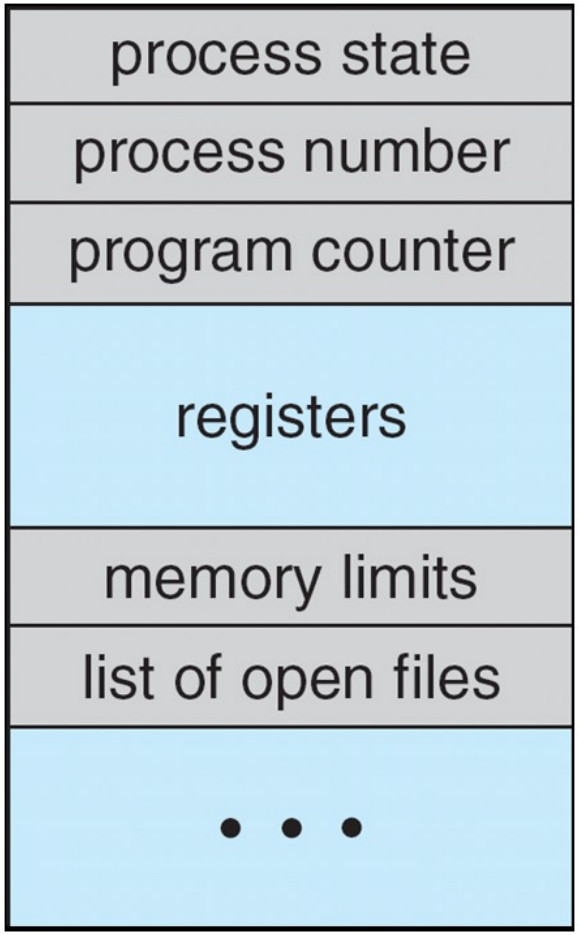
Transitions:
Ready to Running: scheduled by scheduler
Running to Ready: scheduler picks another process, back in ready queue

Running to Waiting (Blocked) : process blocks for input/output
Waiting to Ready: I/O or event done

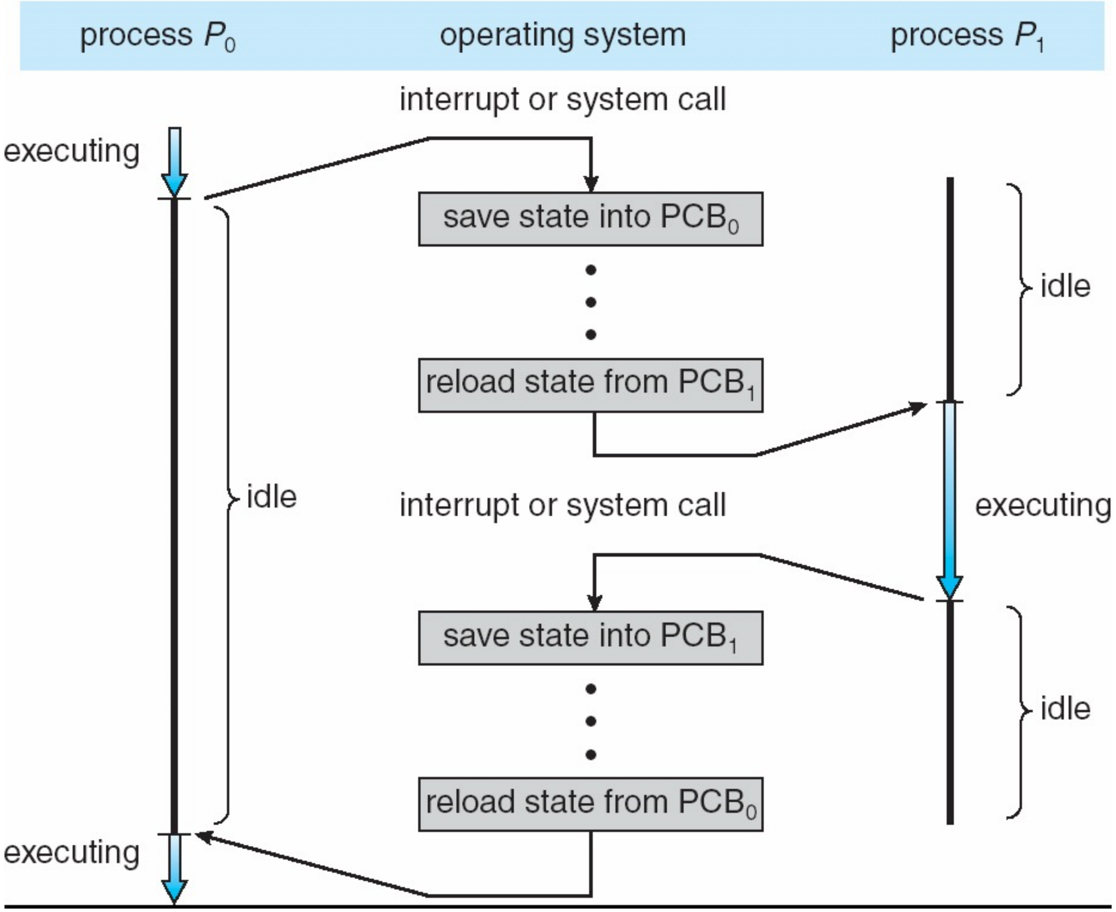
Process Control Block (PCB)

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



CPU Switch From Process to Process



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Demonstration: Processes

- Mac: apps> utilities> activity monitor > CPU etc.
- https://support.apple.com/guide/activity-monitor/welcome/mac
  - See information about processes
  - Name, PID, threads, details ..

