Processes

Process creation

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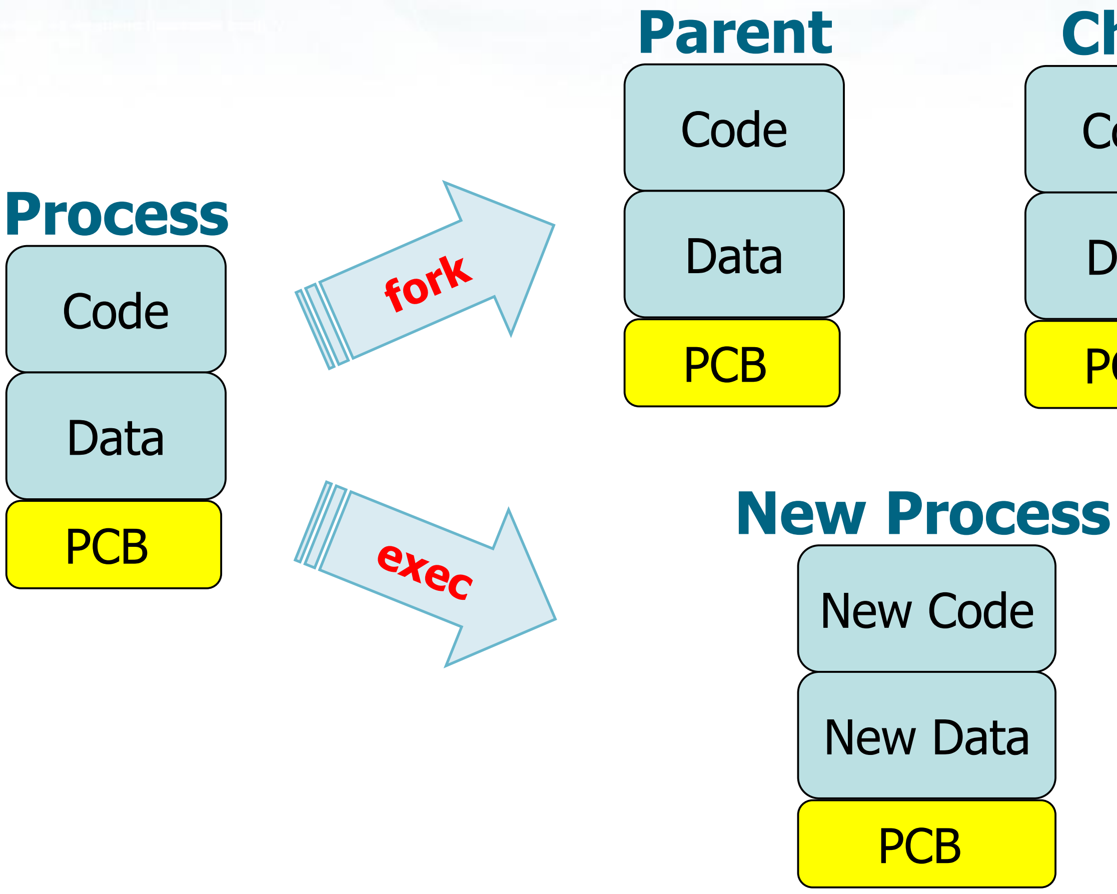
fork and exec system calls

- System call **fork** creates a new process duplicating the calling process, then
  - Parent and child execute **different code sections** Example: a network server duplicates itself at each client request, and the child serves the request while the parent waits for a new client request
  - Parent and child execute **different code**
    - Example: a command interpreter (shell)
    - Uses the **exec** system call

exec system call

- System call **exec substitutes** the process code with the executable code of another program
- The new program begins its execution as usual (from main)
- In particular **exec**
  - Does not create a new process
  - Substitutes the calling process image with the image of another program.
  - The process PID does not change
    - fork → duplicates an **existent process**
    - exec → executes a **new program**

Address space



exec system call

- **6** versions of exec system call
  - execl, execlp, execle
  - execv, execvp, execve

