Lecture Note 5.
Process Programming

October 2, 2020

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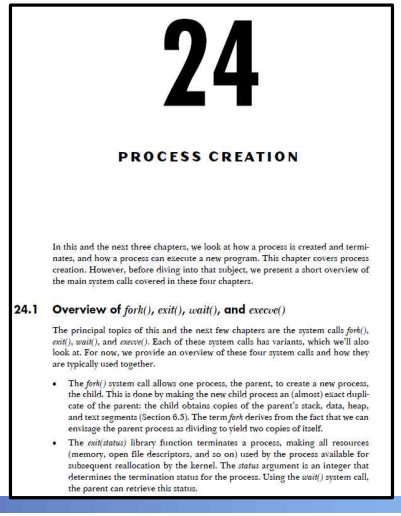
Objectives

- Understand process-related system calls
- Learn how to create a new process
- Learn how to execute a new program
- Discuss about shell (command interpreter)
- Understand issues on multitask
  - ✓ Synchronization, virtual address, thread, …

- Refer to Chapter 24, 27, 29 in the LPI and Chapter 8 in the CSAPP



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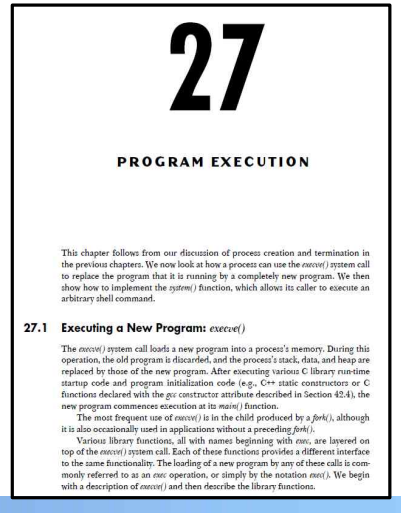
PROCESS CREATION

In this and the next three chapters, we look at how a process is created and terminates, and how a process can execute a new program. This chapter covers process creation. However, before diving into that subject, we present a short overview of the main system calls covered in these four chapters.

24.1 Overview of *fork()*, *exit()*, *wait()*, and *execve()*

The principal topics of this and the next few chapters are the system calls *fork()*, *exit()*, *wait()*, and *execve()*. Each of these system calls has variants, which we'll also look at. For now, we provide an overview of these four system calls and how they are typically used together.

- The *fork()* system call allows one process, the parent, to create a new process, the child. This is done by making the new child process an (almost) exact duplicate of the parent: the child obtains copies of the parent's stack, data, heap, and text segments (Section 6.3). The term *fork* derives from the fact that we can envisage the parent process as dividing to yield two copies of itself.
- The *exit(status)* library function terminates a process, making all resources (memory, open file descriptors, and so on) used by the process available for subsequent reallocation by the kernel. The *status* argument is an integer that determines the termination status for the process. Using the *wait()* system call, the parent can retrieve this status.



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PROGRAM EXECUTION

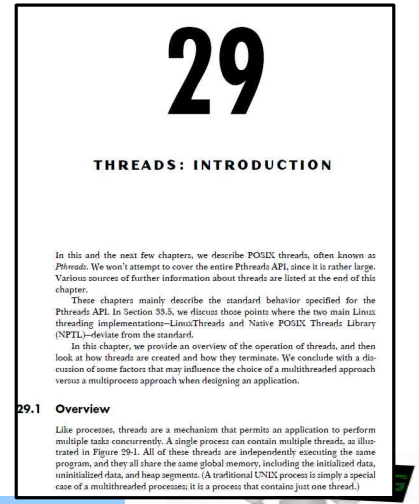
This chapter follows from our discussion of process creation and termination in the previous chapters. We now look at how a process can use the *execve()* system call to replace the program that it is running by a completely new program. We then show how to implement the *system()* function, which allows its caller to execute an arbitrary shell command.

27.1 Executing a New Program: *execve()*

The *execve()* system call loads a new program into a process's memory. During this operation, the old program is discarded, and the process's stack, data, and heap are replaced by those of the new program. After executing various C library run-time startup code and program initialization code (e.g., C++ static constructors or C functions declared with the *gcc* constructor attribute described in Section 42.4), the new program commences execution at its *main()* function.

The most frequent use of *execve()* is in the child produced by a *fork()*, although it is also occasionally used in applications without a preceding *fork()*.

Various library functions, all with names beginning with *exec*, are layered on top of the *execve()* system call. Each of these functions provides a different interface to the same functionality. The loading of a new program by any of these calls is commonly referred to as an *exec* operation, or simply by the notation *exec()*. We begin with a description of *execve()* and then describe the library functions.



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THREADS: INTRODUCTION

In this and the next few chapters, we describe POSIX threads, often known as *Pthreads*. We won't attempt to cover the entire Pthreads API, since it is rather large. Various sources of further information about threads are listed at the end of this chapter.

These chapters mainly describe the standard behavior specified for the Pthreads API. In Section 33.5, we discuss those points where the two main Linux threading implementations—LinuxThreads and Native POSIX Threads Library (NPTL)—deviate from the standard.

In this chapter, we provide an overview of the operation of threads, and then look at how threads are created and how they terminate. We conclude with a discussion of some factors that may influence the choice of a multithreaded approach versus a multiprocess approach when designing an application.

29.1 Overview

Like processes, threads are a mechanism that permits an application to perform multiple tasks concurrently. A single process can contain multiple threads, as illustrated in Figure 29-1. All of these threads are independently executing the same program, and they all share the same global memory, including the initialized data, uninitialized data, and heap segments. (A traditional UNIX process is simply a special case of a multithreaded processes; it is a process that contains just one thread.)

Introduction

- Process-related system calls
  - ✓ Basic
    - fork(), clone() : create a process, create a task_struct (like inode)
    - execve() : execute a new program (binary loading)
    - exit() : terminate a process
    - wait(), waitpid() : wait for a process's termination (child or designated)
    - getpid() : get a process ID

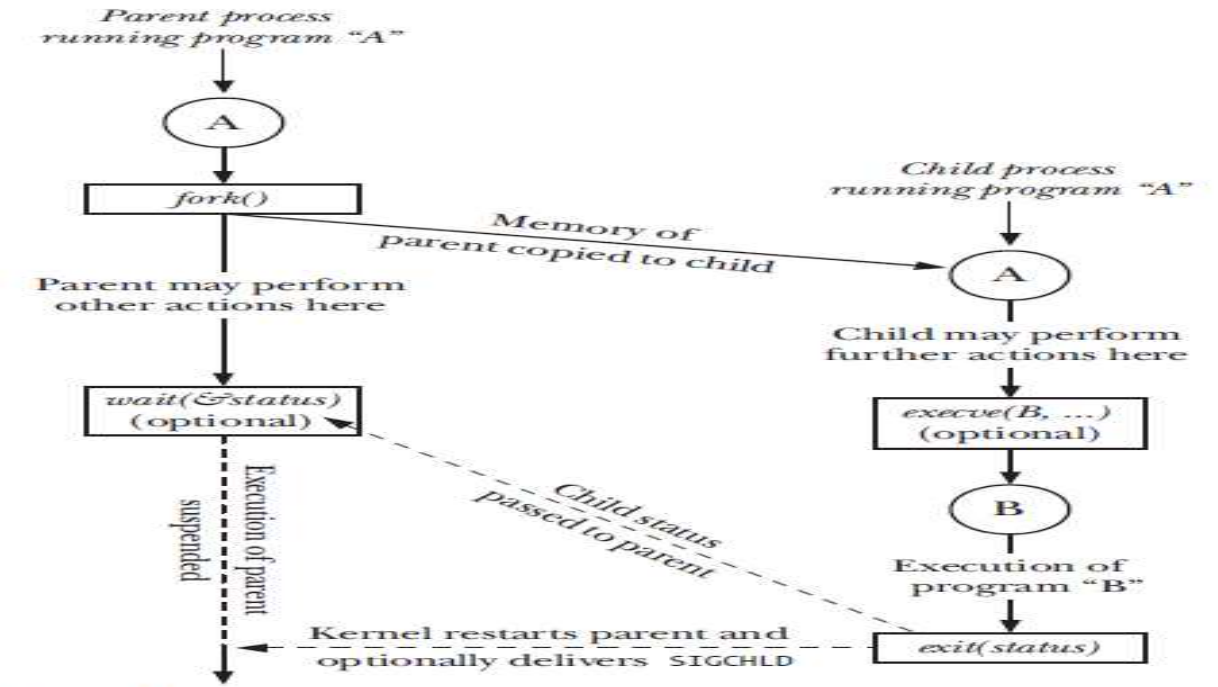
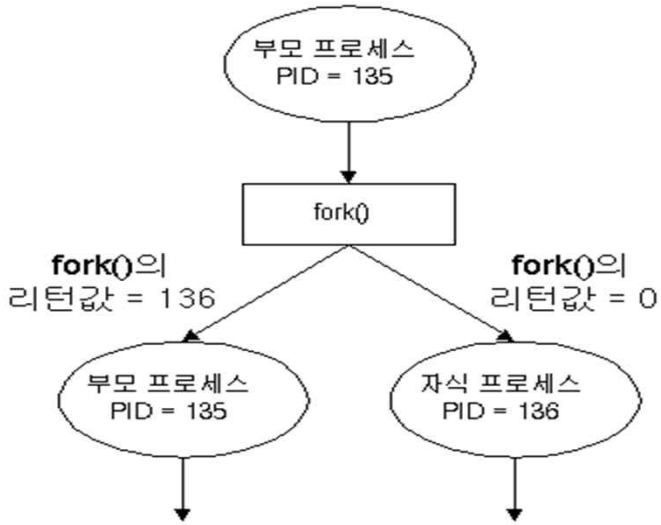


Figure 24-1: Overview of the use of *fork()*, *exit()*, *wait()*, and *execve()*

(Source: LPI)

Process creation (1/6)

- fork() system call
  - ✓ Make a new process whose memory image (text, data, …) is the same as the existing process
    - Existing process: parent process
    - New process: child process
  - ✓ Split the flow control into two (system's viewpoint)
    - One for parent and the other for child process
  - ✓ Two return values (program's viewpoint)
    - Parent process: child's pid (always larger than 0)
    - Child process: 0



Process creation (2/6)

- Practice 1: making two control flows

```
/* fork_test.c example, Sept. 26, choijm@dku.edu */
#include <sys/types.h>
#include <unistd.h>
#include <stdio.h>
#include <stdlib.h>

main()
{
        pid_t fork_return;
        printf("Hello, my pid is %d\n", getpid());

        if ( (fork_return = fork()) < 0) {
                perror("fork error"); exit(1);
        } else if (fork_return == 0) {          /* child process */
                printf("child: pid = %d, ppid = %d\n", getpid(), getppid());
        } else {        /* parent process */
                wait();
                printf("parent: I created child with pid=%d\n", fork_return);
        }

        /* Following line is executed by both parent and child */
        printf("Bye, my pid is %d\n", getpid());
}
```

The flow of control is divided here.