- Windows 10 Ctrl+Alt+Del
- https://www.howtogeek.com/405806/windows-task-manager-the-complete-guide/ : Task manager

Threads

- So far, 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
- Coming up in next chapter

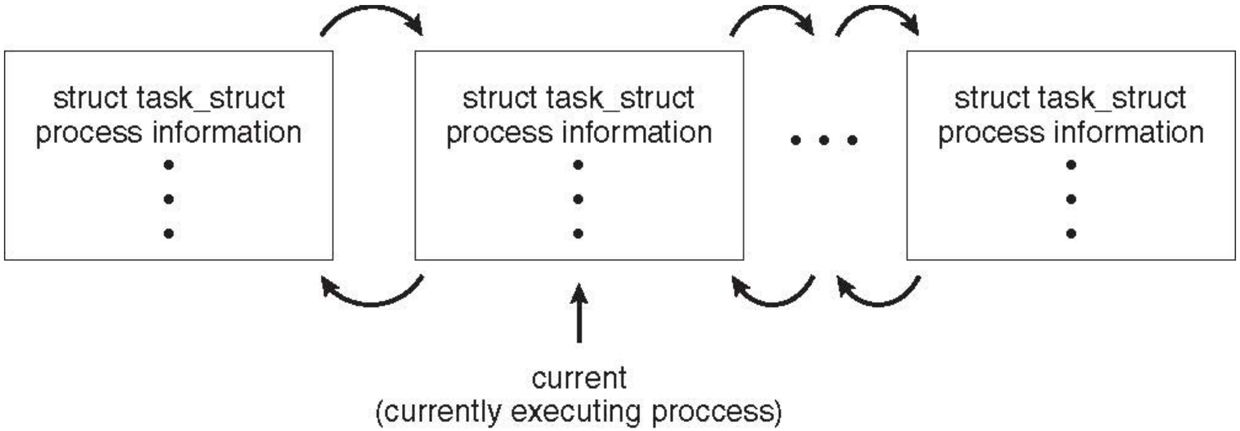
PCB Representation in Linux

Represented by the C structure `task_struct.`

Fields may include

```
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 */
```

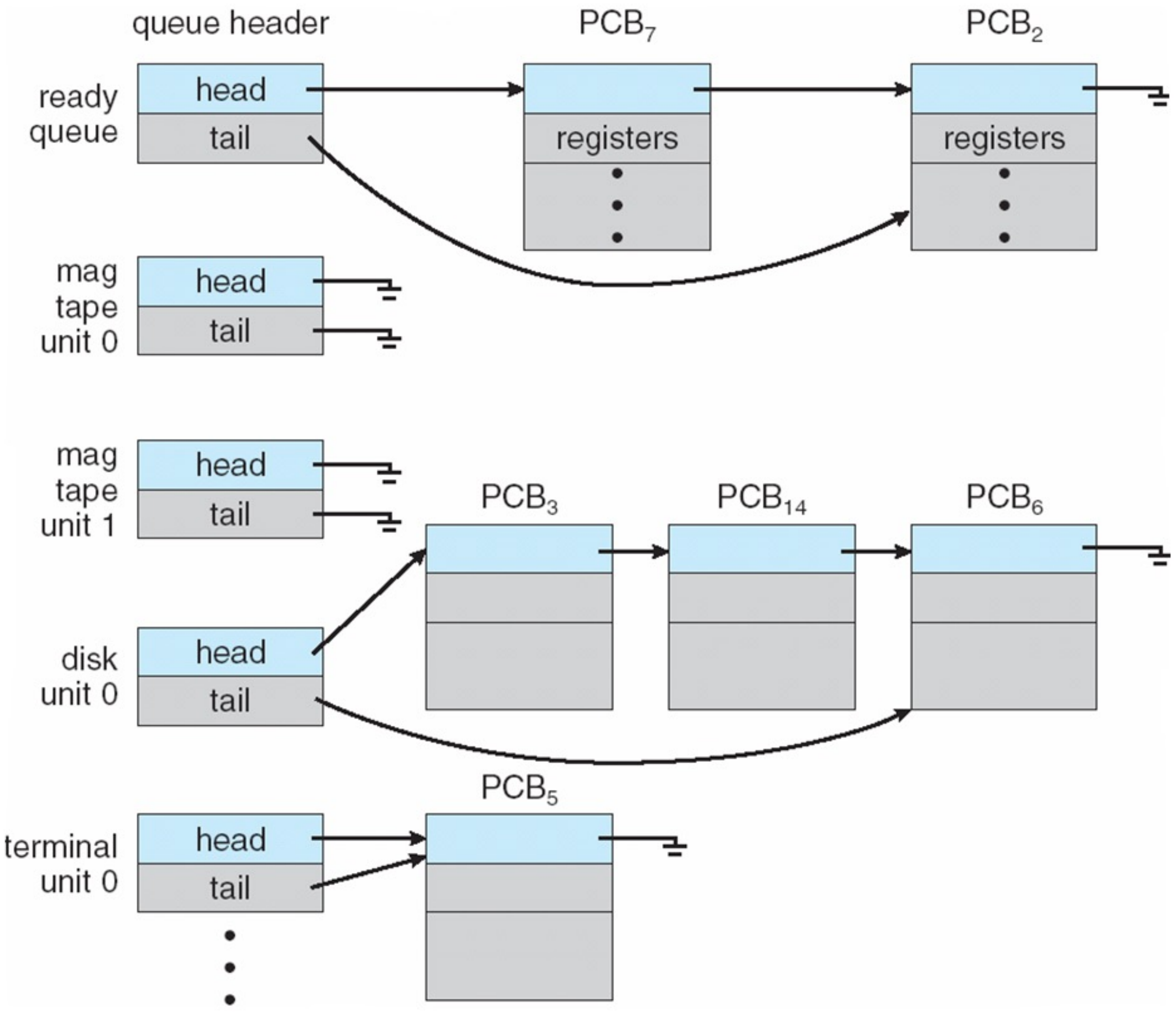
Unlike an array, the elements of a struct can be of different data types



