Ch8. Processes and Programs - Studying sh

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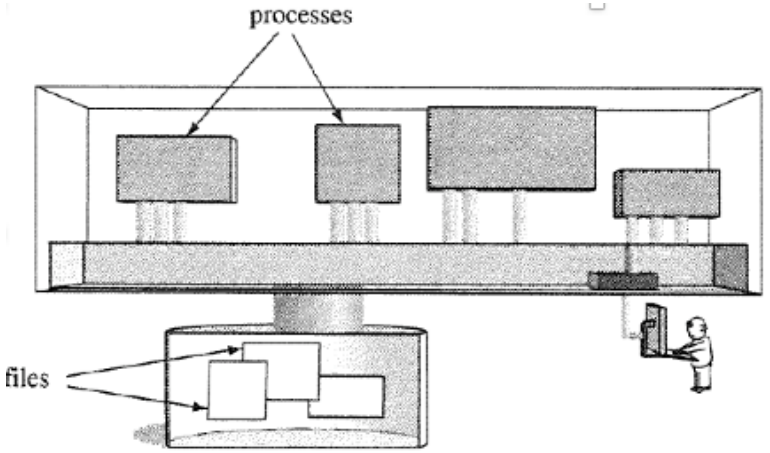
Objectives

- Ideas and Skills
  - What a Unix **shell** does
  - The Unix model of a **process**
  - How to **run a program**
  - How to **create a process**
  - How **parent and child processes communicate**
- System Calls
  - fork, exec, wait, exit
- Commands
  - sh, ps

Contents

Program and Process

- Program
  - A sequence of machine-language instructions stored in a file
- Running a program means
  - Load that list of machine-language instructions into memory
  - The processor(CPU) execute the instructions one by one
- Process = Programs in action
  - *A process is an* ***instance of a computer program that is being executed.*** *It* is a piece of program that is loaded, being executing and running in the system.



Learning about Processes with “ps” command

- **ps** : list current processes

```
seokin@compasslab1:~$ ps
  PID TTY          TIME CMD
23467 pts/0    00:00:00 bash
23476 pts/0    00:00:00 ps
```

  - **PID**
    - process ID
  - **TTY**
    - the name of the console or terminal that the user logged into
  - **TIME**
    - the amount of CPU time in minutes and seconds that the process has been running
  - **CMD**
    - the name of the command that launched the process

Learning about Processes with “ps” command

- **ps -a**

```
[seokin@compasslab1:~$ ps -a
  PID TTY          TIME CMD
  973 tty1     00:00:00 gnome-session-b
  980 tty1     00:01:39 gnome-shell
  999 tty1     00:00:00 Xwayland
 1373 tty1     00:00:00 ibus-daemon
 1376 tty1     00:00:00 ibus-dconf
 1379 tty1     00:00:00 ibus-x11
 1416 tty1     00:00:00 gsd-xsettings
 1424 tty1     00:00:00 gsd-a11y-settin
 1432 tty1     00:00:00 gsd-clipboard
 1433 tty1     00:04:04 gsd-color
 1436 tty1     00:00:00 gsd-datetime
 1438 tty1     00:00:00 gsd-housekeepin
 1440 tty1     00:00:00 gsd-keyboard
 1441 tty1     00:00:00 gsd-media-keys
 1444 tty1     00:00:00 gsd-mouse
 1446 tty1     00:00:01 gsd-power
```

⋮

-a option

- lists more processes, including ones being run by other users and at other terminals
- the output from –a does not include the shell

Learning about Processes with “ps” command

ps -al

```
$ ps -la
  F S   UID   PID  PPID  C PRI  NI ADDR  SZ WCHAN  TTY          TIME CMD
000 S   504  1779  1731  0  69   0   -  1086 do_sel pts/0    00:00:13 gv
000 S   504  1780  1779  0  69   0   -  2309 do_sel pts/0    00:00:07 gs
000 S   504  1781  1731  0  72   0   -  1320 do_sel pts/0    00:00:01 vi
000 S   519  2013  1993  0  69  19   -  1300 do_sel pts/2    00:00:23 xpain
000 S   519  2017  1993  0  69   0   -   363 read_c pts/2    00:00:02 mail
000 R   500  2023  1755  0  79   0   -   750 -      pts/1    00:00:00 ps
```

- **S** : status of each process.
  - S: sleeping, R : running
- **UID** : user ID
- **PID** : process ID
- **PPID** : parent process ID
- **PRI** : priority
  - higher numbers mean lower priority

- NI : niceness level
  - 19(nicest) ~ -20(not nice to other)
  - a process with a higher nice number will yield CPU time to other processes on the system.
  - ※ The kernel uses these values, PRI & NI, to decide when to run processes.

Learning about Processes with “ps” command

- **ps -al**

```
$ ps -la
  F S   UID   PID  PPID  C PRI  NI ADDR  SZ WCHAN  TTY          TIME CMD
000 S   504  1779  1731  0  69   0  -  1086 do_sel pts/0    00:00:13 gv
000 S   504  1780  1779  0  69   0  -  2309 do_sel pts/0    00:00:07 gs
000 S   504  1781  1731  0  72   0  -  1320 do_sel pts/0    00:00:01 vi
000 S   519  2013  1993  0  69  19  -  1300 do_sel pts/2    00:00:23 xpain
000 S   519  2017  1993  0  69   0  -   363 read_c pts/2    00:00:02 mail
000 R   500  2023  1755  0  79   0  -   750 -      pts/1    00:00:00 ps
```

- **SZ :** process size (KB)
  - the amount of memory the process is using
- **WCHAN :** wait channel
  - Name of the kernel function in which the process is sleeping (waiting on)
  - All the processes in this example are waiting for input; the entries read_c and do_sel refer to the kernel function

- **ADDR and F**
  - no longer used, but appear in the output for compatibility with programs that expect to see them.

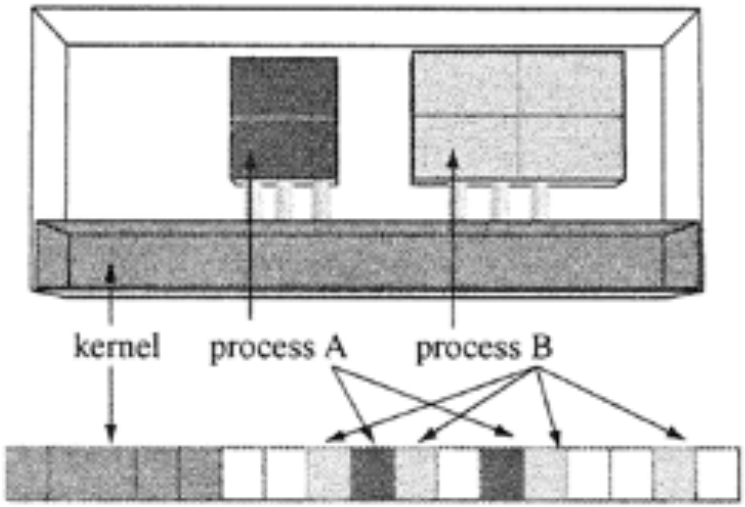
Learning about Processes with “ps” command

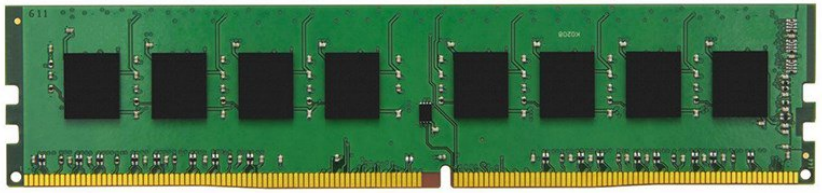
- **ps –af**

```
[seokin@compasslab1:~$ ps -af
UID          PID  PPID  C STIME TTY          TIME CMD
gdm          973   969  0 10月 24 tty1   00:00:00 /usr/lib/gnome-session/gnome-session-b
gdm          980   973  0 10月 24 tty1   00:01:39 /usr/bin/gnome-shell
gdm          999   980  0 10月 24 tty1   00:00:00 /usr/bin/Xwayland :1024 -rootless -ter
gdm         1373   980  0 10月 24 tty1   00:00:00 ibus-daemon --xim --panel disable
gdm         1376  1373  0 10月 24 tty1   00:00:00 /usr/lib/ibus/ibus-dconf
gdm         1379     1  0 10月 24 tty1   00:00:00 /usr/lib/ibus/ibus-x11 --kill-daemon
gdm         1416   973  0 10月 24 tty1   00:00:00 /usr/lib/gnome-settings-daemon/gsd-xse
gdm         1424   973  0 10月 24 tty1   00:00:00 /usr/lib/gnome-settings-daemon/gsd-a11

                                .........

seokin    23530 23467  0 23:36 pts/0    00:00:00 ps -af
```