This message is printed out twice.

Process creation (3/6)

- Practice 1: execution results

choijm@embedded4: ~/syspro/chap5

```
choijm@embedded4:~/syspro/chap5$
choijm@embedded4:~/syspro/chap5$ more fork_test.c
/* fork_test.c example, Sept. 26,
#include <sys/types.h>
#include <unistd.h>
#include <stdio.h>
#include <stdlib.h>

main()
{
        pid_t pid;
        printf("Hello, my pid is
        if ( (pid = fork()) < 0)
                perror("fork erro
        } else if (pid == 0) {  /*
                printf("child: pid
        } else {        /* parent
                wait();
                printf("parent: I
        }

        /* Following line is execu
        printf("Bye, my pid is %d\
}

choijm@embedded4:~/syspro/chap5$
```

choijm@sungmin-Samsung-DeskTop-System: ~/syspro/chap5

```
main()
{
    pid_t pid;
    printf("Hello, my pid is %d\n", getpid());

    if ( (pid = fork()) < 0) {
        perror("fork error"); exit(1);
    } else if (pid == 0) {  /* child process */
        printf("child: pid = %d, ppid = %d\n", getpid(), getppid());
    } else {    /* parent process */
        wait();
        printf("parent: I created child with pid=%d\n", pid);
    }

    /* Following line is executed by both parent and child */
    printf("Bye, my pid is %d\n", getpid());
}

choijm@sungmin-Samsung-DeskTop-System:~/syspro/chap5$
choijm@sungmin-Samsung-DeskTop-System:~/syspro/chap5$ gcc -o fork_test fork_test
.c
choijm@sungmin-Samsung-DeskTop-System:~/syspro/chap5$
choijm@sungmin-Samsung-DeskTop-System:~/syspro/chap5$ ./fork_test
Hello, my pid is 23798
child: pid = 23799, ppid = 23798
Bye, my pid is 23799
parent: I created child with pid=23799
Bye, my pid is 23798
choijm@sungmin-Samsung-DeskTop-System:~/syspro/chap5$
choijm@sungmin-Samsung-DeskTop-System:~/syspro/chap5$
```

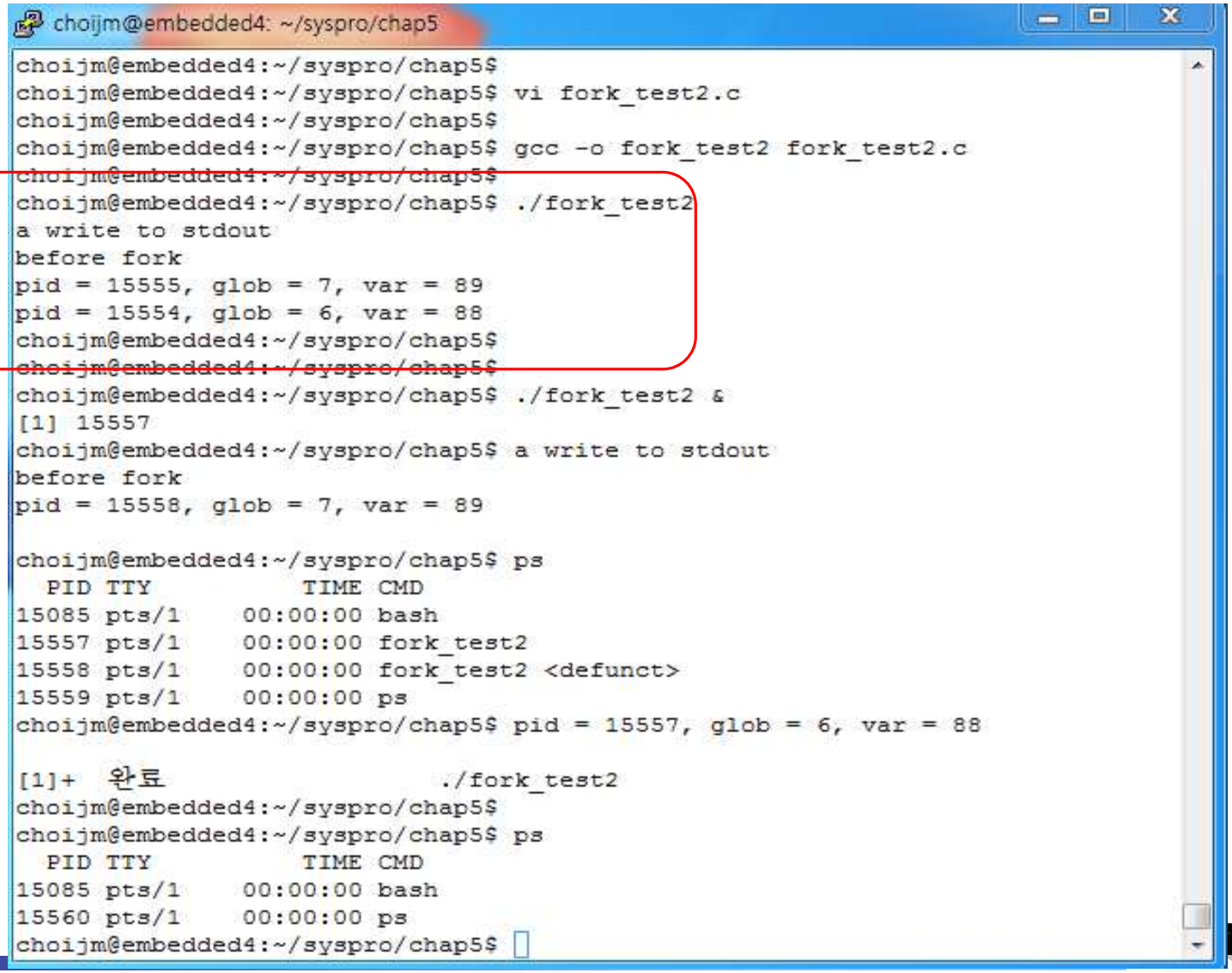
Process creation (4/6)

- Practice 2: variable (local and global) management

```
/* fork_test2.c: accessing variables, Sept. 26, choijm@dku.edu */
/* Note: This code is borrowed from "Advanced Programming in the UNIX Env." */
#include <unistd.h>
#include <stdio.h>
#include <stdlib.h>

int             glob = 6;  char             buf[] = "a write to stdout\n";

int main(void)
{
                int             var = 88;  pid_t            fork_return;

                if (write(STDOUT_FILENO, buf, sizeof(buf)) != sizeof(buf)) {
                                perror("write error"); exit(1);
                }
                printf("before fork\n");                                /* we don't flush stdout */

                if ( (fork_return = fork()) < 0) {
                                perror("fork error"); exit(1);
                } else if (fork_return == 0) {                          /* child */
                                glob++; var++;                          /* modify variables */
                } else
                                sleep(2);                               /* parent */
                printf("pid = %d, glob = %d, var = %d\n", getpid(), glob, var);
                exit(0);
}
```

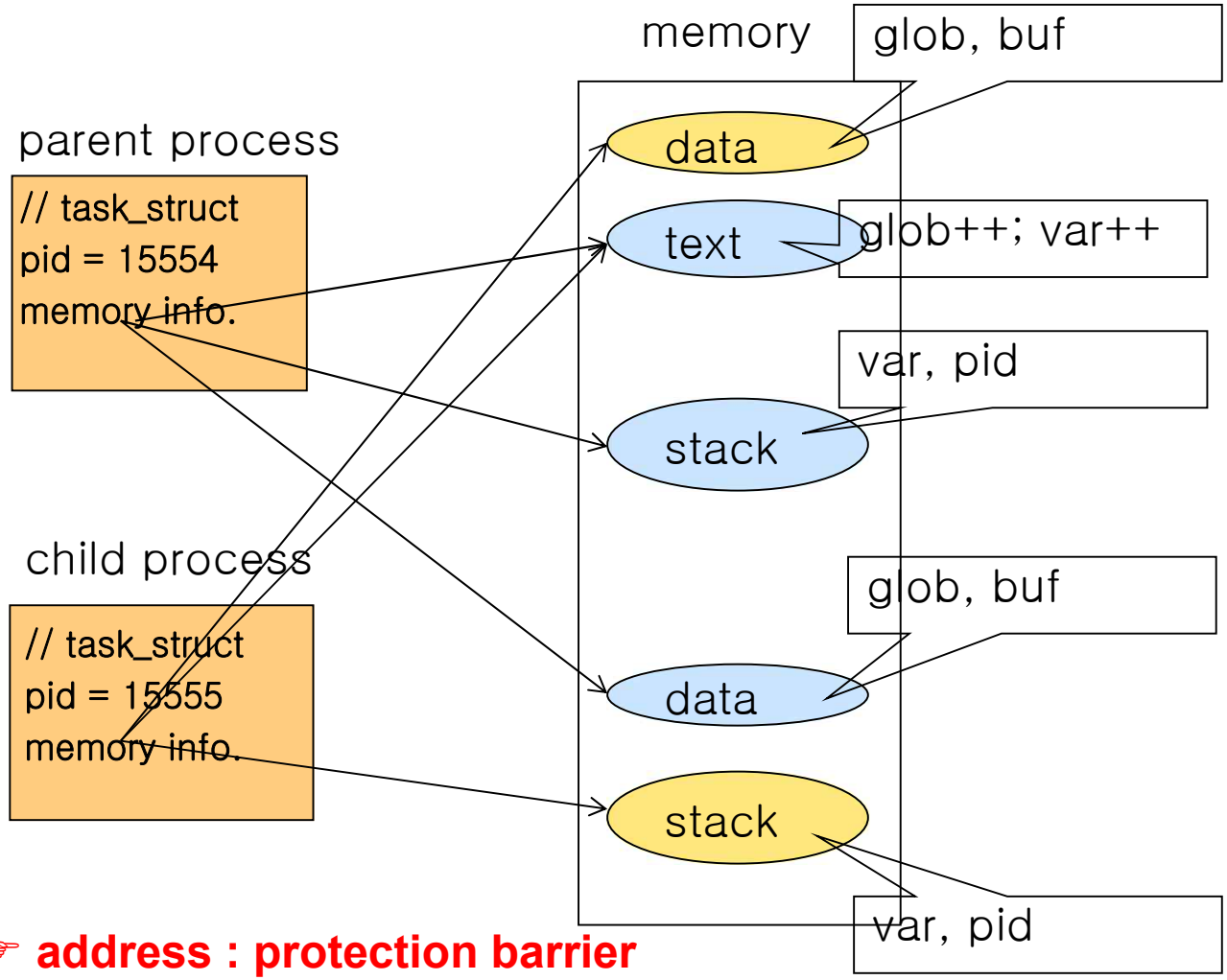
Process creation (5/6)

- Practice 2: execution results



Process creation (6/6)

- System's viewpoint of fork()



- address : protection barrier
- We can exploit "COW(Copy_on_Write)" for enhancing performance
- We do not consider "Paging" in this slide.