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



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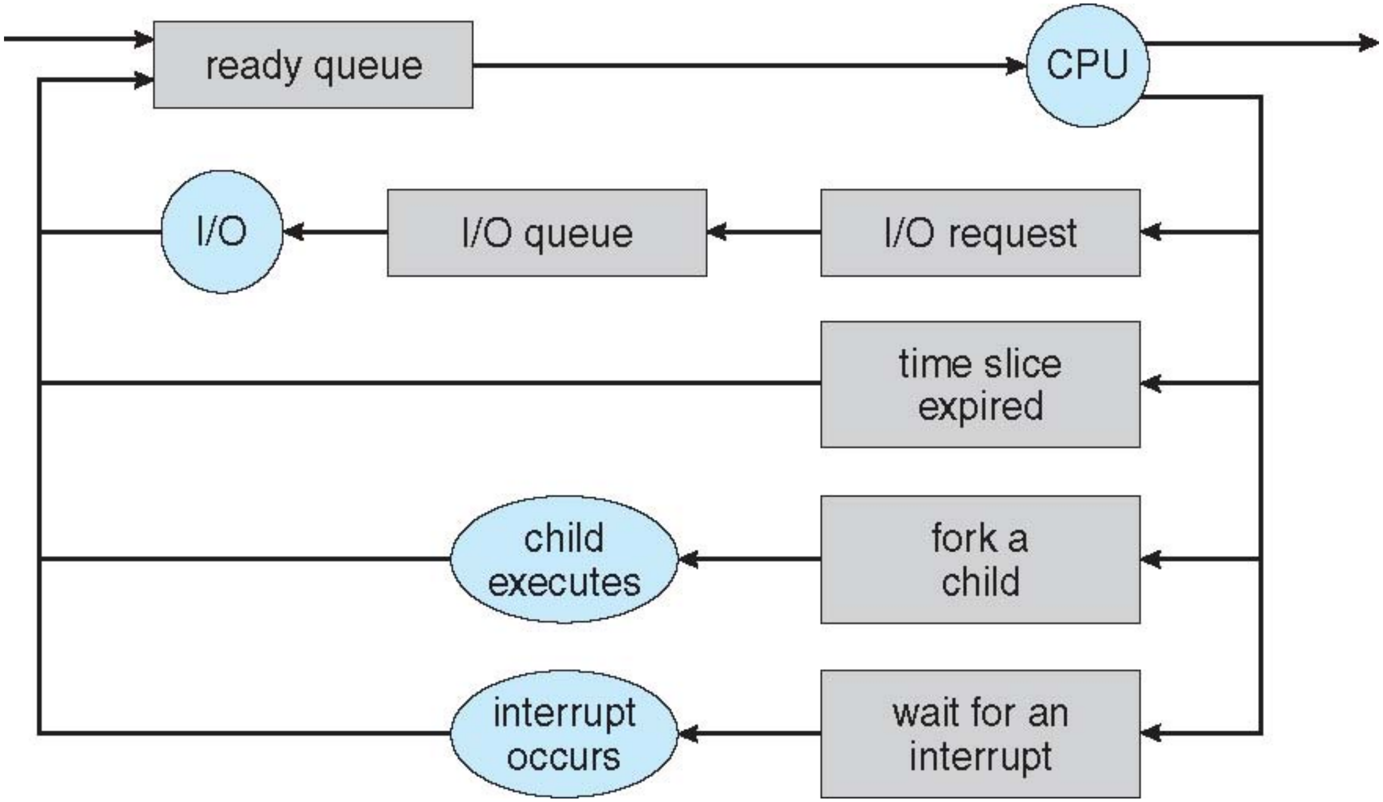
Representation of Process Scheduling

