Processes

Focus:

Process model

Process management case study: Unix/Linux/Mac OS X

(Windows is a little different.)

fork

`pid_t fork()`

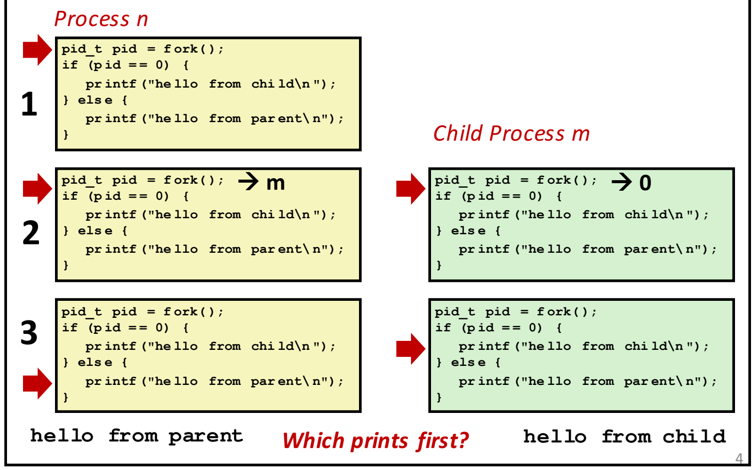
1. **Clone** current ***parent*** process to **create** identical ***child*** process, including all state (memory, registers, **program counter**, …).
2. Continue executing both copies with ***one difference:***
   - **returns 0** to the **child process**
   - **returns child's process ID (`pid`)** to the **parent process**

```
pid_t pid = fork();
if (pid == 0) {
   printf("hello from child\n");
} else {
   printf("hello from parent\n");
}
```

`fork` is unique: called *in one process,* returns *in two processes!*

(once in parent, once in child)

fork example



```
pid_t pid = fork();
if (pid == 0) {
   printf("hello from child\n");
} else {
   printf("hello from parent\n");
}
```

hello from parent *Which prints first?* hello from child

fork again

Parent and child continue from *private copies* of same state.

Memory contents (**code**, globals, **heap**, **stack**, etc.),

Register contents, **program counter**, file descriptors…

Only difference: return value from `fork()`

Relative execution order of parent/child after `fork()` undefined

```
void fork1() {
  int x = 1;
  pid_t pid = fork();
  if (pid == 0) {
    printf("Child has x = %d\n", ++x);
  } else {
    printf("Parent has x = %d\n", --x);
  }
  printf("Bye from process %d with x = %d\n", getpid(), x);
}
```

fork-exec

fork-exec model:

`fork()` clone current process

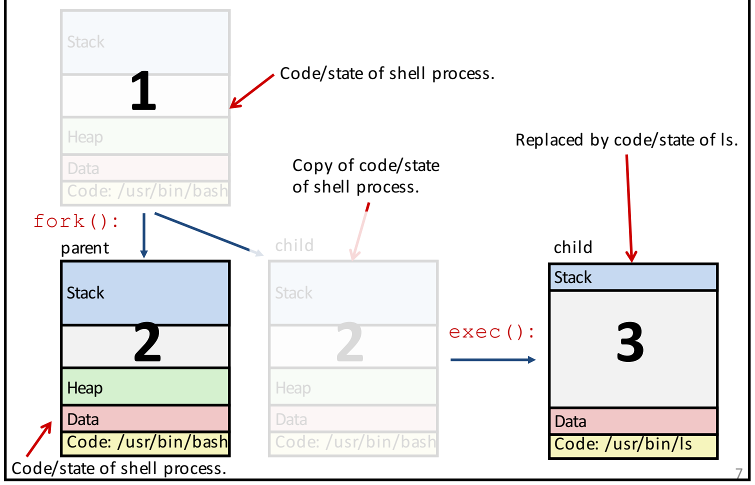
`execv()` replace process code and context (registers, memory) with a fresh program.

See **man 3 execv**, man 2 execve

```
// Example arguments: path="/usr/bin/ls”,
//   argv[0]="/usr/bin/ls”, argv[1]="-ahl", argv[2]=NULL
void fork_exec(char* path, char* argv[]) {
    pid_t pid = fork();
    if (pid != 0) {
        printf("Parent: created a child %d\n”, pid);
    } else {
        printf("Child: exec-ing new program now\n");
        execv(path, argv);
    }
    printf("This line printed by parent only!\n");
}
```

Exec-ing a new program

When you run the command `ls` in a shell:



`execv`: load/start program

`int execv(char* filename,`
`          char* argv[])`

loads/starts program in current process:

Executable `filename`

With argument list `argv`

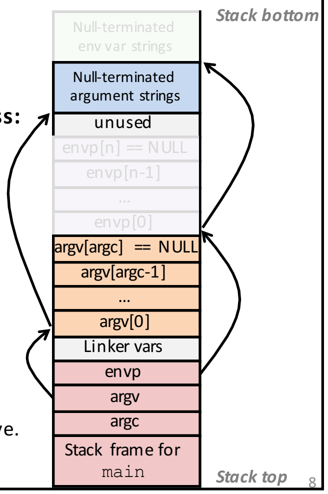
overwrites code, data, and stack

Keeps pid, open files, a few other items

does not return

unless error

Also sets up *environment*. See also: execve.