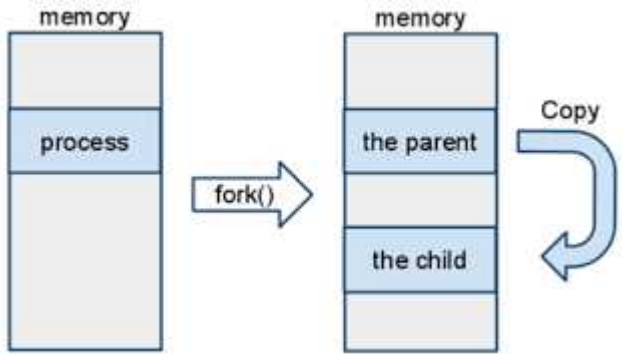
Quiz for 6th-Week 2nd-Lesson

- Quiz
  - ✓ 1. Discuss the return values of the fork() system call (hint: there are two return values).
  - ✓ 2. Answer the following 24.1 question appeared in LPI.
  - ✓ Bonus) What is the “fork bomb attack”?
  - ✓ Due: until 6 PM Friday of this week (9th, October)

24.7 Exercises

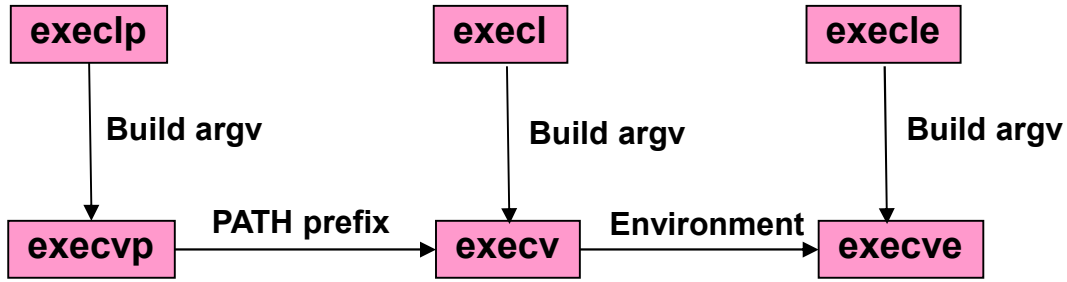
24-1. After a program executes the following series of *fork()* calls, how many new processes will result (assuming that none of the calls fails)?

```
fork();
fork();
fork();
```



Process execution (1/7)

- execve() system call
  - ✓ Execute a new program
    - Replace the current process's memory image (text, data, stack) with new binary
  - ✓ Six interfaces



Syntax

```
int execlp(const char *filename, const char *arg0, …, const char argn, (char *) 0);
int execvp(const char *filename, char *const argv[ ]);
int execl(const char *pathname, const char *arg0, …, const char *argn, (char *) 0);
int execv(const char *pathname, char *const argv[ ]);
int execle(const char *pathname, const char *arg0, …, const char *argn, (char *) 0,
    char *const envp[ ]);
int execve(const char *pathname, char *const argv[ ], char *const envp[ ]);
```

Process execution (2/7)

- Practice 3: executing a new program (binary)

```
/* execl_test.c:  execute a hello program, Sept. 27, choijm@dku.edu */
#include      <unistd.h>
#include      <stdio.h>
#include      <stdlib.h>

int main(int argc, char *argv[])
{
      pid_t fork_return, d_pid; int exit_status = -1;

      if ((fork_return = fork()) == -1) {
            // fork error handling
      } else if (fork_return == 0) {        // child
            execl("./hello", "./hello", (char *)0);
            printf("Child.. I'm here\n");
            // if execl() succeeds, the above printf() is not executed!!
            exit(1);
      } else {                    // parent
            d_pid = wait(&exit_status);
            printf("Parent.. I'm here\n");
            printf("exit status of process %d is %d\n", d_pid, exit_status);
      }
}
```

What does this comment mean?

Process execution (3/7)

- Practice 3: execution results

choijm@localhost:~/syspro_examples/chap5

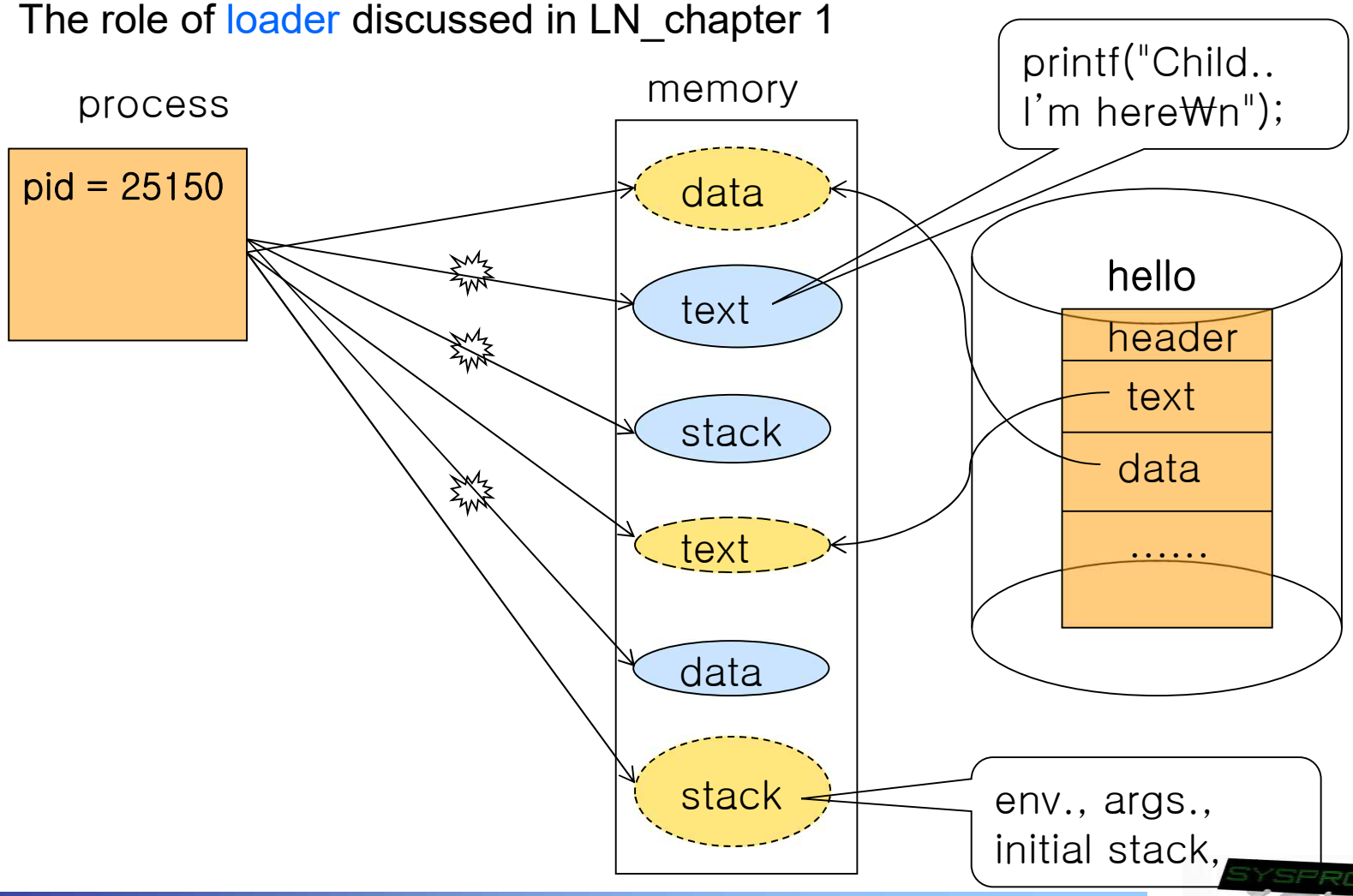
```
[choijm@localhost chap5]$
[choijm@localhost chap5]$ more hello.c
#include <stdio.h>
#include <stdlib.h>

main()
{
        printf("Hello World\n");
        exit(0);
}
[choijm@localhost chap5]$
[choijm@localhost chap5]$
[choijm@localhost chap5]$ more execl_test.c
/* execl_test.c:  hello 수행 . 9월 27일. choijm@dku.edu */
#include        <unistd.h>
#include        <stdio.h>
#include        <stdlib.h>

int main(int argc, char *argv[])
{
        pid_t pid, d_pid; int exit_status = -1;

        if ((pid = fork()) == -1) {
                // fork error 처리
        } else if (pid == 0) {          // child
                execl("./hello", "./hello", (char *)0);
                printf("Child.. I'm here\n");
                // execl 성공일 경우 여기는 수행될 수 없음
                exit(1);
        } else {                        // parent
                d_pid = wait(&exit_status);
                printf("Parent.. I'm here\n");
                printf("exit status of task %d is %d\n", d_pid, exit_status);
        }
}
[choijm@localhost chap5]$
```

choijm@localhost:~/syspro_examples/chap5

```
[choijm@localhost chap5]$
[choijm@localhost chap5]$ gcc -o hello hello.c
[choijm@localhost chap5]$
[choijm@localhost chap5]$ ./hello
Hello World
[choijm@localhost chap5]$
[choijm@localhost chap5]$
[choijm@localhost chap5]$ gcc -o execl_test execl_test.c
[choijm@localhost chap5]$
[choijm@localhost chap5]$
[choijm@localhost chap5]$ ./execl_test
Hello World
Parent.. I'm here
exit status of task 25150 is 0
[choijm@localhost chap5]$
[choijm@localhost chap5]$ ps
  PID TTY          TIME CMD
24693 pts/0    00:00:00 bash
25152 pts/0    00:00:00 ps
[choijm@localhost chap5]$
[choijm@localhost chap5]$
```

