Processes

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References:

- Chapter 2 of the Tanenbaum's book
- Chapter 4 of OSTEP book
- man pages in any UNIX/Linux system

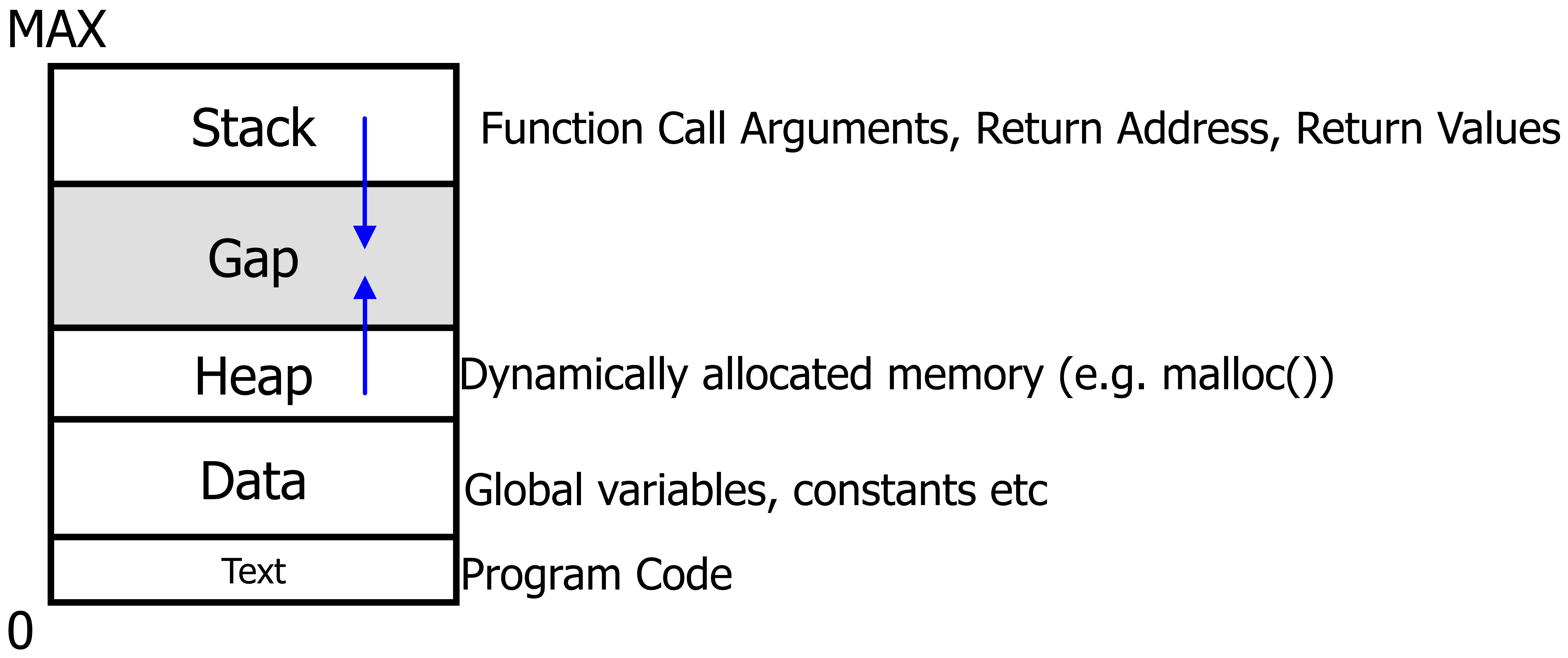
Process versus Program

- Program
  - Program is a passive executable file stored in the disk
  - Contains static code and static data

- Process: A program in execution. A process contains:
  - Code
  - Procedure call stack
  - Memory (static and dynamic data)
  - Registers: Program counter, Stack pointer, General purpose registers
  - Program is just one component of a process.
  - Open files, connections

- There can be multiple processs running the same program
  - Example: many users can run “ls” at the same time

Memory Layout of a typical process



- Stack and heap grow towards each other

System calls to control process lifetime

- fork()
  - Create a process

- exec()
  - Run a new program
  - More accurately: Replace the current process with a new program image