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



Assumes a single CPU. Common until recently

Schedulers

- **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 frequently (milliseconds) ⇒ (must be fast)**
- **Long-term scheduler** (or **job scheduler**) – selects which processes should be brought into the ready queue
  - Long-term scheduler is invoked infrequently (seconds, minutes) ⇒ (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***

Multitasking in Mobile Systems

- Some mobile systems (e.g., early version of iOS) 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
- Newer iOS supports multitasking better. iOS 14: picture in picture
- 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.

ARE YOU SURE YOU WANT TO SIT AT THE KIDS TABLE?
Window Phone 7
the ENTERPRISE
Mobile OSs
www.jklossner.com
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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 ➔ the longer the context switch
- Time dependent on hardware support
  - Some hardware provides multiple sets of registers per CPU ➔ multiple contexts loaded at once

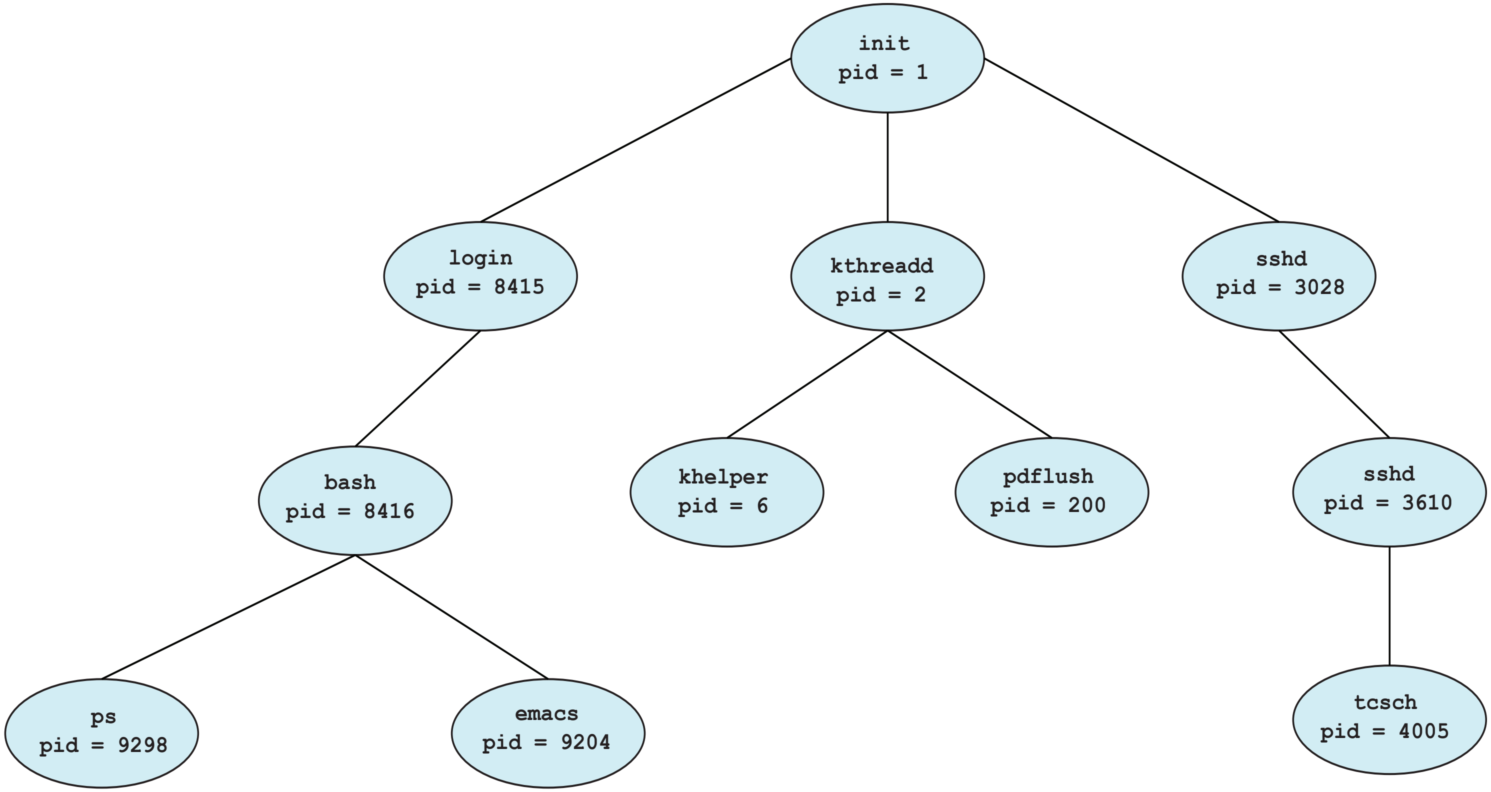
Processes creation & termination

Processes creation & termination

Process Creation

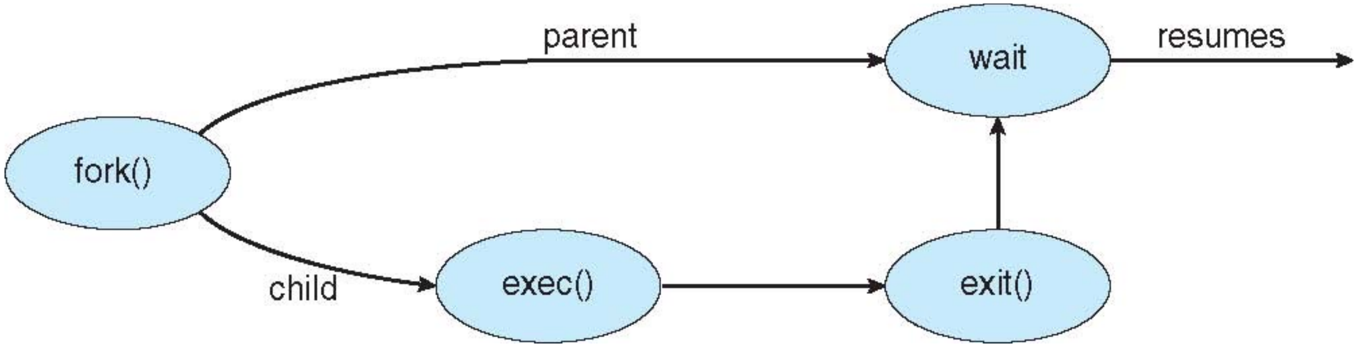
- **Parent** process create **children** processes, which, in turn create other processes, forming a **tree** of processes
- Generally, process identified and managed via a **process identifier** (**pid**)
- Resource sharing options
  - Parent and children share all resources
  - Children share subset 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
  - **`exec()`** system call used after a **`fork()`** to replace the process' memory space with a new program



Fork ( ) to create a child process

- Fork creates a copy of process
- Return value from fork (): integer
  - When > 0:
    - Running in (original) Parent process
    - return value is pid of new child
  - When = 0:
    - Running in new Child process
  - When < 0:
    - Error! Perhaps exceeds resource constraints. sets errno (a global variable in errno.h)
    - Running in original process
- All of the state of original process duplicated in both Parent and Child! Almost ..
  - Memory, File Descriptors (next topic), etc…