Process execution (4/7)

- System's viewpoint of execve()
  - ✓ Replace memory image (text, data, stack) with new one
  - ✓ The role of loader discussed in LN_chapter 1



Process execution (5/7)

- Practice 4: parameter passing to main() via shell

```
/* execl_test2.c:  printing argv[] and env[], Sept. 27, choijm@dku.edu */
#include <stdio.h>
int main(int argc, char *argv[], char *envp[])
{
        int i;
        for (i=0; argv[i]; i++)
                printf("arg %d = %s\n", i, argv[i]);
        for (i=0; envp[i]; i++)
                printf("env %d = %s\n", i, envp[i]);
}
```

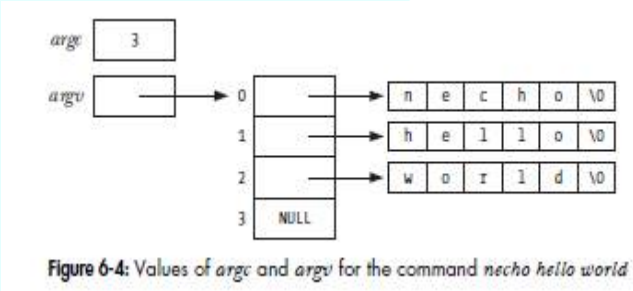


Figure 6-4: Values of *argc* and *argv* for the command *necho hello world*

```
choijm@embedded4: ~/syspro/chap5
choijm@embedded4:~/syspro/chap5$
choijm@embedded4:~/syspro/chap5$ vi execl_test2.c
choijm@embedded4:~/syspro/chap5$
choijm@embedded4:~/syspro/chap5$ gcc -o execl_test2 execl_test2.c
choijm@embedded4:~/syspro/chap5$
choijm@embedded4:~/syspro/chap5$ ./execl_test2 123 45678 hi DKU
arg 0 = ./execl_test2
arg 1 = 123
arg 2 = 45678
arg 3 = hi
arg 4 = DKU
env 0 = CPLUS_INCLUDE_PATH=/usr/include/i386-linux-gnu
env 1 = TERM=xterm
env 2 = SHELL=/bin/bash
env 3 = XDG_SESSION_COOKIE=a54ab53171ce938286893ed500000006-1443663425.239313
-310125375
env 4 = SSH_CLIENT=220.149.236.218 55483 22
env 5 = LIBRARY_PATH=/usr/lib/i386-linux-gnu
env 6 = SSH_TTY=/dev/pts/1
env 7 = USER=choijm
env 8 = LS_COLORS=rs=0:di=01;34:ln=01;36:mh=00:pi=40;33:so=01;35:do=01;35:bd=
40;33;01:cd=40;33;01:or=40;31;01:su=37;41:sg=30;43:ca=30;41:tw=30;42:ow=34;42
:st=37;44:ex=01;32:*.tar=01;31:*.tgz=01;31:*.arj=01;31:*.taz=01;31:*.lzh=01;3
1:*.lzma=01;31:*.tlz=01;31:*.txz=01;31:*.zip=01;31:*.z=01;31:*.Z=01;31:*.dz=0
1;31:*.gz=01;31:*.lz=01;31:*.xz=01;31:*.bz2=01;31:*.bz=01;31:*.tbz=01;31:*.tb
z2=01;31:*.tz=01;31:*.deb=01;31:*.rpm=01;31:*.jar=01;31:*.war=01;31:*.ear=01;
31:*.sar=01;31:*.rar=01;31:*.ace=01;31:*.zoo=01;31:*.cpio=01;31:*.7z=01;31:*.
rz=01;31:*.jpg=01;35:*.jpeg=01;35:*.gif=01;35:*.bmp=01;35:*.pbm=01;35:*.pgm=0
1;35:*.ppm=01;35:*.tga=01;35:*.xbm=01;35:*.xpm=01;35:*.tif=01;35:*.tiff=01;35
:*.png=01;35:*.svg=01;35:*.svgz=01;35:*.mng=01;35:*.pcx=01;35:*.mov=01;35:*.m
pg=01;35:*.mpeg=01;35:*.m2v=01;35:*.mkv=01;35:*.webm=01;35:*.ogm=01;35:*.mp4=
01;35:*.m4v=01;35:*.mp4v=01;35:*.vob=01;35:*.qt=01;35:*.nuv=01;35:*.wmv=01;35
:*.asf=01;35:*.rm=01;35:*.rmvb=01;35:*.flc=01;35:*.avi=01;35:*.fli=01;35:*.fl
```

Process execution (6/7)

- Practice 5: parameter passing to main() via execle()

```
/* execle_test3.c:  parameter passing, Sept. 27, choijm@dku.edu */
#include   <sys/types.h>
#include   <unistd.h>
#include   <stdio.h>
#include   <wait.h>

int main(int argc, char *argv[])
{
   pid_t fork_return, d_pid; int exit_status;
   char *const myenv[] = {"sys programming", "is", "fun", (char *)0};

   if ((fork_return = fork()) == -1) {
      // fork error handling
   } else if (fork_return == 0) {     // child
      execle("./execl_test2", "./execl_test2", “Hi", “DKU", (char *)0, myenv);
      printf("Child.. I’m here\n");
      // if execl succeeds, this printf() is not carried out!!
   } else {          // parent
      d_pid = wait(&exit_status);
      printf(“exit pid = %d with status = %d\n", d_pid, WEXITSTATUS(exit_status));
   }
}
```

Process execution (7/7)

- Practice 5: execution results

```
choijm@embedded: ~/syspro18/chap5
choijm@embedded:~/syspro18/chap5$ gcc -o execle_test3 execle_test3.c
choijm@embedded:~/syspro18/chap5$
choijm@embedded:~/syspro18/chap5$ ./execle_test3
arg 0 = ./execl_test2
arg 1 = Hi
arg 2 = DKU
env 0 = sys programming
env 1 = is
env 2 = fun
exit pid = 31727 with status = 0
choijm@embedded:~/syspro18/chap5$
choijm@embedded:~/syspro18/chap5$ more execle_test3.c
/* execle_test3.c:  parameter passing, Sept. 27, choijm@dku.edu */
#include    <sys/types.h>
#include    <unistd.h>
#include    <stdio.h>
#include    <wait.h>

int main(int argc, char *argv[])
{
    pid_t pid, d_pid; int exit_status;
    char *const myenv[] = {"sys programming", "is", "fun", (char *)0};

    if ((pid = fork()) == -1) {
        // fork error handling
    } else if (pid == 0) {      // child
        execle("./execl_test2", "./execl_test2", "Hi", "DKU", (char *)0, myenv);
        printf("Child.. I'm here\n");
        // if execl succeeds, this printf() is not carried out!!
    } else {            // parent
        d_pid = wait(&exit_status);
        printf("exit pid = %d with status = %d\n", d_pid, WEXITSTATUS(exit_status));
    }
```

Binary format (1/2)

- ELF (Executable Linking Format)

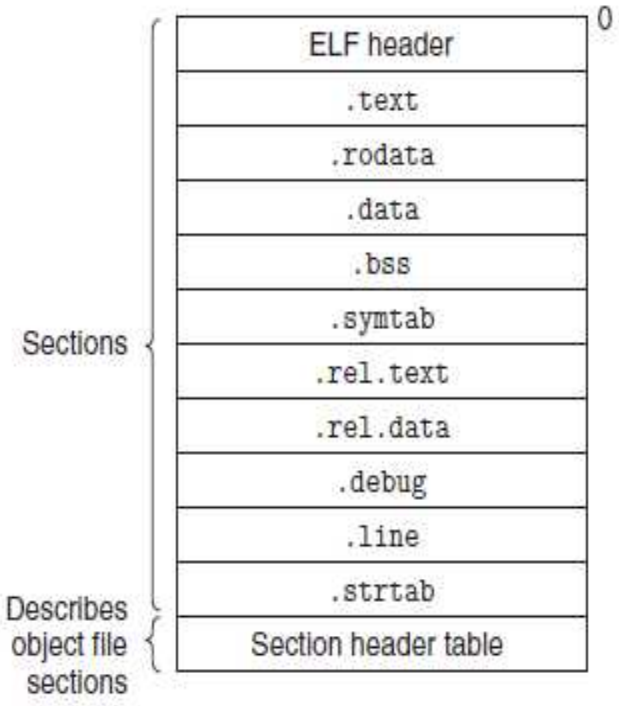


Fig. 7.3 Typical ELF relocatable object file

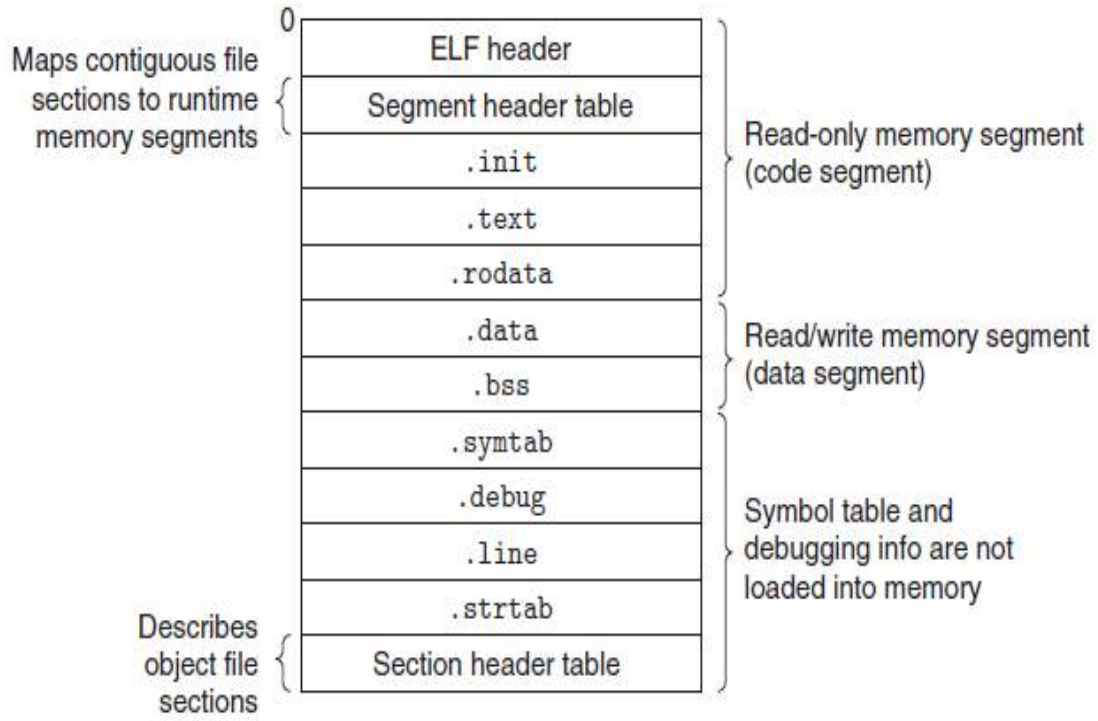


Fig. 7.11 Typical ELF executable object file

(Source: CSAPP)