  - The username is displayed instead of the UID number
  - Completed command line is listed in the CMD column

Computer Memory & Computer Program





- Memory in a Unix system is divided into kernel space and user space
- Processes live in user space
- Processes are usually divided into smaller chunks, just as disk files are divided into disk blocks
- As a file has an allocation list of disk blocks, a process has a structure to hold the allocation list of memory pages

Computer Memory & Computer Program

- Creating a process is similar to creating a disk file.
  - Kernel has to find some free pages of memory to hold the machine-language codes and data bytes for the program.
  - Kernel sets up some data structures to store memory allocation information and the attributes of the process.

Contents

THE SHELL

- A shell is a program that manages processes and runs programs

- Thee main functions of shells
  (a) Shells run programs
  (b) Shells manage input and output
  (c) Shells can be programmed

THE SHELL

```
seokin@compasslab1:~$ ls
'[2018-2nd-sysp-001]HW1CopyaDirectory'       dir1                log                 system_programming
'[2018-2nd-sysp-001]HW1CopyaDirectory.zip'   Documents           Music               Templates
 a                                           Downloads           Pictures            test
 add_user.py                                 examples.desktop    play_again1.c       Videos
 a.out                                       hw1                 Public              workspace
 Desktop                                     lab_dir_creation    student_id
seokin@compasslab1:~$ ps
  PID TTY          TIME CMD
24041 pts/0    00:00:00 bash
24050 pts/0    00:00:00 ps
```

- Running Programs
  - The shell loads programs into memory and runs them
  - Shell = program launcher

THE SHELL

```
seokin@compasslab1:~$ ls
'[2018-2nd-sysp-001]HW1CopyaDirectory'        dir1                log              student_id
'[2018-2nd-sysp-001]HW1CopyaDirectory.zip'    Documents           ls.txt           system_programming
 a                                            Downloads           Music            Templates
 add_user.py                                  examples.desktop    Pictures         test
 a.out                                        hw1                 play_again1.c    Videos
 Desktop                                      lab_dir_creation    Public           workspace
seokin@compasslab1:~$ ls > ls.txt
seokin@compasslab1:~$ ls | grep P
Pictures
Public
seokin@compasslab1:~$
```

- Managing Input and Output
  - >, <, | are symbols for input/output redirection
  - With the symbols, a user tells the shell to attach the input and output of processes to disk file or to other processes

THE SHELL

```
seokin@compasslab1:~$ for ((num =0; num <3 ; num++))
> do
> echo "num:$num"
> done
num:0
num:1
num:2
```

- Programming
  - The shell is also a programming language with variables and flow control (if, while, etc.)
  - We can make an executable script (shell script)

Contents

How the shell runs programs

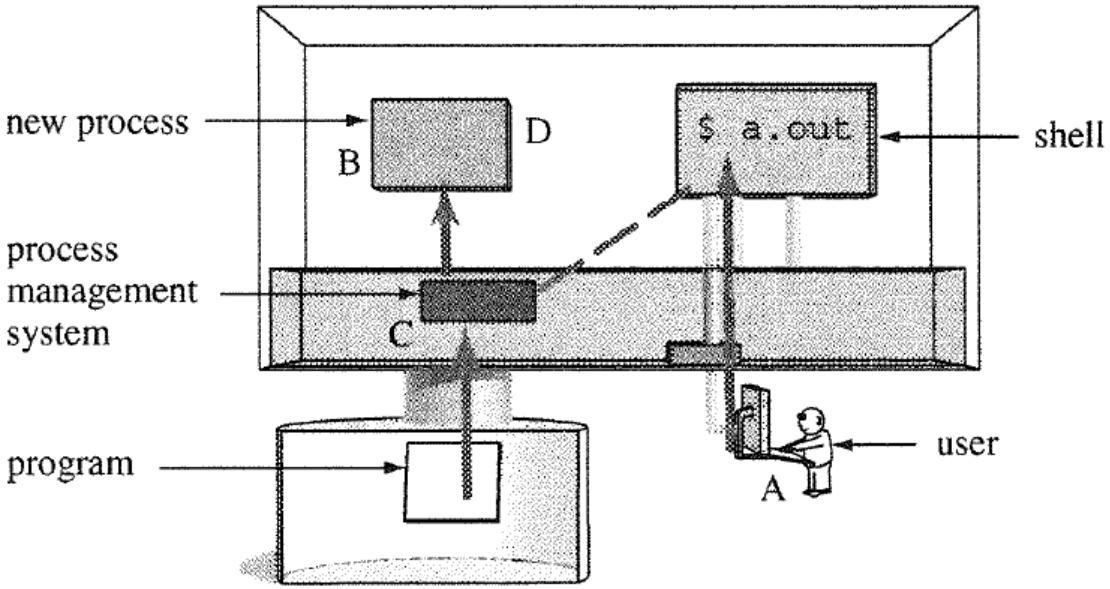


FIGURE 8.4

A user asks a shell to run a program.