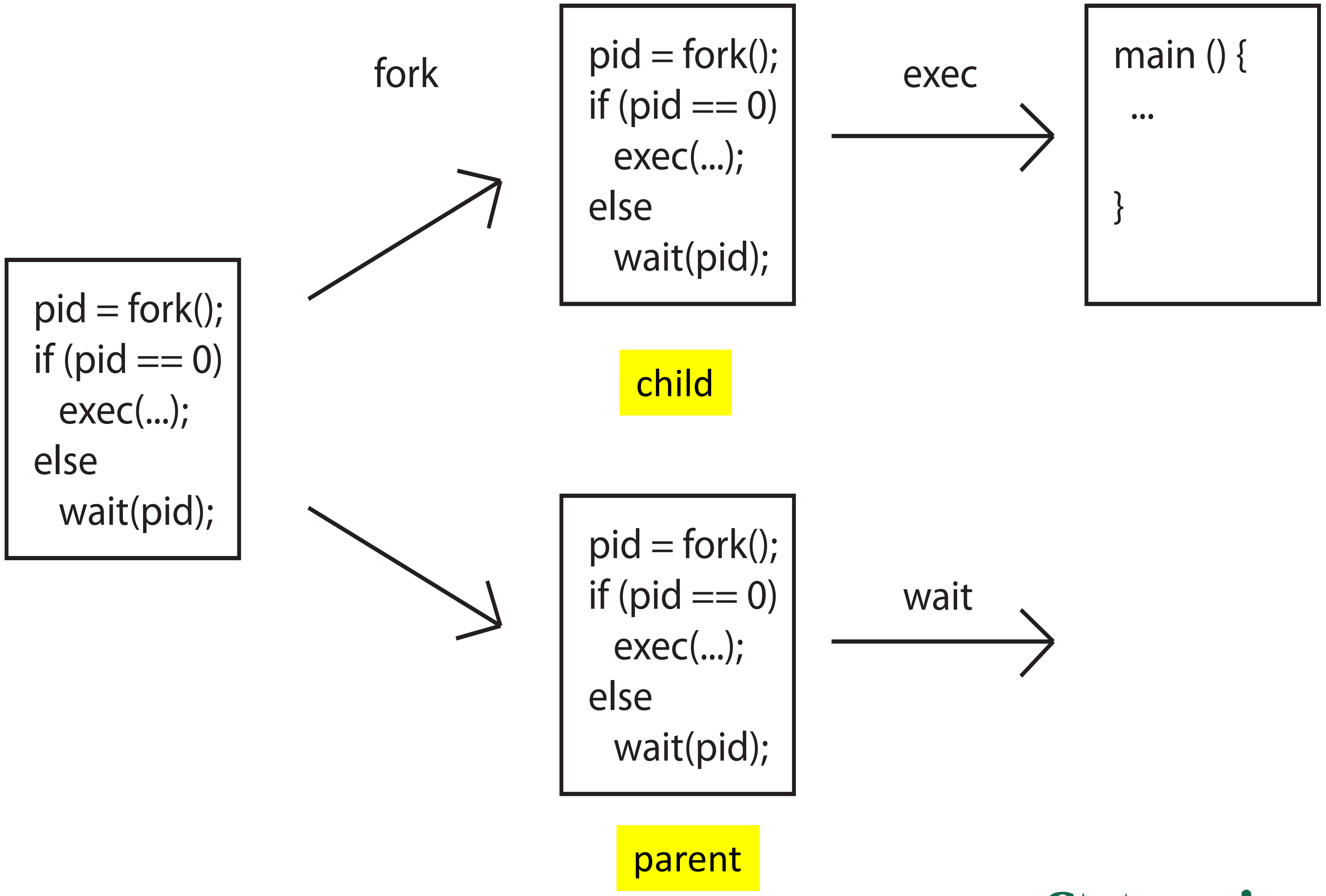
Process Management System Calls

- UNIX fork – system call to create a copy of the current process, and start it running
  - No arguments!
- UNIX exec – system call to *change the program* being run by the current process. Several variations.
- UNIX wait – system call to wait for a process to finish
- Details: see man pages

Some examples:

```
pid_t pid = getpid();   /* get current processes PID */;