- wait() or waitpid()
  - wait for a child process to terminate

- exit()
  - Terminate the calling process

Example : fork() and waitpid()

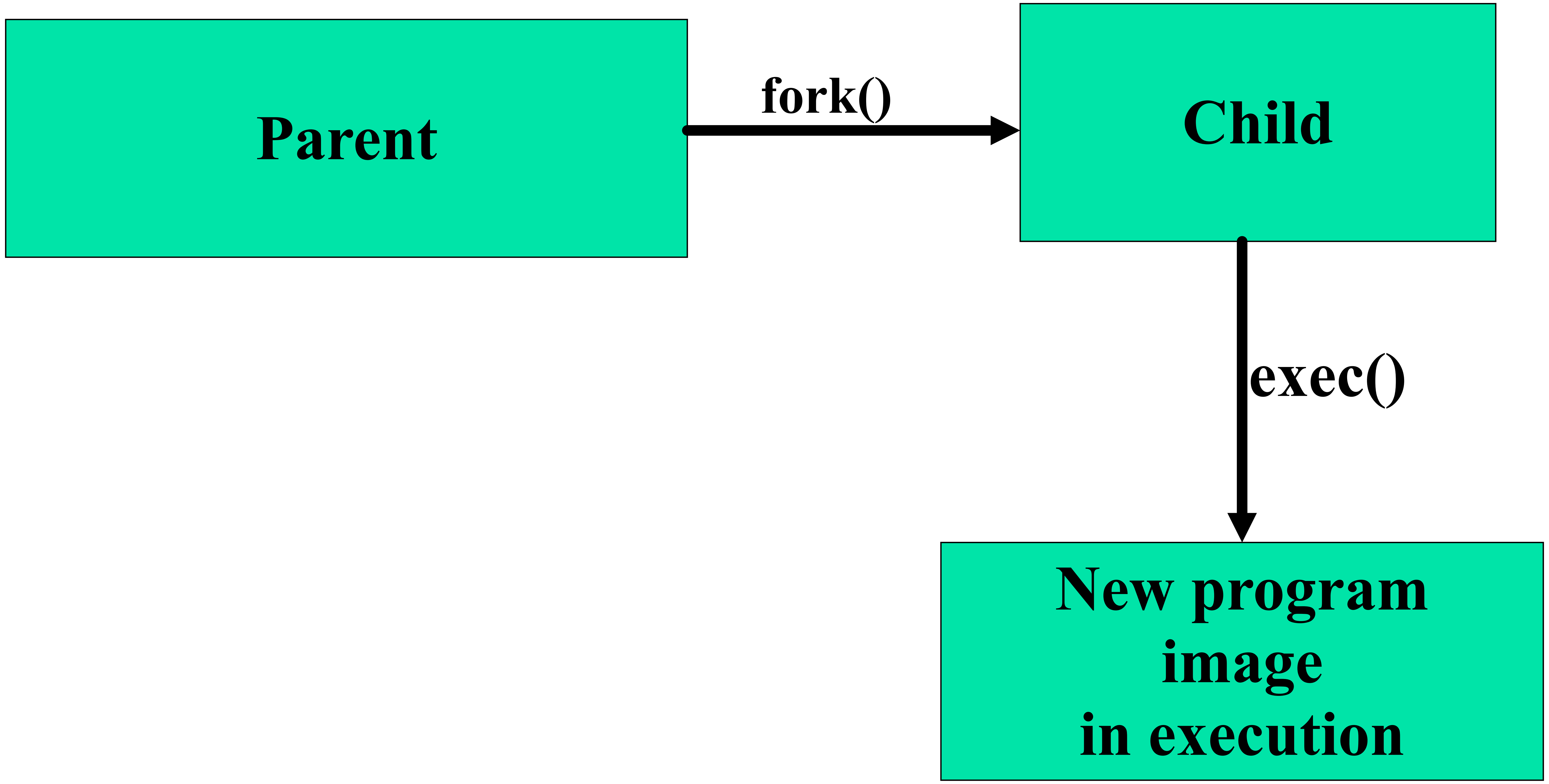
https://oscourse.github.io/examples/fork_ex.c

```
pid = fork();

if (pid < 0) {
        perror("fork failed:");
        exit(1);
}

if (pid == 0) { // Child executes this block
        printf("This is the child\n");
        exit(0);
}

if (pid > 0) { //Parent executes this block

  printf("This is parent. The child is %d\n", pid);

ret = waitpid(pid, &status, 0);
if (ret < 0) {
   perror("waitpid failed:")
   exit(2);
}

printf("Child exited with status %d\n", status);
exit(0);
```