Type	Action
l (list)	**Arguments are a list of strings**
v (vector)	**Arguments is a vector of strings char **arguments**
p (path)	**The executable filename is looked for in the directories listed in the environment variable PATH**
e (environment)	**The last argument is an environment vector envp[] which defines a set of new associations strings name=value**

exec system call

```
#include <unistd.h>
int execl (char *path, char *arg0, ...,   (char *)0);
int execlp (char *name, char *arg0, ...,  (char *)0);
int execle(char *path, const char *arg0,..., char *envp[]);
int execv (char *path, char *argv[]);
int execvp (char *name, char *arg[]);
int execve (char *path, char *arg[],  char *envp[]);
```

- The return value is -1 in case of error

if exec success it cant return

exec system call

- Arguments
  - Pathname of the executable file
    - In the "p" versions the complete path is not necessary. The file must be in one of the directories listed in the environment variable PATH (echo $PATH)
  - Its argument list
    - The first argument is the **name** of the process (its argv[0])]
    - The other argument of the list are the argument for the executable (argv[1, argv[2], etc).
  - Possibly the environment vector

Examples

OK

whereis cp: /bin/cp

User defined name

```
execl("/bin/cp",“mycp","./file1","./file2",NULL);
```

OK

Alternative termination

```
execl("/bin/cp","cp","./file1","./file2",(char*)0);
```

NO

Path is missing

```
execl("cp","File_copy","./file1","./file2",(char*)0);
```

OK

Default path ($PATH)

```
execlp("cp",“cp",“./file1","./file2",(char*)0);
```

exec system call

- execv[p]
  - Uses a single argument: a vector of strings
    - The vector must be properly initialized

```
char *cmd[] = {
  "ls",
  "-laR",
  ".",
  (char *) 0
};
...
execv ("/bin/ls", cmd);
```

Last argument must be the NULL pointer

System call exec ()

- exec[lv]**e**
  - Can provide to the executable a set of environment variables
    - Vector of strings
    - Without "e" the environment of the new process is inherited from the calling process

```
char *env[] = {
  "USER=unknown",
  "PATH=/tmp",
  NULL
};
...
execle (path, arg0, ..., argn, 0, env);
...
execve (path, argv, env);
```

Considerations

- The execed process keeps all open file descriptor (including stdin, stdout, stderr)
  - This allow the process to inherit possible redirections previously set (e.g., by shell)
- Many kernel implement only system call **execve**
  - The other versions are macros that use this system call

Exercise

- Draw the process generation tree of the following C code segment , executed passing as its argument on the command line string ”5”
- What does it display?
- Why?

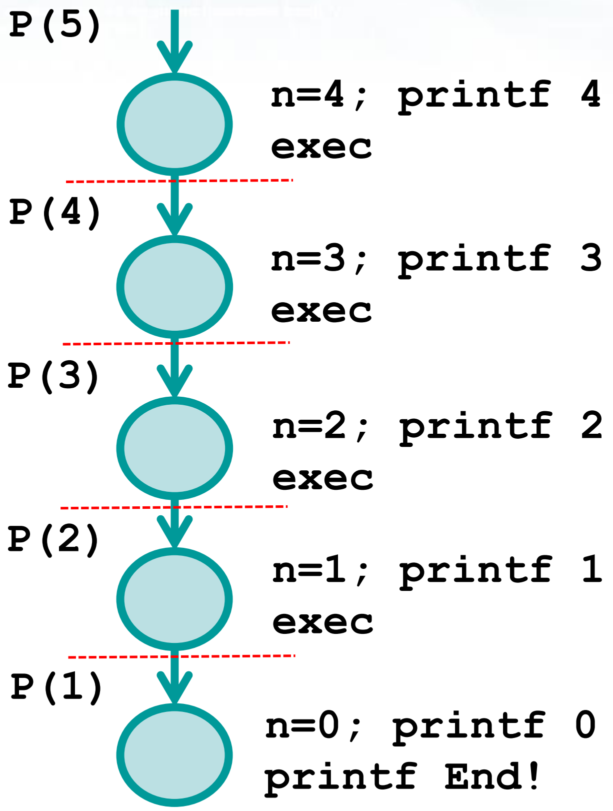
Exercise

Run with n=5

```
#include <stdio.h>
...
#include <unistd.h>
int main (int argc, char ** argv) {
  char str[10];
  int n;
  n = atoi(argv[1]) - 1;
  printf ("%d\n", n);
  if (n>0) {
    sprintf (str, "%d", n);
    execl (argv[0], argv[0], str, NULL);
  }
  printf ("End!\n");
  return 1;
}
```