waitpid(cid, 0, 0);   /* Wait for my child to terminate. */
exit (0);   /* Quit*/
kill(cid, SIGKILL);   /* Kill child*/
```

UNIX Process Management



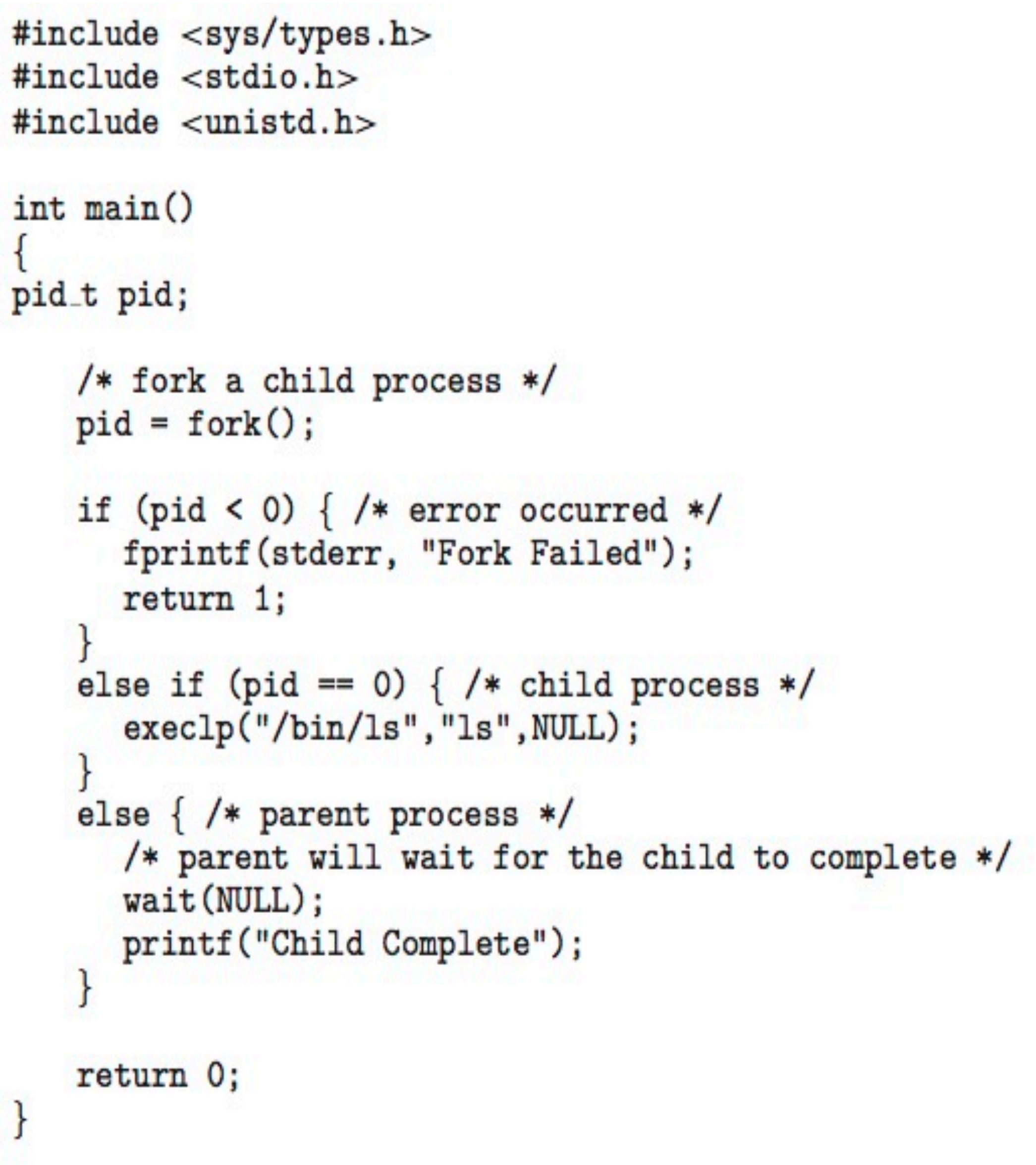
```
pid = fork();
if (pid == 0)
   exec(...);
else
   wait(pid);
```

```
pid = fork();
if (pid == 0)
   exec(...);
else
   wait(pid);
```

```
main () {
  ...

}
```

```
pid = fork();
if (pid == 0)
   exec(...);
else
   wait(pid);
```