- fork() is called once …
  - but it returns twice!!
  - once in the parent and
  - once in the child
- Parent and child are two processes.
- Child is an exact "copy" of parent.
- Return value of fork in child = 0
- Return value of fork in parent = [process ID of child]
- By checking fork's return value, the parent and the child can take different code paths.

Running a new program using exec()

exec() replaces the caller's memory with a new program image.



exec() - Example code

https://oscourse.github.io/examples/exec_ex.c

```
if ((pid = fork()) < 0) {
 fprintf(stderr, "fork failed\n");
 exit(1);
}

if (pid == 0) {
 if( execlp("echo",
       "echo",
       "Hello from the child",
       (char *) NULL) == -1)
  fprintf(stderr, "execl failed\n");

 exit(2);
}

printf("parent carries on\n");
```

- exec() is called once
  - But doesn't return!!
- All I/O descriptors that were open before exec stay open after exec.
  - I/O descriptors = file descriptors, socket descriptors, pipe descriptors etc.
  - This property is very useful for implementing filters.

Different Types of exec()

- `int execl(char * pathname, char * arg0, … , (char *)0);`
  - Full pathname + long listing of arguments

- `int execv(char * pathname, char * argv[]);`
  - Full pathname + arguments in an array

- `int execle(char * pathname, char * arg0, … , (char *)0, char envp[]);`
  - Full pathname + long listing of arguments + environment variables

- `int execve(char * pathname, char * argv[], char envp[]);`
  - Full pathname + arguments in an array + environment variables

- `int execlp(char * filename, char * arg0, … , (char *)0);`
  - Short pathname + long listing of arguments

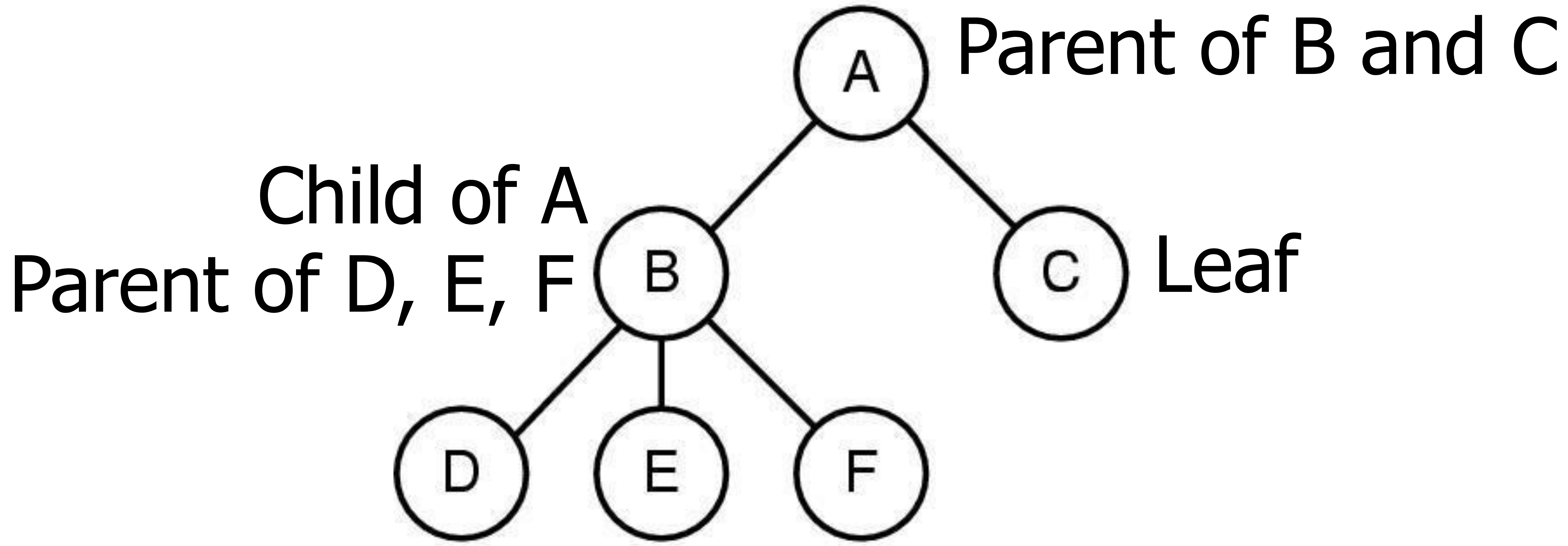
- `int execvp(char * filename, char * argv[]);`
  - Short pathname + arguments in an array