when n=0

Solution



```
int main (int argc, char ** argv) {
  char str[10];
  int n;
  n = atoi(argv[1]) - 1;
  printf ("%d\n", n);
  if (n>0) {
    sprintf (str, "%d", n);
    execl (argv[0], argv[0], str, NULL);
  }
  printf ("End!\n");
  return 1;
}
```

Output

```
4
3
2
1
0
End!
```

Exercise

- Draw the process generation tree of the following C code segment
- What does it display?
- Why?

Exercise

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

int main(){
  int n;
  n=0;
  while (n<3 && fork()){
    if (!fork())
      execlp ("echo", "n++", "n", NULL);
    n++;
    printf ("%d\n", n);
  }
  return (1);
}
```

shell command echo

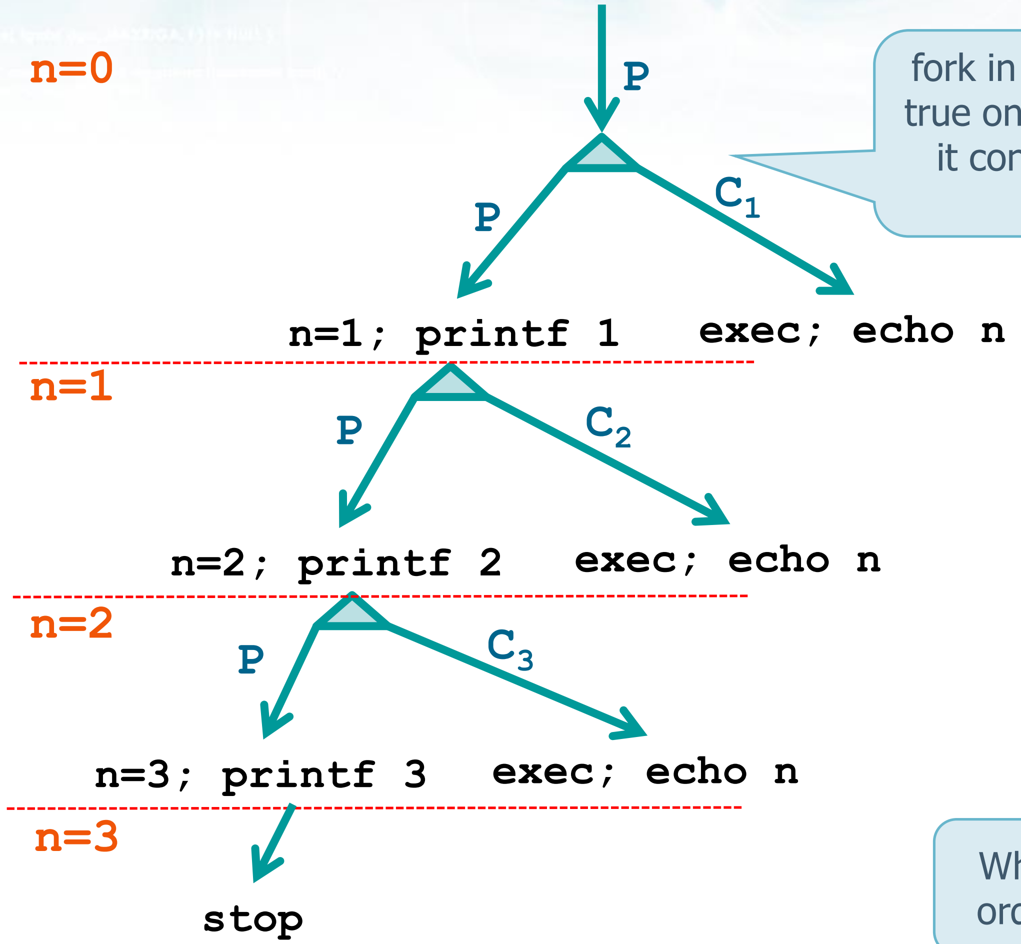
$n -> not exit

just print string n to terminal

//block the loop and dont return

perform sprintf to print var n

Solution



fork in the while condition is true only for the parent, thus it continues, whereas the child exits

Output