C Program Forking Separate Process

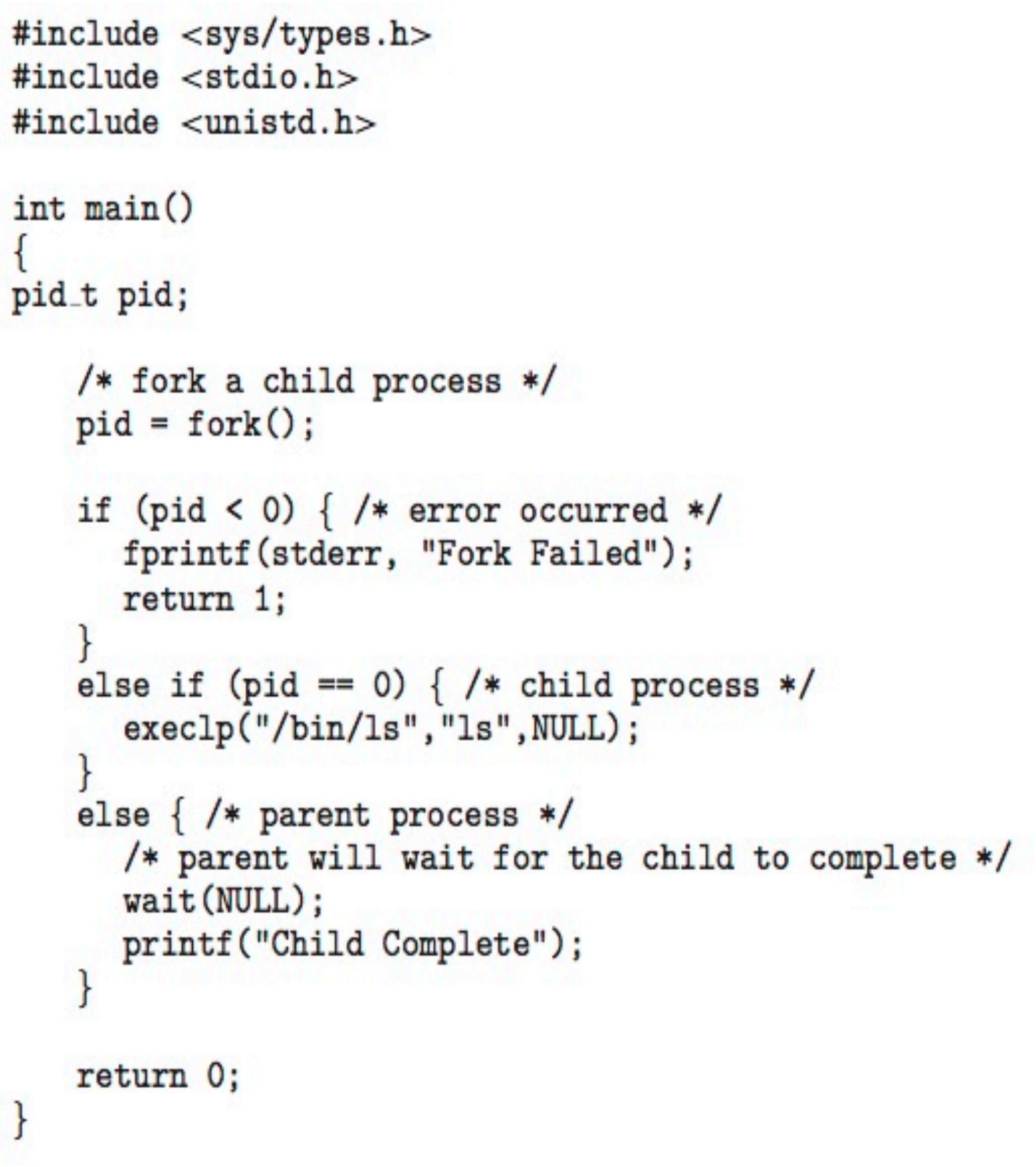


```
#include <sys/types.h>
#include <stdio.h>
#include <unistd.h>

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;
}
```