- More info: check “man 3 exec”

Terminating a process

- Return from main()
- Call exit(status)
  - Exit the program.
  - Status is retrieved by the parent using wait().
  - 0 for normal status, non-zero for error

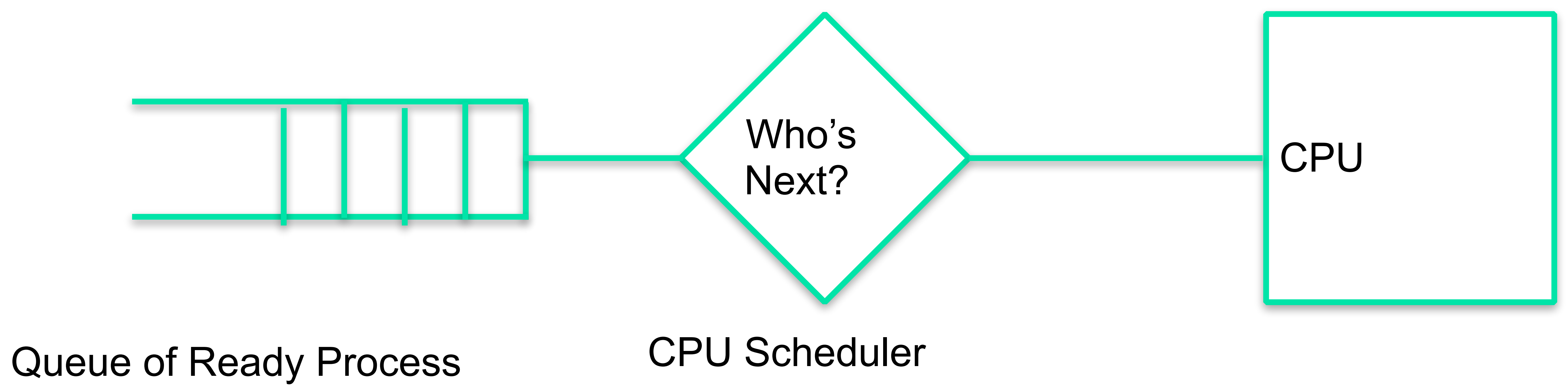
Process Hierarchy Tree



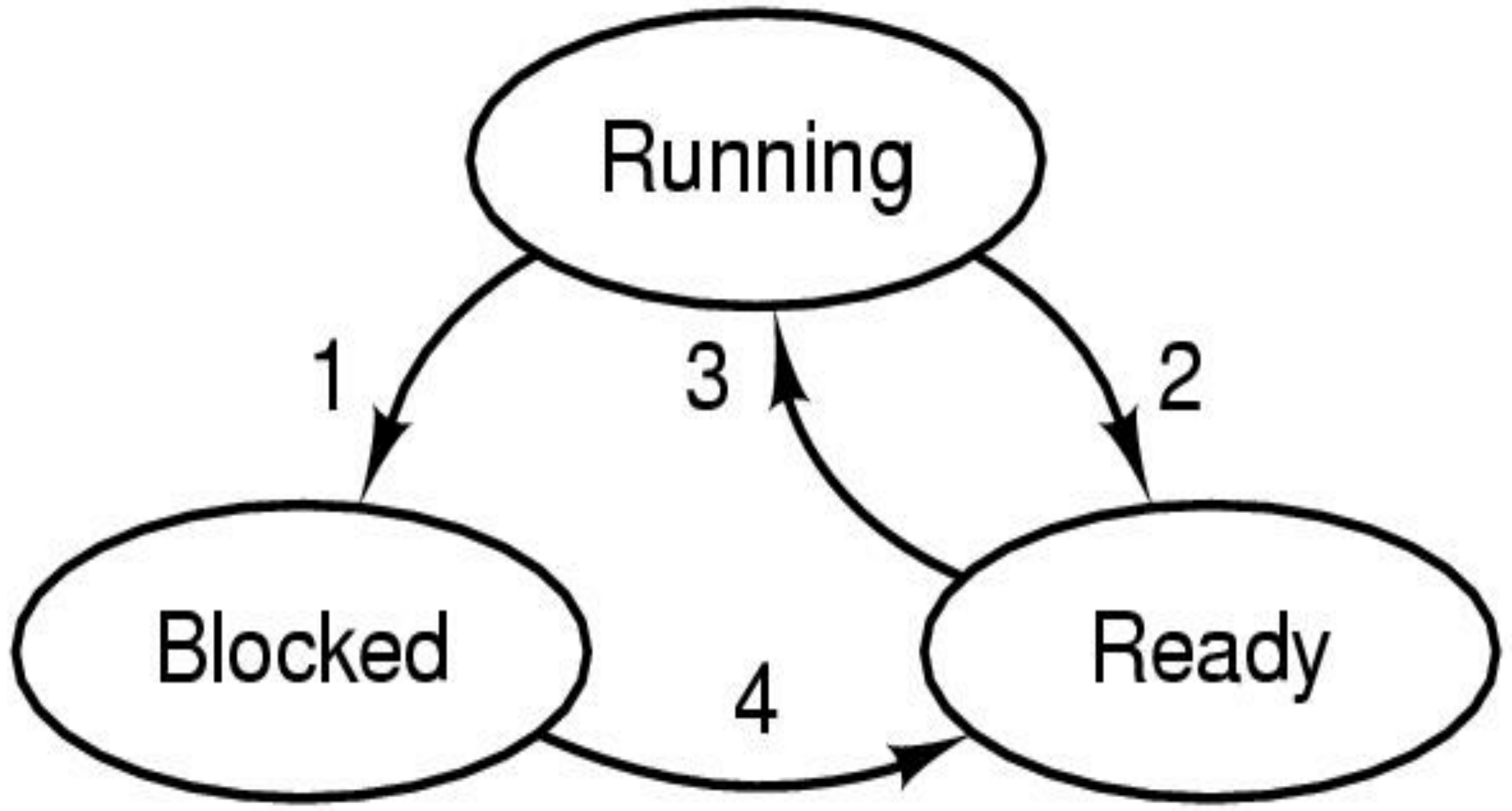
- A created two child processes, B and C
- B created three child processes, D, E, and F