A. The user types a.out

B. The shell creates a new process to run the program

C. The shell loads the program from the disk into the process

D. The program runs in its process until it is done

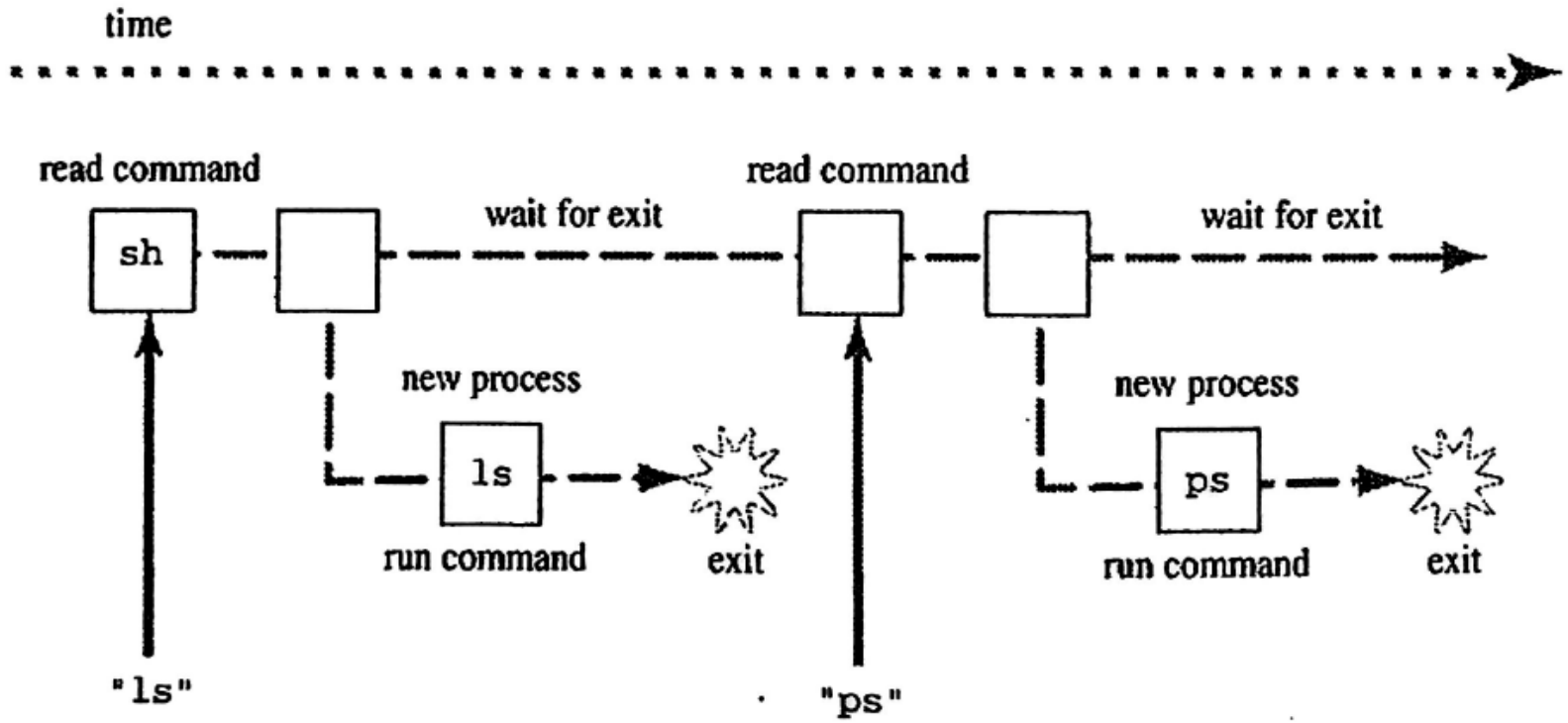
The Main Loop of a Shell

- Shell consists of following loop:

```
while ( ! end_of_input )
     get command
     execute command
     wait for command to finish
```

To write a shell, we need to learn how to

1. Run a program
2. Create a process
3. Wait for exit()



Q1: How Does a Program Run a Program?

- Answer: The program calls “execvp()’ system call

execvp

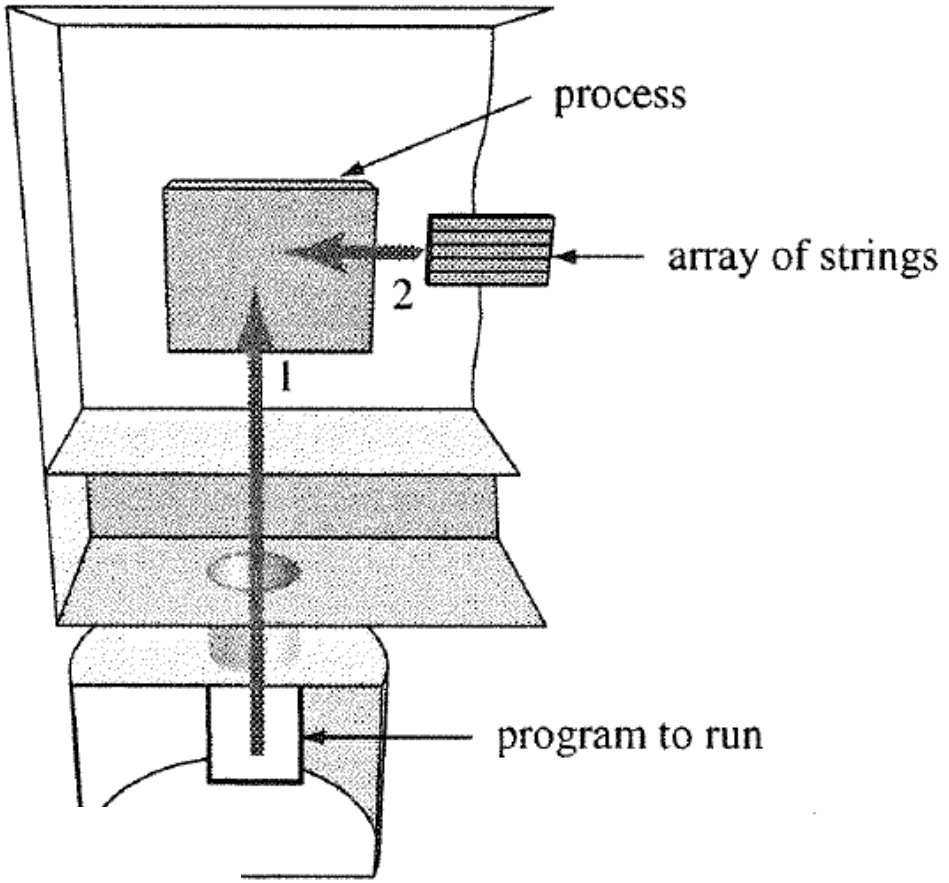
PURPOSE	Execute a file, with PATH searching
INCLUDE	#include <unistd.h>
USAGE	result = execvp(const char *file, const char *argv[])
ARGS	file name of file to execute argv array of strings
RETURNS	-1 if error

Q1: How Does a Program Run a Program?

How Unix runs programs:

`execvp(progname, arglist)`

1. copies the named program into the calling process,
2. passes the specified list of strings to the program as argv[], then
3. runs the program.



1. Program calls `execvp`
2. Kernel loads program from disk into the process
3. Kernel copies `arglist` into the process
4. Kernel calls `main(argc,argv)`

Example 1

```
/* exec1.c - shows how easy it is for a program to run a program
 */
#include <stdio.h>
#include <unistd.h>

main()
{
        char    *arglist[3];
        arglist[0] = "ls";              //First string is the name of the program
        arglist[1] = "-l";
        arglist[2] = 0 ;                //Last string must have a null pointer
        printf("* * * About to exec ls -l\n");
        execvp( "ls" , arglist );
        printf("* * * ls is done. bye\n");
}
```

Example 1

```
*** About to exec 'ls -l'
total 60
drwxrwxr-x 2 seokin seokin 4096  9月  12 01:50 lab1
drwxrwxr-x 2 seokin seokin 4096  9月  12 01:50 lab10
drwxrwxr-x 2 seokin seokin 4096  9月  12 01:50 lab11
drwxrwxr-x 3 seokin seokin 4096  9月  12 01:50 lab12
drwxrwxr-x 3 seokin seokin 4096 10月  17 02:30 lab2
drwxrwxr-x 2 seokin seokin 4096 10月  17 04:32 lab3
drwxrwxr-x 3 seokin seokin 4096 10月  16 23:26 lab4
drwxrwxr-x 2 seokin seokin 4096 10月  24 09:27 lab5
drwxrwxr-x 2 seokin seokin 4096 10月  24 07:55 lab6
drwxrwxr-x 3 seokin seokin 4096 10月  31 00:42 lab7
drwxrwxr-x 2 seokin seokin 4096 10月  31 00:40 lab8
drwxrwxr-x 2 seokin seokin 4096  9月  12 01:50 lab9
drwxrwxr-x 2 seokin seokin 4096  9月  12 01:50 lab_dir_create
drwxrwxr-x 2 seokin seokin 4096 10月   9 19:17 mylab5
-rwxr-xr-x 1 seokin seokin 3222  9月  12 01:50 utmp.h
```

- Where is the second message?

Example 1-1

- Compare pid before execvp and after

- pid_t getpid(void)
  - returns the process ID of the current process
  - unistd.h

Example 1-2

- Process ID after execvp()

```c
/* after.c */

#include <unistd.h>
#include <stdio.h>

void main()
{
        pid_t pid = getpid();

        printf("After execvp(): %d\n", pid);

        return;
}
```

```c
/* before.c */

#include <unistd.h>
#include <stdio.h>

void main()
{
        char *arg[2];
        arg[0] = "./after";
        arg[1] = 0;

        pid_t pid = getpid();

        printf("before execvp(): %d\n", pid);

        execvp(arg[0], arg);

        return;
}
```

Example 1-2

- result

```
[seokin@compasslab1:~/system_programming/labs/lab7$ ./before
Before execvp(): 24317
After execvp(): 24317
[seokin@compasslab1:~/system_programming/labs/lab7$ ./before
Before execvp(): 24318
After execvp(): 24318
[seokin@compasslab1:~/system_programming/labs/lab7$ ./before
Before execvp(): 24319
After execvp(): 24319
[seokin@compasslab1:~/system_programming/labs/lab7$ ./before
Before execvp(): 24320
After execvp(): 24320
[seokin@compasslab1:~/system_programming/labs/lab7$ ./before
Before execvp(): 24321
After execvp(): 24321
```