<sys/types.h> definitions of derived types
<unistd.h>   POSIX API

execlp(3) - Linux man page
http://linux.die.net/man/3/execlp

C Program Forking Separate Process



```
#include <sys/types.h>
#include <stdio.h>
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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;
}
```

<sys/types.h> definitions of derived types
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execlp(3) - Linux man page
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Forking PIDs

```
#include <sys/types.h>
#include <stdio.h>
#include <unistd.h>
int main(){
            pid_t cid;

            /* fork a child process */
            cid = fork();
            if (cid < 0) { /* error occurred */
                fprintf(stderr, "Fork Failed\n");
               return 1;
            }
            else if (cid == 0) { /* child process */
                printf("I am the child %d, my PID is %d\n", cid, getpid());
                 execlp("/bin/ls","ls",NULL);
            }
            else { /* parent process */
                 /* parent will wait for the child to complete */
                 printf("I am the parent with PID %d, my parent is %d, my child is %d\n",getpid(), getppid(), cid);
                 wait(NULL);

                 printf("Child Complete\n");
            }

  return 0;
}
```

```
Ys-MacBook-Air:ch3 ymalaiya$ ./newproc-posix_m
I am the parent with PID 494, my parent is 485, my child is 496
I am the child 0, my PID is 496
DateClient.java                    newproc-posix_m

Child Complete
Ys-MacBook-Air:ch3 ymalaiya$
```

See self-exercise in Teams

https://www.tutorialspoint.com/compile_c_online.php

wait/waitpid

- Wait/waitpid ( ) allows caller to suspend execution until child's status is available
- Process status availability
  - Generally after termination
  - Or if process is stopped
- pid_t waitpid(pid_t pid, int *status, int options);
- The value of pid can be:
  - 0 wait for any child process with same *process group ID* (perhaps inherited)
  - > 0 wait for child whose process group ID is equal to the value of pid
  - -1 wait for any child process *(equi to wait ( ))*
- Status: where status info needs to be saved

Linux: fork ( )

- Search for man fork( )
- http://man7.org/linux/man-pages/man2/fork.2.html

NAME fork - create a child process

SYNOPSIS #include <unistd.h>
pid_t fork(void);

DESCRIPTION fork() creates a new process by duplicating the calling process. The new process is referred to as the child process. …

The child process and the parent process run in separate memory spaces…

The child process is an exact duplicate of the parent process except for the following points: ….

RETURN VALUE On success, the PID of the child process is returned in the parent, and 0 is returned in the child. On failure, -1 is returned in the parent, no child process is created, and errno is set appropriately.

EXAMPLE See pipe(2) and wait(2).

…

errno is a global variable in errno.h

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Process Group ID

- Process group is a collection of related processes
- Each process has a process group ID
- Process group leader?
  - Process with pid==pgid
- A process group has an associated controlling terminal, usually the user's keyboard
  - Control-C: sends interrupt signal (SIGINT) to all processes in the process group
  - Control-Z: sends the suspend signal (SIGSTOP) to all processes in the process group

Applies to foreground processes: those interacting
With the terminal

Process Groups

A child Inherits parent’s process group ID. Parent or child can change group ID of child by using setpgid.

By default, a Process Group comprises:

- Parent (and further ancestors)
- Siblings
- Children (and further descendants)

A process can only send signals to members of its process group

- Signals are a limited form of inter-process communication used in Unix.
- Signals can be sent using system call
  - int kill(pid_t pid, int sig);

Process Termination

- Process executes last statement and then asks the operating system to delete it using the **`exit()`** system call.
  - Returns status data from child to parent (via **`wait()`**)
  - Process’ resources are deallocated by operating system
- Parent may terminate the execution of children processes using the **`kill( )`** system call. Some reasons for doing so:
  - Child has exceeded allocated resources
  - Task assigned to child is no longer required
  - The parent is exiting and the operating systems does not allow a child to continue if its parent terminates

```
kill(child_pid,SIGKILL);
```

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Process Termination

- Some operating systems do not allow child to exists if its parent has terminated. If a process terminates, then all its children must also be terminated.
  - **cascading termination.** All children, grandchildren, etc. are terminated.
  - The termination is initiated by the operating system.
- The parent process may wait for termination of a child process by using the **`wait()`** system call. The call returns status information and the pid of the terminated process

```
pid = wait(&status);
```

- If no parent waiting (did not invoke **`wait()`**) process is a **zombie**
- If parent terminated without invoking **`wait`**, process is an orphan (it is still running, reclaimed by init)

Zombie: a process that has completed execution (via the exit system call) but still has an entry in the process table