CPU scheduler

- Time-shares many processes on one CPU



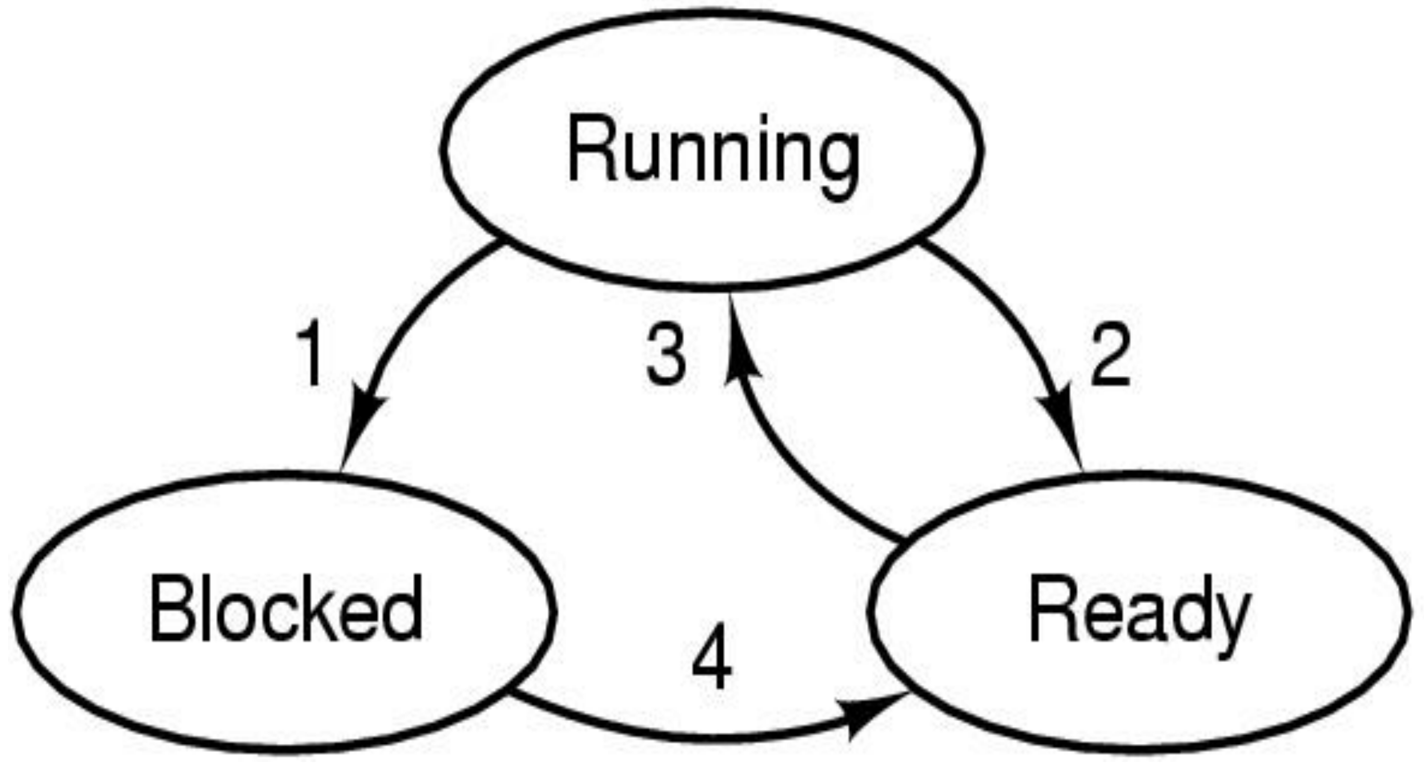
Process Lifecycle



1. Process blocks for input
2. Scheduler picks another process
3. Scheduler picks this process
4. Input becomes available

- Ready
  - Process is ready to execute, but not yet executing
  - Its waiting in the scheduling queue for the CPU scheduler to pick it up.
- Running
  - Process is executing on the CPU
- Blocked
  - Process is waiting (sleeping) for some event to occur.
  - Once the event occurs, process will be woken up, and placed on the scheduling queue.

How do multiple processes share CPU?