What does “execvp()’ system call do

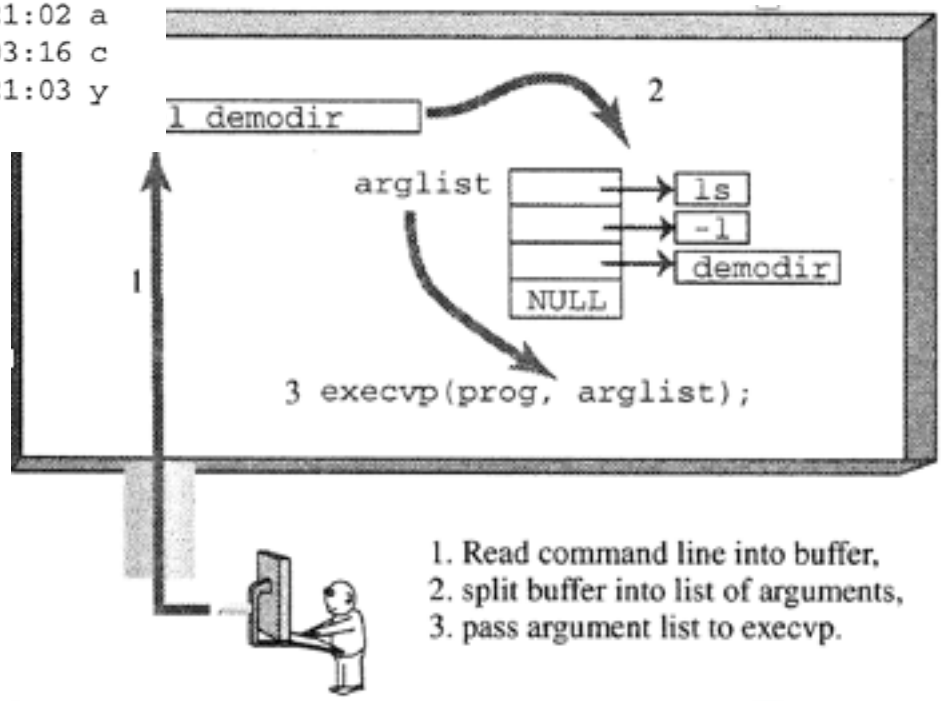
- execvp() system call clears out the machine-language code of the current program from the current process
- Puts the code of the program named in the execvp() system call
- Run that new program
- execvp() changes the memory allocation of the process to fit the space requirements of the new program.
- execvp() does not return if it succeeds

- **The process is the same, the contents are new!**

Example 2: a prompting shell (psh1.c)

- The first version of a shell
  - It will prompts the user for a program name and argumetns and then run the program

```
Arg[0]? ls Enter
Arg[1]? -l Enter
Arg[2]? demodir Enter
Arg[3]? Enter
total 2
drwxr-x---    2 bruce    users        1024 Jul 14 21:02 a
drwxr-x---    3 bruce    users        1024 Jul 16 03:16 c
-rw-r--r--    1 bruce    users           0 Jul 14 21:03 y
$
```



Example 2: a prompting shell (psh1.c)

```
/*      prompting shell version 1    (psh1.c)
 *              Prompts for the command and its arguments.
 *              Builds the argument vector for the call to execvp.
 *              Uses execvp(), and never returns.
 */

#include        <stdio.h>
#include        <signal.h>
#include        <string.h>
#include      <stdlib.h>

#define MAXARGS         20                      /* cmdline args */
#define ARGLEN          100                     /* token length */

char* makestring(char*);
int execute(char*[]);
```

Example 2: a prompting shell (psh1.c)

```
int main()
{
        char    *arglist[MAXARGS+1];            /* an array of ptrs     */
        int     numargs = 0;                    /* index into array     */
        char    argbuf[ARGLEN];                 /* read stuff here      */

        while ( numargs < MAXARGS )
        {                                                ※입력 첫 문자가
                printf("Arg[%d]? ", numargs);            '\n'이 아닐 때 *
                if ( fgets(argbuf, ARGLEN, stdin) && *argbuf != '\n' )
                        arglist[numargs++] = makestring(argbuf);
                else //입력 첫 문자가 '\n'일 때
                {
                        if ( numargs > 0 ){             /* any args?    */
                                arglist[numargs]=NULL;  /* close list   */
                                execute( arglist );     /* do it        */
                                numargs = 0;            /* and reset    */
                         }
                }
        }
        return 0;
}
```

Example 2: a prompting shell (psh1.c)

```
int execute( char *arglist[] )
/*
 *      use execvp to do it
 */
{
        execvp(arglist[0], arglist);            /* do it */
        perror("execvp failed");
        exit(1);
}
```

Example 2: a prompting shell (psh1.c)

```
char * makestring( char *buf )
/*
 * trim off newline and create storage for the string
 */
{
        char    *cp ;

        buf[strlen(buf)-1] = '\0';              /* trim newline */
        cp = malloc( strlen(buf)+1 );           /* get memory   */
        if ( cp == NULL ){                      /* or die       */
                fprintf(stderr,"no memory\n");
                exit(1);
        }
        strcpy(cp, buf);                /* copy chars   */
        return cp;                      /* return ptr   */
}
```

Example 2: a prompting shell (psh1.c)

- How'd it Go?
  - The program works OK
  - but execvp replaces the code of the shell with the code of the command, then exits,

- A solution is to create a new process and have that new process execute the program.

Q2: How Do We Get a New Process?

- Ans: A process calls fork() system call to replicate itself.

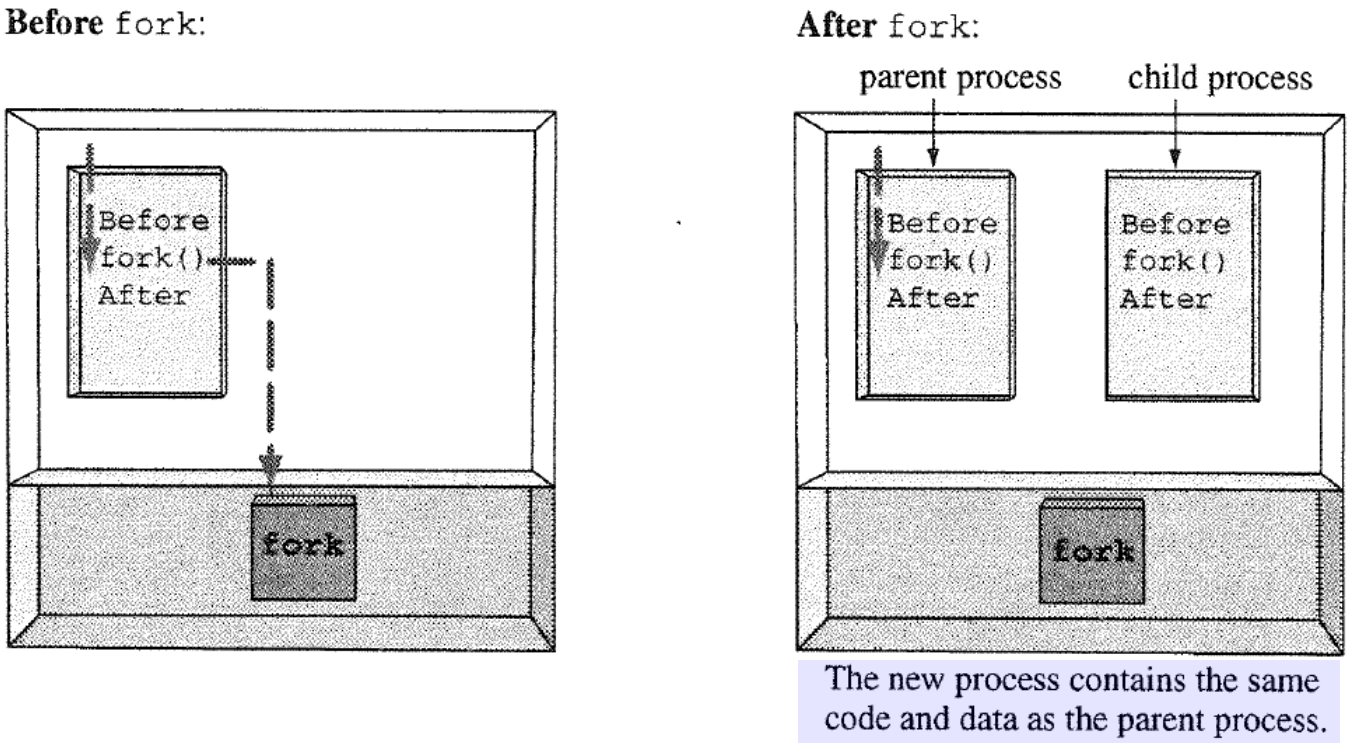


FIGURE 8.8

`fork()` makes a copy of a process.

fork() system call

- The process contains the program and a current location in the program.
- The process then calls fork().
- Control passes into the fork code inside the kernel.