`exit`: end a process

`void exit(int status)`

End process with status: 0 = normal, nonzero = error.

`atexit()` registers functions to be executed upon exit

Zombies!

Terminated process still consumes system resources

- Various tables maintained by OS
- A living corpse, half alive and half dead

Reaping with **`wait/waitpid`**

- Parent *waits* to reap child once child terminates
- Parent receives child exit status.
- Kernel discards process.

What if parent doesn't reap?

- If any parent terminates without reaping a child, then child will be reaped by **`init`** process (pid == 1)
- But in long-running processes we need *explicit* reaping
  - e.g., shells and servers

`wait` for child processes to terminate

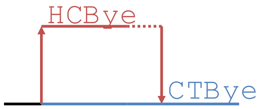
`pid_t waitpid(pid_t pid,` `int* stat, int ops`**`)`**

- Suspend current process (i.e. parent) until child with **`pid`** ends.
- On success:
  - Return **`pid`** when child terminates.
  - Reap child.
  - If `stat != NULL`, waitpid saves termination reason

where it points.

- See also: *man 3 waitpid*

`waitpid` example



```
void fork_wait() {
  int child_status;
  pid_t child_pid = fork();

  if (child_pid == 0) {
    printf("HC: hello from child\n");
  } else {
    if (-1 == waitpid(child_pid, &child_status, 0) {
      perror("waitpid");
      exit(1);
    }
    printf("CT: child %d has terminated\n",
           child_pid);
  }
  printf("Bye\n");
  exit(0);
}
```

Error-checking

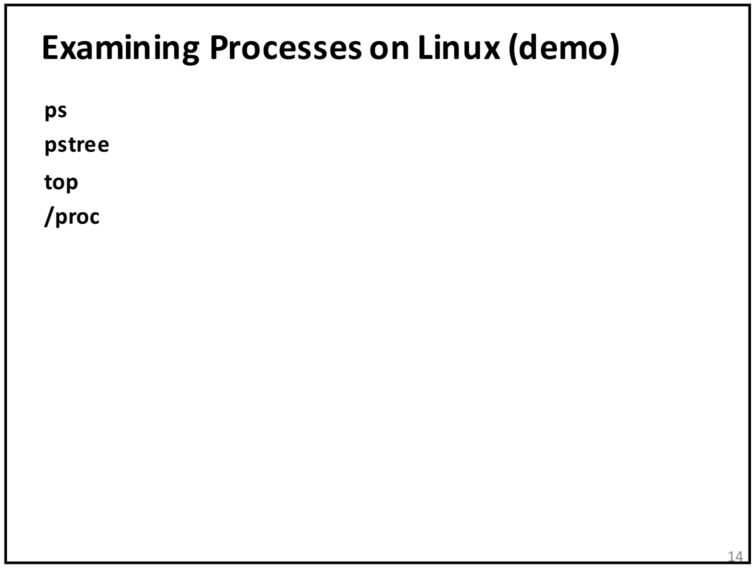
Check return results of system calls for errors! (No exceptions.)

Read documentation for return values.

Use perror to report error, then exit.

`void perror(char* message)`

- Print "message: reason that last system call failed."



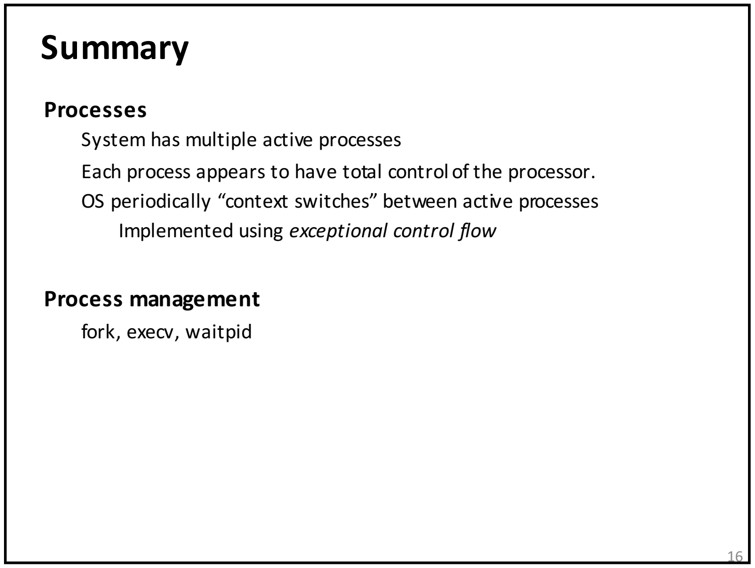
Examining Processes on Linux (demo)

ps

pstree

top

/proc



Summary

Processes

- System has multiple active processes
- Each process appears to have total control of the processor.
- OS periodically "context switches" between active processes
  - Implemented using *exceptional control flow*

Process management

- fork, execv, waitpid