☞ **Why we separate data into two sub-regions (initialized data and bss)?**

Binary format (2/2)

- Real view in Linux

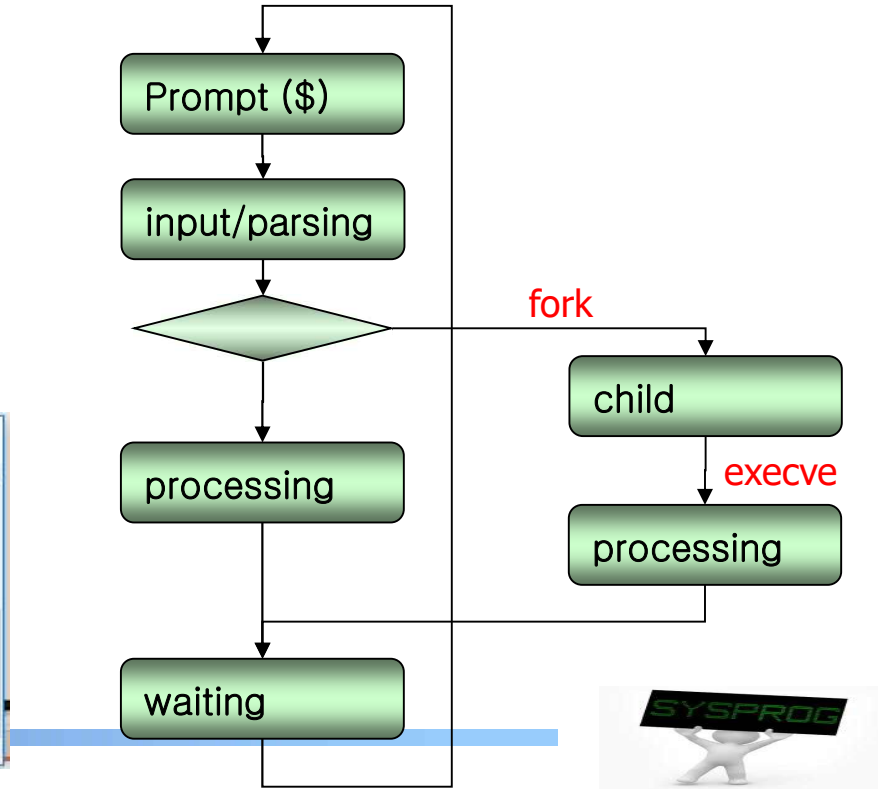
```
choijm@embedded: ~/syspro18/chap1
choijm@embedded:~/syspro18/chap1$ vi test.c
choijm@embedded:~/syspro18/chap1$ more test.c
#include <stdio.h>
int a = 10;
int b = 20;
int c;

main()
{
        c = a + b;
        printf("c = %d\n", c);
}
choijm@embedded:~/syspro18/chap1$ gcc -S test.c
choijm@embedded:~/syspro18/chap1$ gcc -c test.c
choijm@embedded:~/syspro18/chap1$ objdump -h test.o

test.o:     file format elf32-i386

Sections:
Idx Name          Size      VMA       LMA       File off  Algn
  0 .text         00000043  00000000  00000000  00000034  2**0
                  CONTENTS, ALLOC, LOAD, RELOC, READONLY, CODE
  1 .data         00000008  00000000  00000000  00000078  2**2
                  CONTENTS, ALLOC, LOAD, DATA
  2 .bss          00000000  00000000  00000000  00000080  2**0
                  ALLOC
  3 .rodata       00000008  00000000  00000000  00000080  2**0
                  CONTENTS, ALLOC, LOAD, READONLY, DATA
  4 .note.GNU-stack 00000000  00000000  00000000  00000088  2**0
                  CONTENTS, READONLY
  5 .comment      00000023  00000000  00000000  00000088  2**0
                  CONTENTS, READONLY
choijm@embedded:~/syspro18/chap1$ more test.s
        .file   "test.c"
.globl a
        .data
        .align 4
        .type   a, @object
        .size   a, 4
a:
        .long   10
.globl b
        .align 4
        .type   b, @object
        .size   b, 4
```

```
choijm@embedded: ~/syspro18/chap1
choijm@embedded:~/syspro18/chap1$ more test.s
        .file   "test.c"
.globl a
        .data
        .align 4
        .type   a, @object
        .size   a, 4
a:
        .long   10
.globl b
        .align 4
        .type   b, @object
        .size   b, 4
b:
        .long   20
        .section        .rodata
.LC0:
        .string "c = %d\n"
        .text
.globl main
        .type   main, @function
main:
        pushl   %ebp
        movl    %esp, %ebp
        subl    $8, %esp
        andl    $-16, %esp
        movl    $0, %eax
        addl    $15, %eax
        addl    $15, %eax
        shrl    $4, %eax
        sall    $4, %eax
        subl    %eax, %esp
        movl    b, %eax
        addl    a, %eax
        movl    %eax, c
        movl    c, %eax
        movl    %eax, 4(%esp)
        movl    $.LC0, (%esp)
        call    printf
        leave
        ret
        .size   main, .-main
        .comm   c,4,4
        .section        .note.GNU-stack,"",@progbits
        .ident  "GCC: (GNU) 3.4.6 (Debian 3.4.6-5)"
```

Shell (1/5)

- Command interpreter
  - ✓ Execute commands requested by users
- Basic logic
  - ✓ display prompt, input parsing
  - ✓ for external commands: do fork() and execve() at child process
  - ✓ for internal commands: perform in shell without fork() and execve()
- Advanced functions
  - ✓ Background processing
  - ✓ Redirection
  - ✓ Pipe (fork twice)
  - ✓ Shell script

```
choijm@embedded: ~/programming
choijm@embedded:~$ ls
examples.desktop  music  programming  README  sysprol8  tmp
choijm@embedded:~$
choijm@embedded:~$ cat README
About this machine
choijm@embedded:~$
choijm@embedded:~$ cd programming
choijm@embedded:~/programming$
choijm@embedded:~/programming$ ls
a.out  hello_backup.c  hello.c  README  README_new
choijm@embedded:~/programming$ gcc hello.c
choijm@embedded:~/programming$
```



Shell (2/5)

- Sample example

```
/* Simple shell, Kyoungmoon Sun(msg2me@msn.com), */
/* Dankook Univ. Embedded System Lab.  2008/7/2  */
#include <unistd.h>
...

bool cmd_help( int argc, char* argv[]) {
        ...
}
int tokenize( char* buf, char* delims, char* tokens[], int maxTokens ) {
        ...
        token = strtok( buf, delims );
        while( token != NULL && token_count < maxTokens ) {
                ...
        }
}
bool run( char* line ) {
        ...
        token_count = tokenize( line, delims, tokens, sizeof( tokens ) / sizeof( char* ) );
        // handling internal command such as cd, stty and exit
        // handling redirection, pipe and background processing
        if( (child = fork()) ==  0 ) {
                execvp( tokens[0], tokens );
        }
        wait (); ...
}
int main() {
        char line[1024];
        while(1) {
                printf( "%s $ ", get_current_dir_name() );
                fgets( line, sizeof( line ) - 1, stdin );
                if( run( line ) == false ) break;
        }
        ...
}
```

tokens[0] = "cat"
tokens[1] = "alphabet.txt"
or
tokens[0] = "gcc"
tokens[1] = "-o"
tokens[2] = "hello"
tokens[3] = "hello.c"

same as execlp("cat", "cat", "alphabet.txt", (char *)0);

$ cat alphabet.txt
or
$ gcc –o hello hello.c

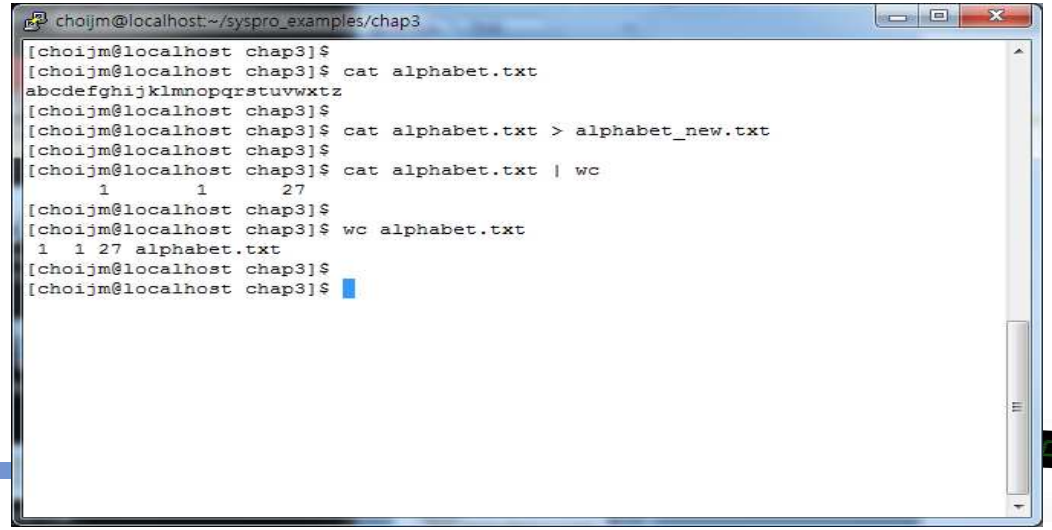
Shell (3/5)