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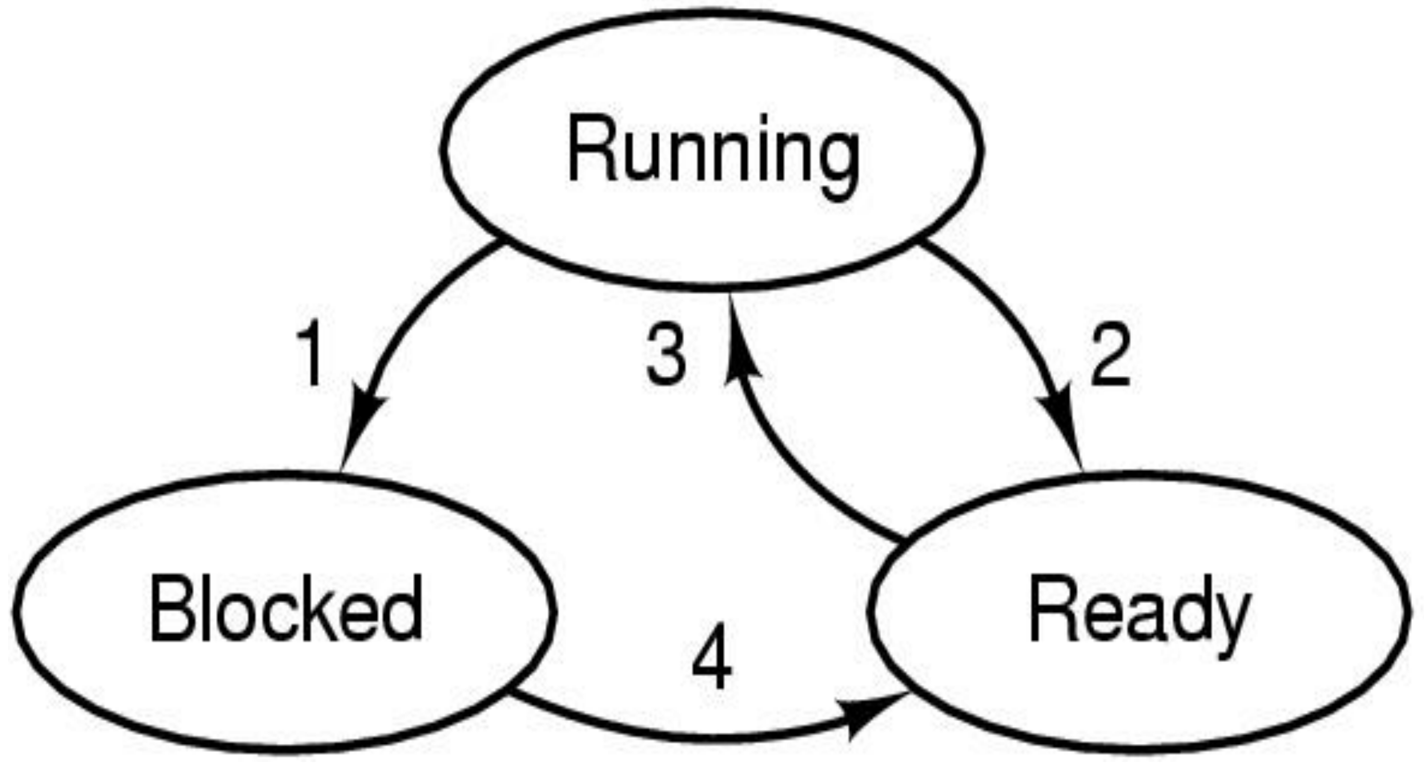
Time	Process_0	Process_1	Notes
1	Running	Ready	
2	Running	Ready	
3	Running	Ready	
4	Running	Ready	Process_0 now done
5	–	Running	
6	–	Running	
7	–	Running	
8	–	Running	Process_1 now done

Figure 4.3: **Tracing Process State: CPU Only**

How do multiple processes share CPU?



1. Process blocks for input
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Time	$Process_0$	$Process_1$	Notes
1	Running	Ready	
2	Running	Ready	
3	Running	Ready	$Process_0$ initiates I/O
4	Blocked	Running	$Process_0$ is blocked,
5	Blocked	Running	so $Process_1$ runs
6	Blocked	Running	
7	Ready	Running	I/O done
8	Ready	Running	$Process_1$ now done
9	Running	–	
10	Running	–	$Process_0$ now done

Figure 4.4: **Tracing Process State: CPU and I/O**

Examining Processes in Unix/Linux

- ps command
  - Standard process attributes

- /proc directory
  - More interesting information if you are the root.

- top command
  - Examining CPU and memory usage statistics.

Orphan process

- When a parent process dies, child process becomes an orphan process.
- The init process (pid = 1) becomes the parent of the orphan processes.
- Here's an example:
  - https://oscourse.github.io/examples/orphan.c
  - Do a 'ps –l' after running the above program and check parent's PID of the orphan process.
  - After you are done remember to kill the orphan process 'kill –9 <pid>'

Zombie Process

- When a child dies, a SIGCHLD signal is sent to the parent.
- If parent doesn’t wait()on the child, and child exit()s, it becomes a zombie (status “Z” seen with ps).
- Zombies hang around till parent calls wait() or waitpid().
- But they don’t take up any system resources.
  - Just an integer status is kept in the OS.
  - All other resources are freed up.