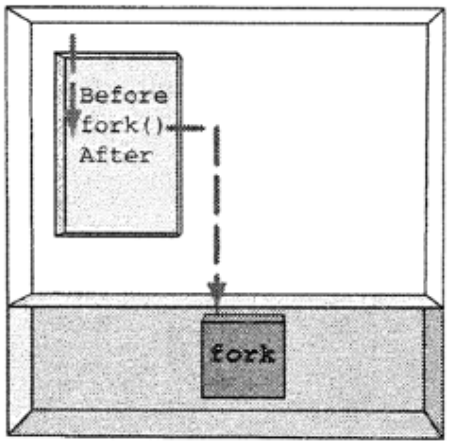
- The kernel does this:

  (a) **Allocates** a new chunk of memory and kernel data structures.

  (b) **Copies** the original process into the new process

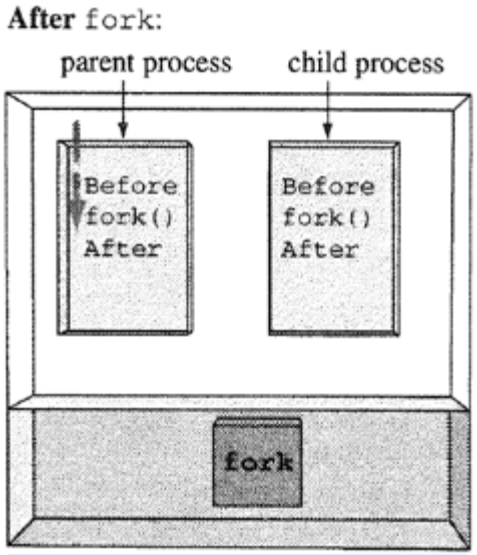
  (c) **Adds** the new process to the set of running processes

  (d) **Returns** control back to both processes



fork() system call

- After a process calls fork, there are two separate process,
  - both digitally identical,
  - both in the middle of the same code,
  - but each a separate process can go its own way.



The new process contains the same code and data as the parent process.

Creating an new process Example : forkdemo1.c

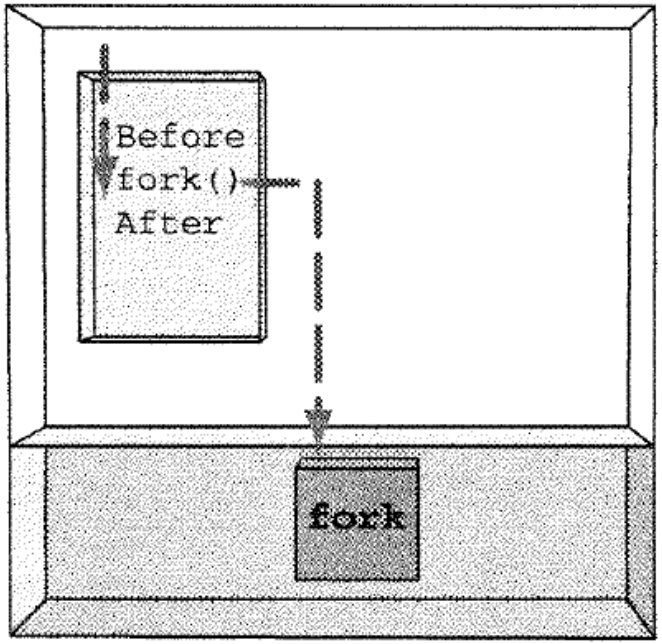
```
/*  forkdemo1.c
 *      shows how fork creates two processes, distinguishable
 *      by the different return values from fork()
 */
#include      <stdio.h>
#include      <unistd.h>
main()
{
        int     ret_from_fork, mypid;

        mypid = getpid();                              /* who am i?          */
        printf("Before: my pid is %d\n", mypid);   /* tell the world     */

        ret_from_fork = fork();

        sleep(1);
        printf("After: my pid is %d, fork() said %d\n",
                        getpid(), ret_from_fork);
}
```

```
$ cc forkdemo1.c -o forkdemo1
$ ./forkdemo1
Before: my pid is 4170
After: my pid is 4170, fork() said 4171
$ After: my pid is 4171, fork() said 0
```

Three lines!... Why?

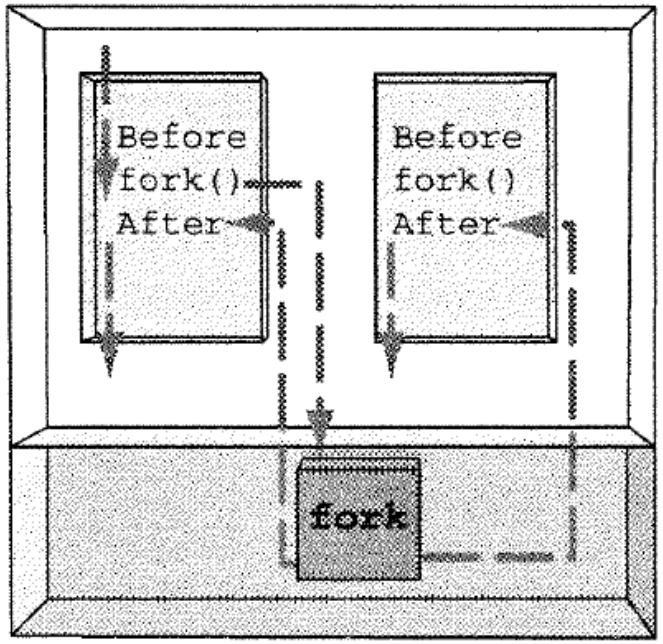
Creating an new process Example : forkdemo1.c

Before `fork`:



One flow of control enters the fork kernel code.

After `fork`:



Two flows of control return from fork kernel code.

FIGURE 8.9

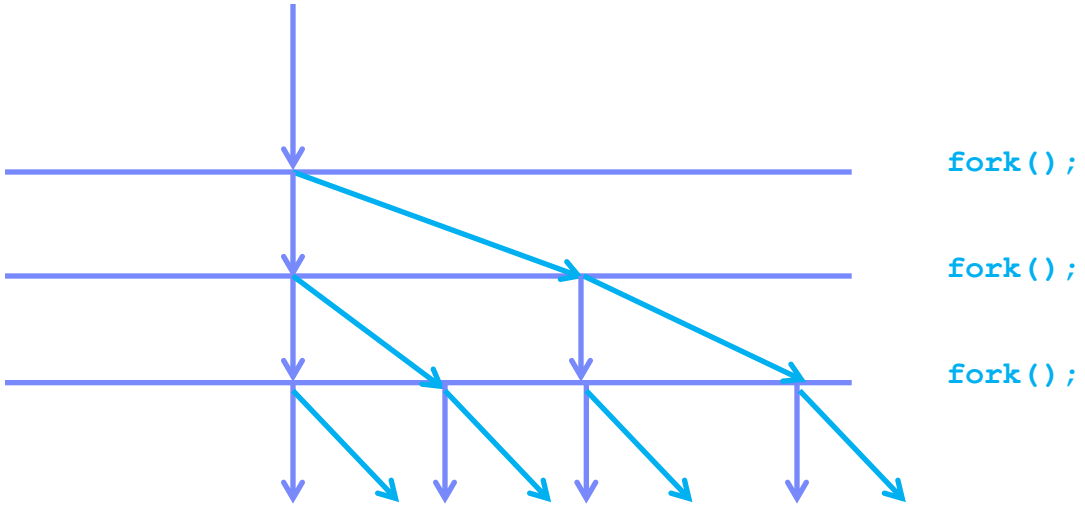
The child executes the code after `fork()`.