- Execution example

```
choijm@localhost:~/syspro_examples/chap5
[choijm@localhost chap5]$ ls
exam1.c     execl_test.c   execl_test3    fork_test.c   hello
exam1.o     execl_test2    execl_test3.c  fork_test2    hello.c
execl_test  execl_test2.c  fork_test      fork_test2.c  mysh.c
[choijm@localhost chap5]$
[choijm@localhost chap5]$ gcc -o mysh mysh.c
[choijm@localhost chap5]$
[choijm@localhost chap5]$ ./mysh
/home/choijm/syspro_examples/chap5 $
/home/choijm/syspro_examples/chap5 $ ls
exam1.c     execl_test.c   execl_test3    fork_test.c   hello    mysh.c
exam1.o     execl_test2    execl_test3.c  fork_test2    hello.c
execl_test  execl_test2.c  fork_test      fork_test2.c  mysh
/home/choijm/syspro_examples/chap5 $
/home/choijm/syspro_examples/chap5 $ gcc -o hello hello.c
/home/choijm/syspro_examples/chap5 $
/home/choijm/syspro_examples/chap5 $ ./hello
Hello World
/home/choijm/syspro_examples/chap5 $
/home/choijm/syspro_examples/chap5 $ help
/***************Simple Shell***************/
You can use it just as the conventional shell

Some examples of the built-in commands
cd        : change directory
exit      : exit this shell
quit      : quit this shell
help      : show this help
?         : show this help
/******************************************/
/home/choijm/syspro_examples/chap5 $
/home/choijm/syspro_examples/chap5 $ ps
  PID TTY          TIME CMD
  307 pts/1    00:00:00 ps
32568 pts/1    00:00:00 bash
32765 pts/1    00:00:00 mysh
/home/choijm/syspro_examples/chap5 $
/home/choijm/syspro_examples/chap5 $ exit
[choijm@localhost chap5]$
[choijm@localhost chap5]$ ps
  PID TTY          TIME CMD
  308 pts/1    00:00:00 ps
32568 pts/1    00:00:00 bash
[choijm@localhost chap5]$
```

Shell (4/5)

- Background processing
  - ✓ both shell and command run concurrently
  - ✓ how to: do not use wait()
- Redirection
  - ✓ read/write data from/to file instead of STDIN/STDOUT
  - ✓ how to: replace STDIN/STDOUT with file's fd using dup2() before execve() (➔ refer to LN3)
- pipe
  - ✓ create two processes and make them communicate via pipe
  - ✓ how to: replace STDIN/STDOUT with fd[0]/fd[1] using pipe() and dup2() before execve()

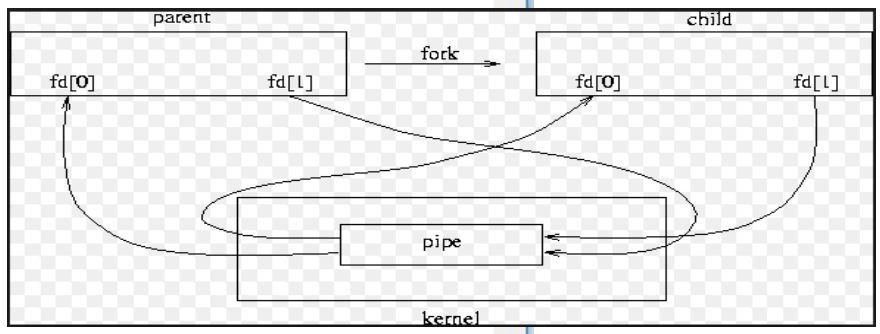


Shell (5/5)

- pipe() example
  - ✓ One of IPC (Inter Process Communication) mechanisms

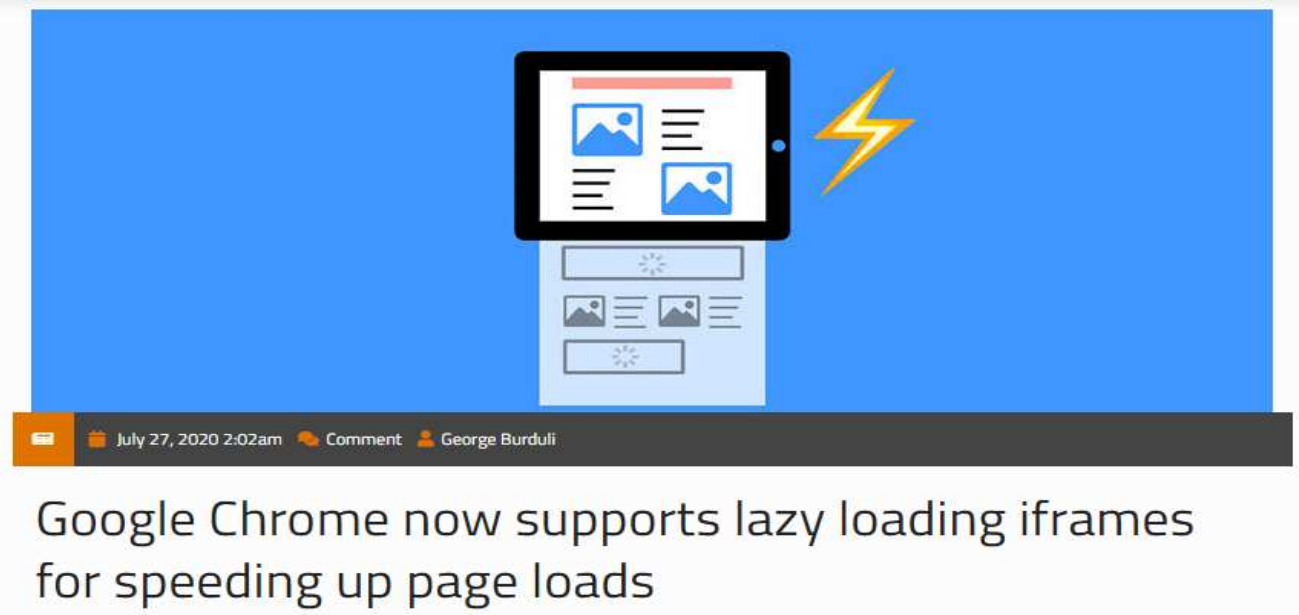
choijm@embedded: ~/syspro18/chap5

```
choijm@embedded:~/syspro18/chap5$ vi pipe_exam.c
choijm@embedded:~/syspro18/chap5$
choijm@embedded:~/syspro18/chap5$ cat pipe_exam.c
/* Pipe example by J. Choi, choijm@dankook.ac.kr */
#include <unistd.h>
#include <stdio.h>

int main()
{
    int fd[2];
    char bufc[16], bufp[16];
    int read_size = 0;

    pipe(fd);    // need to handle if exceptions occur
    if (fork() == 0) {
        write(fd[1], "Thank you", 10);
        sleep(1);
        read_size = read(fd[0], bufc, 16);
        bufc[read_size] = '\0';
        printf("%s by pid %d\n", bufc, getpid());
        exit(0);
    }
    else {
        read_size = read(fd[0], bufp, 16);
        bufp[read_size] = '\0';
        printf("%s by pid %d\n", bufp, getpid());
        write(fd[1], "My pleasure", 12);
        wait();
        close(fd[0]); close(fd[1]);
    }
}
choijm@embedded:~/syspro18/chap5$ gcc -o pipe_exam pipe_exam.c
choijm@embedded:~/syspro18/chap5$ ./pipe_exam
Thank you by pid 838
My pleasure by pid 839
choijm@embedded:~/syspro18/chap5$
```



Quiz for 7th-Week 1st-Lesson

- Quiz
  - ✓ 1. Statements after execve() are not executed (see Slide 12). Explain why they are not executed?
  - ✓ 2. What is the benefit of the on-demand loading (also called as lazy loading)?
  - ✓ Due: until 6 PM Friday of this week (16th, October)



Advanced Process Programming (1/9)

- Until now
  - ✓ We learned about the fork() and execve()
  - ✓ We can create multiple processes and run multiple programs

- From now on
  - ✓ Advanced process related system calls
    - signal, nice, gettimeofday, ptrace
  - ✓ Multiple processes raise several issues
    - Scheduling and Context switch
    - Memory management (memory sharing/protection)
    - IPC (Inter Process Communication)
    - Race condition and Synchronization
    - thread
    - …

Advanced Process Programming (2/9)

- Process-related system calls
  - ✓ Advanced
    - signal(), kill(), alarm() : signal handling such as register a signal handler (signal catch function) and signal delivery
    - sleep(), pause() : block for a certain period or until receiving a signal
    - nice(), getpriority(), setpriority() : control process priority
    - sched_setscheduler(), sched_getscheduler(), sched_setparam(), sched_getparam() : control process scheduling policy and parameters
    - times(), gettimeofday() : get timing information of a process and get the current time
    - ptrace() : allow a process to control the execution of other processes

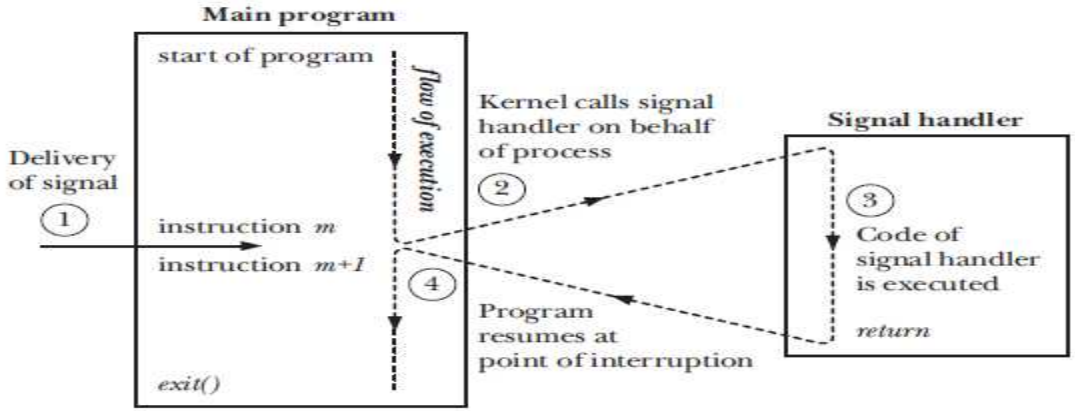


Figure 20-1: Signal delivery and handler execution

(Source: LPI)

Advanced Process Programming (3/9)

- Process-related system calls
  - ✓ File descriptor after fork()