Children creating process example : forkdemo2.c

```
/* forkdemo2.c - shows how child processes pick up at the return
 *               from fork() and can execute any code they like,
 *               even fork().  Predict number of lines of output.
 */
#include      <stdio.h>
#include      <unistd.h>

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

Children creating process example : forkdemo2.c

```
my pid is 24740
my pid is 24740
my pid is 24741
my pid is 24742
my pid is 24744
my pid is 24745
my pid is 24743
my pid is 24746
my pid is 24747
seokin@compasslab1:~/system_programming/labs/lab7$
```



fork() system call

fork	
PURPOSE	Create a process
INCLUDE	#include < unistd.h >
USAGE	pid_t result = fork(void)
ARGS	none
RETURNS	-1 : if error 0 : to child process pid : pid of child to parent process

Distinguishing parent from child Example : forkdemo3.c

```
/*  forkdemo3.c - shows how the return value from fork()
 *                allows a process to determine whether
 *                it is a child or process
 */
#include      <stdio.h>
#include      <unistd.h>
main()
{
        int     fork_rv;
        printf("Before: my pid is %d\n", getpid());

        fork_rv = fork();                   /* create new process   */

        if ( fork_rv == -1 )                /* check for error      */
                perror("fork");

        else if ( fork_rv == 0 )
                printf("I am the child.  my pid=%d\n", getpid());
        else
                printf("I am the parent. my child is %d\n", fork_rv);
}
```

- Three skills needed to build a shell:
  - 1. Create a new process
  - 2. Run a program (execvp)
  - **3. Tell the parent wait until the child process finishes executing the command**

Q3: How Does the Parent Wait for the Child to exit?

- Ans: A process calls wait() system call to wait for a child to finish.

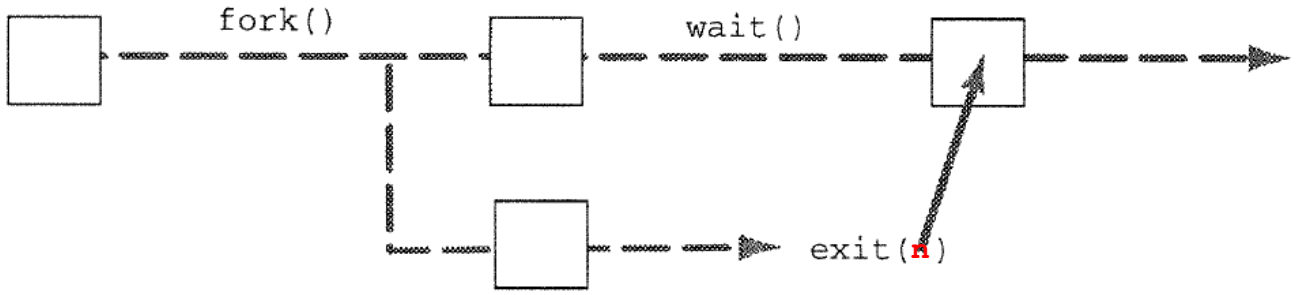
```
pid = wait( &status );
```

- The wait system call does two things:
  - It pauses the calling process until a child process finishes running.
  - It retrieves the value the child process had passed to exit.

wait() system call

wait	
PURPOSE	Wait for process termination
INCLUDE	#include < sys/types.h > #include <sys/wait.h >
USAGE	pid_t result = wait(int *statusptr)
ARGS	statusptr child result
RETURNS	-1 : if error pid : of terminated process
SEE ALSO	waitpid(2), wait3(2)

wait() system call



※ exit(n);
n is a number of between 0 and 255

FIGURE 8.10

wait pauses the parent until the child finishes.

- When the child calls exit(),
  - the kernel wakes up the parent and
  - delivers the value the child passed to exit().

- Thus, wait() performs two operations
  - notification and communication

Notification Example : waitdemo1.c

```
/* waitdemo1.c - shows how parent pauses until child finishes
 */

#include        <stdio.h>
#include       <stdlib.h>
#define DELAY   2

main()
{
        int  newpid;
        void child_code(int), parent_code(int);
        printf("before: mypid is %d\n", getpid());

        if ( (newpid = fork()) == -1 )
                perror("fork");
        else if ( newpid == 0 )
                child_code(DELAY);
        else
                parent_code(newpid);
}
```

Notification Example : waitdemo1.c

```
/*
 * new process takes a nap and then exits
 */
void child_code(int delay)
{
        printf("child %d here. will sleep for %d seconds\n", getpid(),
          delay);
        sleep(delay);
        printf("child done. about to exit\n");
        exit(17);
}
```

Notification Example : waitdemo1.c

```
/*
 * parent waits for child then prints a message
 */
void parent_code(int childpid)
{
        int wait_rv;              /* return value from wait() */
        wait_rv = wait(NULL);
        printf("done waiting for %d. Wait returned: %d\n", childpid,
          wait_rv);
}
```