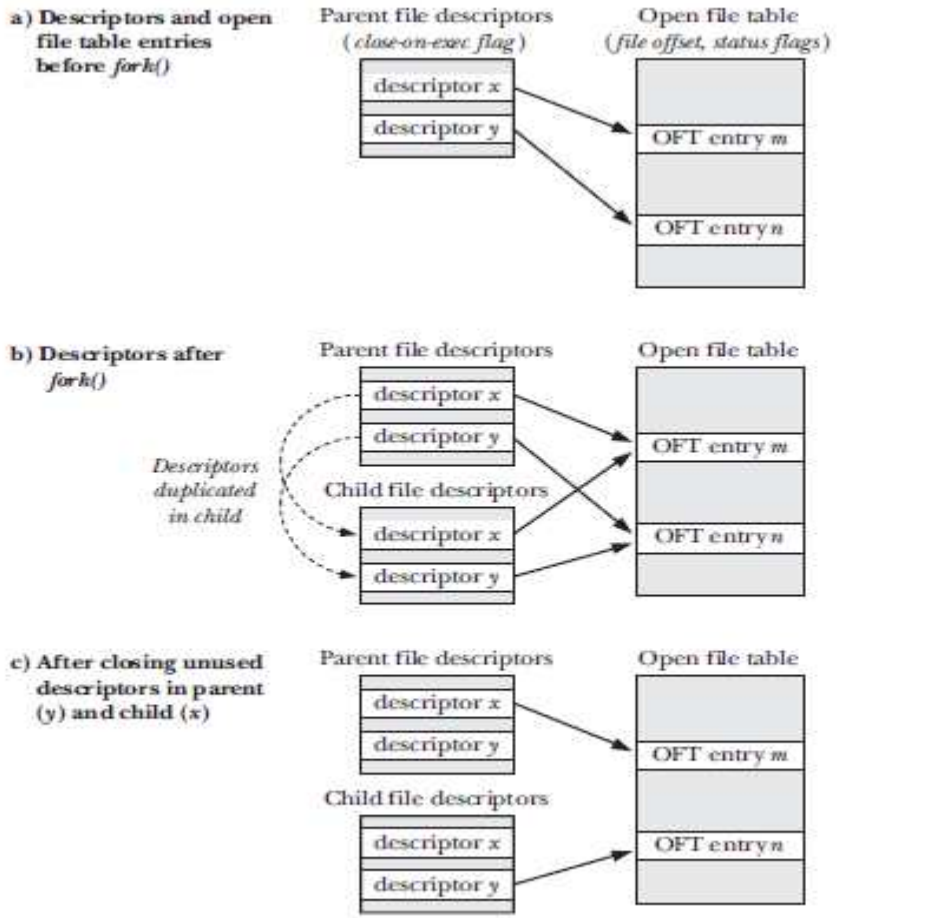


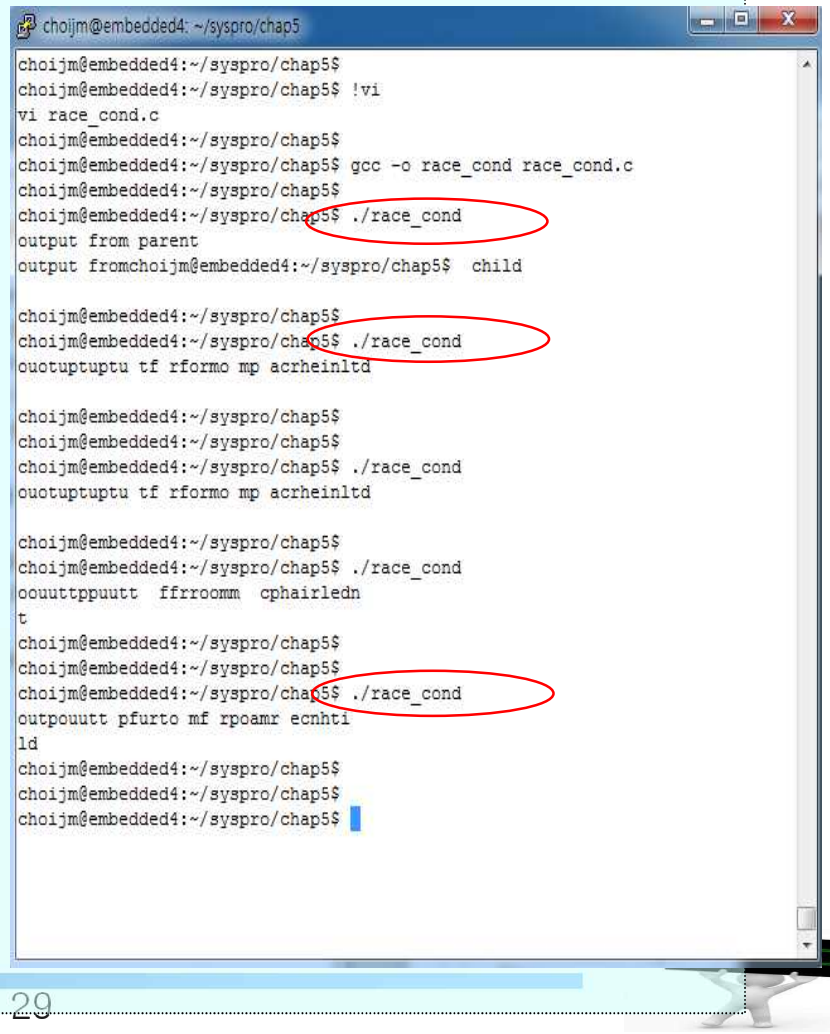
Figure 24-2: Duplication of file descriptors during *fork()*, and closing of unused descriptors

(Source: LPI)

Advanced Process Programming (4/9)

- Race condition

```
/* Race condition example by choijm. From Advanced Programming in UNIX Env.*/
#include   <sys/types.h>
#include   <unistd.h>

static void charatatime(char *str) {
   int i;

   for (; *str; str++) {
      for (i=0; i<1000; i++);
      write(STDOUT_FILENO, str, 1);
   }
}

int main(void) {
   pid_t   pid;

   if ( (pid = fork()) < 0) {
      perror("fork");
      exit(1);
   } else if (pid == 0) {
      charatatime("output from child\n");
   } else {
      charatatime("output from parent\n");
   }
}
```



Advanced Process Programming (5/9)

- When two processes run concurrently

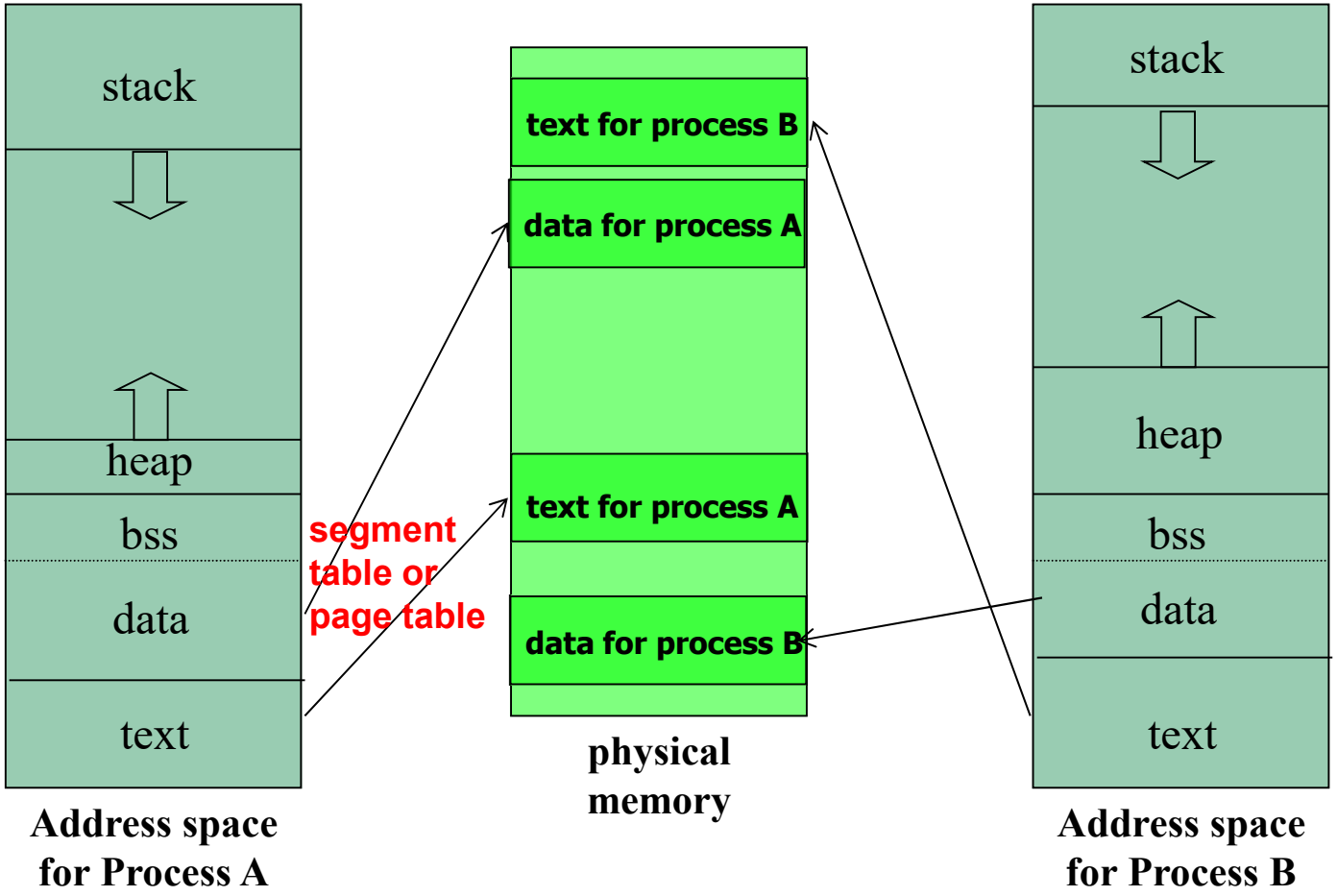
```
/* virtual_address.c: printing memory address , Oct. 9, choijm@dku.edu  */

int glob1, glob2;
main()
{
   int m_local1, m_local2;

   printf("process id = %d\n", getpid());
   printf("main local: \n\t%p, \n\t%p\n", &m_local1, &m_local2);
   printf("global: \n\t%p, \n\t%p\n", &glob2, &glob1);

   while (1);
}
```