```
$ ./waitdemo1
before: mypid is 10328
child 10329 here. will sleep for 2 seconds
child done. about to exit
done waiting for 10329. Wait returned: 10329
```

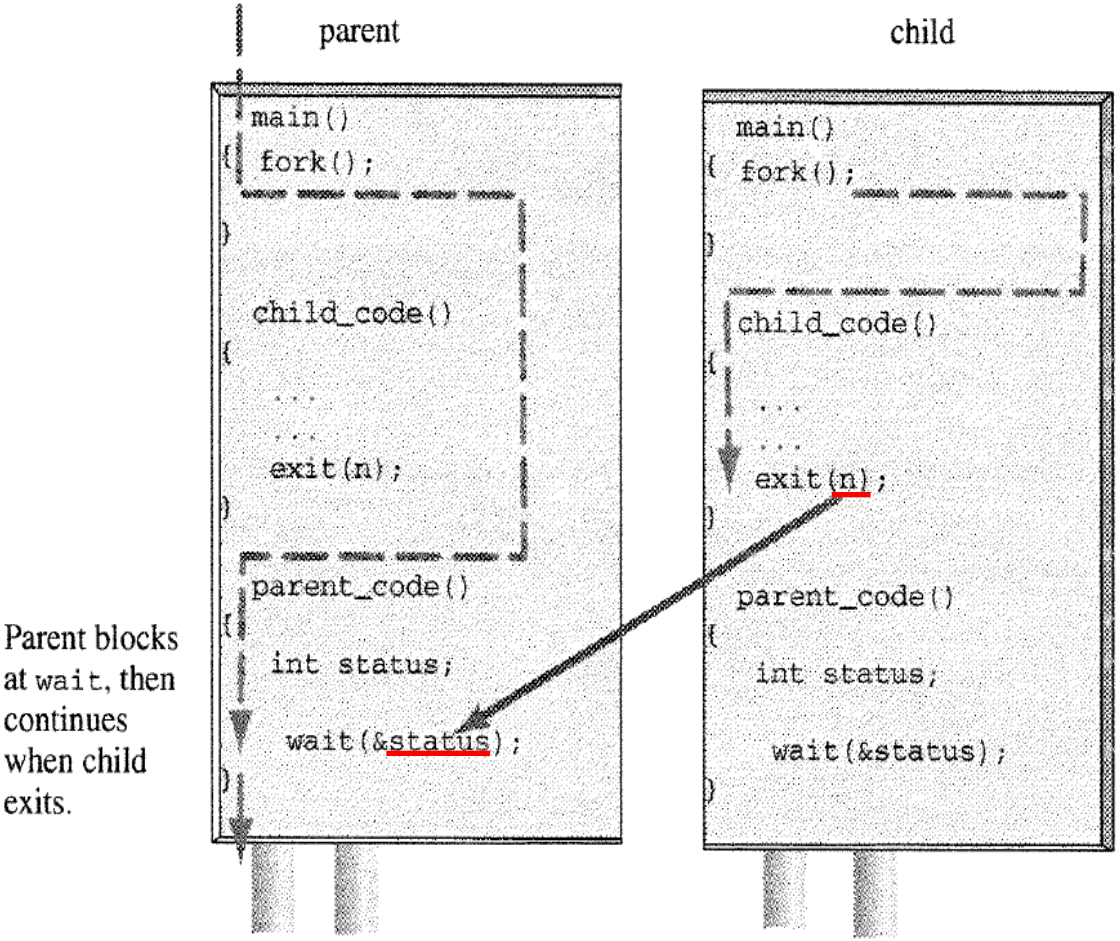


FIGURE 8.11

Control flow and communication with `wait()`.

Purpose of wait() system call

- To notify the parent that a child process finished running
- To tell the parent how a child process finished
  - A process ends in one of three ways
    - Success
    - Failure
    - Death
  - A process can succeed at its task:
    exit(0) or return 0 from main
  - A process can fail at its task:
    exit(nonzerovalue)
  - A process might be killed by a signal

How does the parent know if the child's exit status

- How does the parent know if the child succeeded, failed, or died?
  - Answer is in the argument (integer pointer) to wait() system call
    - Eight bit for exit value, seven bits for signal number, one bit to indicate a core dump

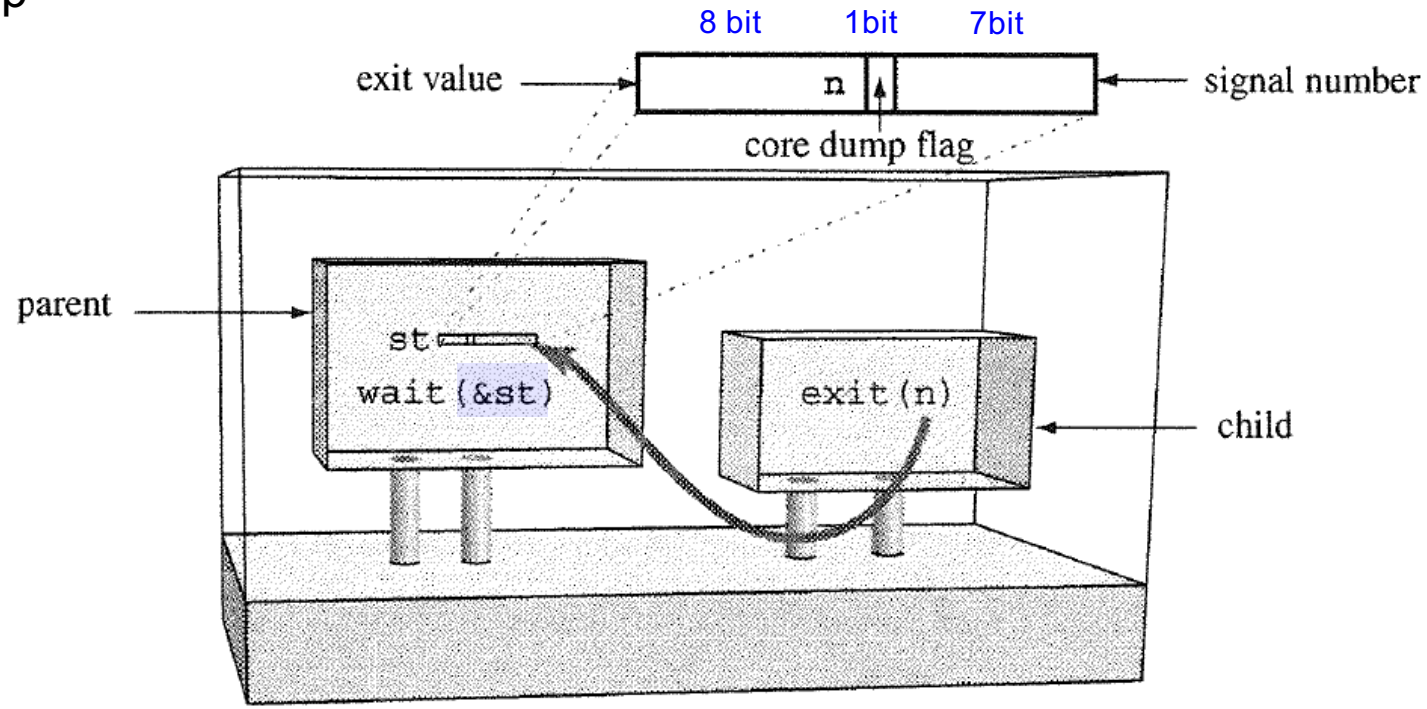


FIGURE 8.12

The child status value has three parts.

Communication Example: waitdemo2.c

```
/* waitdemo2.c - shows how parent gets child status
 */

#include        <stdio.h>
#include       <stdlib.h>
#define DELAY   5

main()
{
        int  newpid;
        void child_code(), parent_code();

        printf("before: mypid is %d\n", getpid());

        if ( (newpid = fork()) == -1 )
                perror("fork");
        else if ( newpid == 0 )
                child_code(DELAY);
        else
                parent_code(newpid);
}
```

Communication Example: waitdemo2.c

```
/*
 * new process takes a nap and then exits
 */
void child_code(int delay)
{
        printf("child %d here. will sleep for %d seconds\n", getpid(),
          delay);
        sleep(delay);
        printf("child done. about to exit\n");
        exit(17);
}
```

Communication Example: waitdemo2.c

```
/*
 * parent waits for child then prints a message
 */
void parent_code(int childpid)
{
        int wait_rv;              /* return value from wait() */
        int child_status;
        int high_8, low_7, bit_7;

        wait_rv = wait(&child_status);
        printf("done waiting for %d. Wait returned: %d\n", childpid,
          wait_rv);

        high_8 = child_status >> 8;     /* 1111 1111 0000 0000 */
        low_7  = child_status & 0x7F;   /* 0000 0000 0111 1111 */
        bit_7  = child_status & 0x80;   /* 0000 0000 1000 0000 */
        printf("status: exit=%d, sig=%d, core=%d\n", high_8, low_7,
          bit_7);
}
```

Communication Example: waitdemo2.c

- Run in the background and use kill to send SIGTERM to the child:

```
$ ./waitdemo2 &
$ before: mypid is 10857
child 10858 here. will sleep for 5 seconds
kill 10858
$ done waiting for 10858. Wait returned: 10858
status: exit=0, sig=15, core=0
                SIGTERM
```

8.4.5 Summary：How the Shell Runs Programs

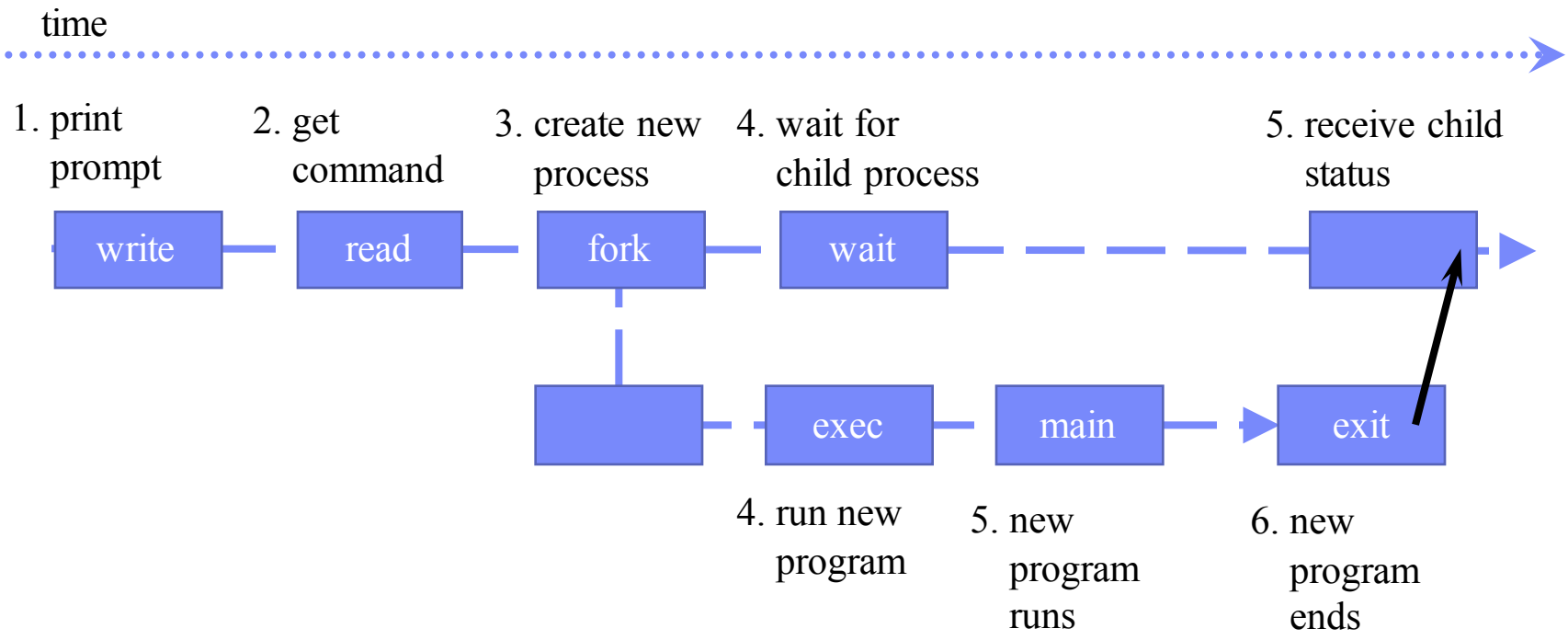
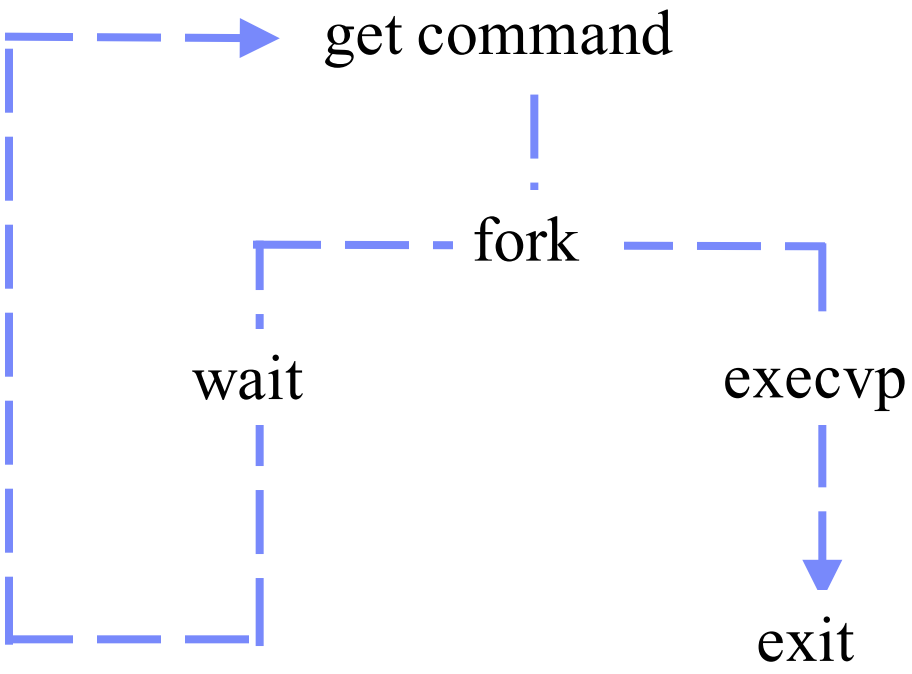


FIGURE 8.13 Shell loop with fork(), exec(), and wait()

Contents

Wring a shell : psh2.c

- Logic diagram



Wring a shell : psh2.c

```
/**  prompting shell version 2 (psh2.c)
 **
 **              Solves the 'one-shot' problem of version 1
 **                      Uses execvp(), but fork()s first so that the
 **                      shell waits around to perform another command
 **              New problem: shell catches signals.  Run vi, press ^c.
 **/

#include        <stdio.h>
#include        <signal.h>
#include        <string.h>
#include        <stdlib.h>

#define MAXARGS         20                      /* cmdline args */
#define ARGLEN          100                     /* token length */

char* makestring(char*);
void execute(char*[]);
```

Wring a shell : psh2.c

```
int main()
{
        char    *arglist[MAXARGS+1];            /* an array of ptrs     */
        int     numargs = 0;                    /* index into array     */
        char    argbuf[ARGLEN];                 /* read stuff here      */

        while ( numargs < MAXARGS )
        {
                printf("Arg[%d]? ", numargs);
                if ( fgets(argbuf, ARGLEN, stdin) && *argbuf != '\n' )
                        arglist[numargs++] = makestring(argbuf);
                else
                {
                        if ( numargs > 0 ){             /* any args?    */
                                arglist[numargs]=NULL;  /* close list   */
                                execute( arglist );     /* do it        */
                                numargs = 0;            /* and reset    */
                        }
                }
        }
        return 0;
}
```

Wring a shell : psh2.c

```
execute( char *arglist[] )
/*
 *      use fork and execvp and wait to do it
 */
{
        int     pid,exitstatus;                 /* of child     */

        pid = fork();                           /* make new process */
        switch( pid ){
                case -1:
                        perror("fork failed");
                        exit(1);
                case 0:
                        execvp(arglist[0], arglist);          /* do it */
                        perror("execvp failed");
                        exit(1);
                default:
                        while( wait(&exitstatus) != pid )
                                ;
                        printf("child exited with status %d,%d\n",
                                        exitstatus>>8, exitstatus&0377);
        }
}
```

Wring a shell : psh2.c

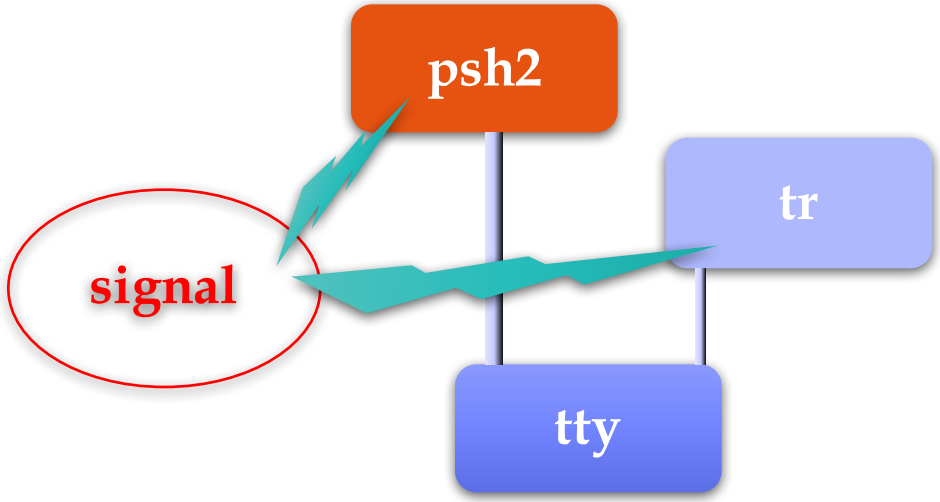
```
char *makestring( char *buf )
/*
 * trim off newline and create storage for the string
 */
{
        char    *cp, *malloc();

        buf[strlen(buf)-1] = '\0';                  /* trim newline */
        cp = malloc( strlen(buf)+1 );               /* get memory   */
        if ( cp == NULL ){                          /* or die       */
                fprintf(stderr,"no memory\n");
                exit(1);
        }
        strcpy(cp, buf);                    /* copy chars   */
        return cp;                          /* return ptr   */
}
```

```
$ ./psh2
Arg[0]? tr
Arg[1]? [a-z]
Arg[2]? [A-Z]
Arg[3]?
hello
HELLO
now to press
NOW TO PRESS
Ctrl-Cpress ^C here
$
```

Signals and psh2.c

- What happen if we press Ctrl-C when psh2 is waiting for the child process to finish? …

```
$ ./psh2
Arg[0]? tr
Arg[1]? [a-z]
Arg[2]? [A-Z]
Arg[3]?
hello
HELLO
now to press
NOW TO PRESS
Ctrl-Cpress ^C here
$
```



The SIGINT killed not only ‘tr’ but also ‘psh2’