☞ **Virtual address**

```
choijm@embedded4: ~/syspro/chap5
choijm@embedded4:~/syspro/chap5$ vi virtual_address.c
choijm@embedded4:~/syspro/chap5$
choijm@embedded4:~/syspro/chap5$ gcc -o virtual_address virtual_address.c
choijm@embedded4:~/syspro/chap5$
choijm@embedded4:~/syspro/chap5$ ./virtual_address &
[1] 16579
choijm@embedded4:~/syspro/chap5$ process id = 16579
main local:
        0xffca1294,
        0xffca1290
global:
        0x80496f4,
        0x80496f0

choijm@embedded4:~/syspro/chap5$ ./virtual_address &
[2] 16580
choijm@embedded4:~/syspro/chap5$ process id = 16580
main local:
        0xffdcaba4,
        0xffdcaba0
global:
        0x80496f4,
        0x80496f0

choijm@embedded4:~/syspro/chap5$
choijm@embedded4:~/syspro/chap5$ ps
  PID TTY          TIME CMD
15085 pts/1    00:00:01 bash
16579 pts/1    00:00:09 virtual_address
16580 pts/1    00:00:07 virtual_address
16581 pts/1    00:00:00 ps
choijm@embedded4:~/syspro/chap5$
```

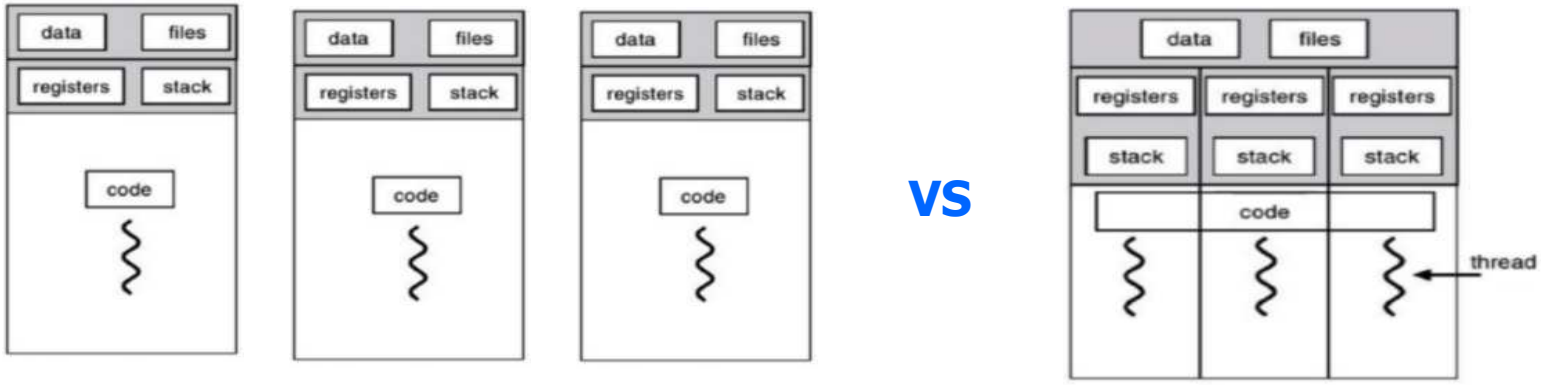
Advanced Process Programming (6/9)

- When two processes run concurrently (cont')



Advanced Process Programming (7/9)

- Thread introduction
  - ✓ Process
    - Data: independent model
    - Pros: 1) isolation, 2) easy to debug
    - Cons: 1) slow, 2) need explicit IPC (Inter-process communication)
  - ✓ Thread
    - Data: shared model
    - Pros: 1) fast and use less memory, 2) sharing
    - Cons: 1) all threads are killed if a thread has a problem, 2) hard to debug



(Source: https://www.toptal.com/ruby/ruby-concurrency-and-parallelism-a-practical-primer)

Advanced Process Programming (8/9)

- Thread: programming example

```
// fork example
// by J. Choi  (choijm@dku.edu)
#include <stdio.h>
#include <stdlib.h>

int a = 10;

void *func()
{
	a++;
	printf("pid = %d\n", getpid());
}

int main()
{
	int pid;

	if ((pid = fork()) == 0) { //need exception handle
		func();
		exit(0);
	}
	wait();
	printf("a = %d by pid = %d\n", a, getpid());
}
```

```
// thread example
// by J. Choi (choijm@dku.edu)
#include <stdio.h>
#include <stdlib.h>

int a = 10;

void *func()
{
	a++;
	printf("pid = %d\n", getpid());
}

int main()
{
	int p_thread;

	if ((pthread_create(&p_thread, NULL, func, (void
*)NULL)) < 0) {
		exit(0);
	}
	pthread_join(p_thread, (void *)NULL);
	printf("a = %d by pid = %d\n", a, getpid());
}
```

Advanced Process Programming (9/9)

- Thread: compile and execution

```
choijm@sungmin-Samsung-DeskTop-System: ~/syspro/chap5
choijm@sungmin-Samsung-DeskTop-System:~/syspro/chap5$ vi fork_sharing_test.c
choijm@sungmin-Samsung-DeskTop-System:~/syspro/chap5$
choijm@sungmin-Samsung-DeskTop-System:~/syspro/chap5$ vi thread_sharing_test.c
choijm@sungmin-Samsung-DeskTop-System:~/syspro/chap5$
choijm@sungmin-Samsung-DeskTop-System:~/syspro/chap5$ gcc -o fork_sharing_test fork_sharing_test.c
choijm@sungmin-Samsung-DeskTop-System:~/syspro/chap5$
choijm@sungmin-Samsung-DeskTop-System:~/syspro/chap5$ gcc -o thread_sharing_test thread_sharing_test.c -lpthread
choijm@sungmin-Samsung-DeskTop-System:~/syspro/chap5$
choijm@sungmin-Samsung-DeskTop-System:~/syspro/chap5$ ./fork_sharing_test
pid = 16134
a = 10 by pid = 16133
choijm@sungmin-Samsung-DeskTop-System:~/syspro/chap5$
choijm@sungmin-Samsung-DeskTop-System:~/syspro/chap5$ ./thread_sharing_test
pid = 16135
a = 11 by pid = 16135
choijm@sungmin-Samsung-DeskTop-System:~/syspro/chap5$
choijm@sungmin-Samsung-DeskTop-System:~/syspro/chap5$ more thread_sharing_test.c
// thread example
// by J. Choi (choijm@dku.edu)
#include <stdio.h>
#include <stdlib.h>

int a = 10;

void *func()
{
    a++;
    printf("pid = %d\n", getpid());
}

int main()
{
    int p_thread;

    if ((pthread_create(&p_thread, NULL, func, (void *)NULL)) < 0) {
        exit(0);
    }
    pthread_join(p_thread, (void *)NULL);
```

Summary

- Understand how to create a process
- Understand how to execute a new program
- Grasp the role and internals of shell
- Discuss issues on multitask
  - ✓ IPC (Inter Process Communication)
  - ✓ Race condition
  - ✓ Virtual memory
  - ✓ Differences between process and thread

☞ **Homework 4: Make a shell**

✓ Requirements

- implement basic logic (parsing, fork(), execve())

- implement background processing

- shows student's ID and date (using whoami and date)

- Make a report that includes a snapshot (22 page) and discussion.

1) Upload the report to the e-Campus (pdf format!!, 30th October)

2) Send the report and source code to TA (이성현: wwbabaww@gmail.com)

✓ Bonus: implement redirection

Appendix 1

- Revisit “gdb”

choijm@embedded: ~/syspro

```
int tokenize(char *line , char *tokens[], int maxToken) {
    int t_cnt = 0;
    char *token, *delimiter = " \n";

    token = strtok(line, delimiter);

    while(token && t_cnt < maxToken) {
        tokens[t_cnt++] = token;
        token = strtok(NULL, delimiter);
    }
    tokens[t_cnt] = '\0';
    return t_cnt;
}

bool run(char *line) {
    pid_t pid;  int i, j, fd, t_cnt;
    bool t_bg = false;
    char *tokens[10];

    t_cnt = tokenize(line, tokens, sizeof(tokens) /sizeof(char *));
    if(t_cnt == 0) return true;
    if(strcmp(tokens[0], "exit") == 0) return false;
"mysh.c" 72 lines --30%--                                    27,10-13
```

choijm@embedded: ~/syspro

```
choijm@embedded:~/syspro$ vi mysh.c
choijm@embedded:~/syspro$ gcc -g -o mysh mysh.c
choijm@embedded:~/syspro$ gdb mysh
GNU gdb (Ubuntu 7.11.1-0ubuntu1~16.5) 7.11.1
Copyright (C) 2016 Free Software Foundation, Inc.
License GPLv3+: GNU GPL version 3 or later <http://gnu
This is free software: you are free to change and redi
There is NO WARRANTY, to the extent permitted by law.
and "show warranty" for details.
This GDB was configured as "x86_64-linux-gnu".
Type "show configuration" for configuration details.
For bug reporting instructions, please see:
<http://www.gnu.org/software/gdb/bugs/>.
Find the GDB manual and other documentation resources
<http://www.gnu.org/software/gdb/documentation/>.
For help, type "help".
Type "apropos word" to search for commands related to
Reading symbols from mysh...done.
(gdb) br 27
Breakpoint 1 at 0x80486ec: file mysh.c, line 27.
(gdb) run
Starting program: /home/choijm/syspro/mysh
/home/choijm/syspro$ ls -l

Breakpoint 1, run (line=0xffffd4b0 "ls -l\n") at mysh.
27              t_cnt = tokenize(line, tokens, sizeof(
(gdb) p line
$1 = 0xffffd4b0 "ls -l\n"
(gdb) p tokens[0]
$2 = 0x41fd <error: Cannot access memory at address 0x
(gdb) n
28              if(t_cnt == 0) return true;
(gdb) p tokens[0]
$3 = 0xffffd4b0 "ls"
(gdb) p tokens[1]
$4 = 0xffffd4b3 "-l"
(gdb) c
```

Quiz for 7th-Week 2nd-Lesson

- Quiz
  - ✓ 1. Discuss how to overcome the problem of the Slide 29 (Synchronization problem). Use what we learnt only (not use lock or semaphore which you will learn in the OS course)
  - ✓ 2. Each tab of a browser can be implemented either process or thread. Which is better? Explain your own opinion.
  - ✓ Due: until 6 PM Friday of this week (16th, October)