```
1
2
3
n
n
n
```

Which order?

Example

Program **./pgrm** exec itself if it receives as argument 1 or 2

```
...
n = atoi (argv[1]);
switch (n) {
  case 1:
    printf(“#1:PID=%d;PPID=%d\n", getpid(), getppid());
    sleep (n*10);
    execlp ("./pgrm", "./Pgrm", "2", (char *) 0);
    break;
  case 2:
    printf("#2:PID=%d;PPID=%d\n", getpid(), getppid());
    sleep (n*10);
    execlp ("./pgrm", “myPgrm", "3", (char *) 0);
    break;
  default:
    printf("#3:PID=%d;PPID=%d\n", getpid(), getppid());
    sleep (n*10);
    break;
}
return (1);
```

Same pathname but argv[0] (its name) changes

Example

Run with n=1

Shell commands (in blue)

PID does not change

```
> ./pgrm 1 &
[2] 2471
#1: PID=2471; PPID=2045
> ps -aux | grep 2471
user 2471 0.0 0.0 4192 352 pts/2 S 19:29 0:00 ./pgrm 1
#2: PID=2471; PPID=2045
> ps -aux | grep 2471
user 2471 0.0 0.0 4192 356 pts/2 S 19:29 0:00 ./Pgrm 2
#3: PID=2471; PPID=2045
> ps -aux | grep 2471
User 2471 0.0 0.0 4192 356 pts/2 S 19:29 0:00 myPgrm 3
[2]+  Exit 1   ./pgrm 1
```

The name changes

UNIX shell skeleton

- Command run in foreground
  - <command>

```
while (TRUE) {
  write_prompt;
  read_command (command, parameters);
  if (fork() == 0)
    /* Child: Execute command */
    execve (command, parameters);
else
    /* Parent: Wait child */
    wait (&status);
}
```

like >

can do sth

UNIX shell skeleton

- Command run in background
  - <command> **&**

fg %2

```
while (TRUE) {
  write_prompt;
  read_command (command, parameters);
  if (fork() == 0)
    /* Child: Execute command */
    execve (command, parameters);
/* else */
    /* Parent: does not wait */
    /* wait (&status); */
}
```

the child will become zombie process

sol inform the kernel not want to wait

Command execution

- It can be useful to execute a **shell command** from a process
  - For example for appending a date to a filename or to a file
- System call **system** solves this problem
  - It is defined by the standard ISO C and POSIX

system() system call

```
#include <stdlib.h>

int system (const char *string);
```

- System call system
  - Forks a shell, which execute the string command, while the parent process waits the termination of the shell command
  - Returns
    - -1 or 127 on error
    - The exit value of the shell that executed the command (with the format of **`waitpid`**)

Example

```
...
system ("date");
...
```

```
...
system ("ls -laR");
...
```

```
char str[L];
...
strcpy (str, "ls -la");
system (str);
...
```

system() implementation

```
int system (const char *cmd) {
  pid_t pid;
  int status;
  if (cmd == NULL)
    return(1);
  if ( (pid = fork()) < 0) {
    status = -1;
  } else if (pid == 0) {     child become the shell
    execl("/bin/sh", "sh", "-c", cmd, (char *) 0);
    _exit(127);
  } else {
    while (waitpid (pid, &status, 0) < 0)
      if (errno != EINTR) {
        status = -1;
        break;
      }
  }
  return(status);
}
```

Exercise

- Draw the process generation tree of the following C program, executed passing as its argument on the command line string "4"
- What does it display?
- Why?

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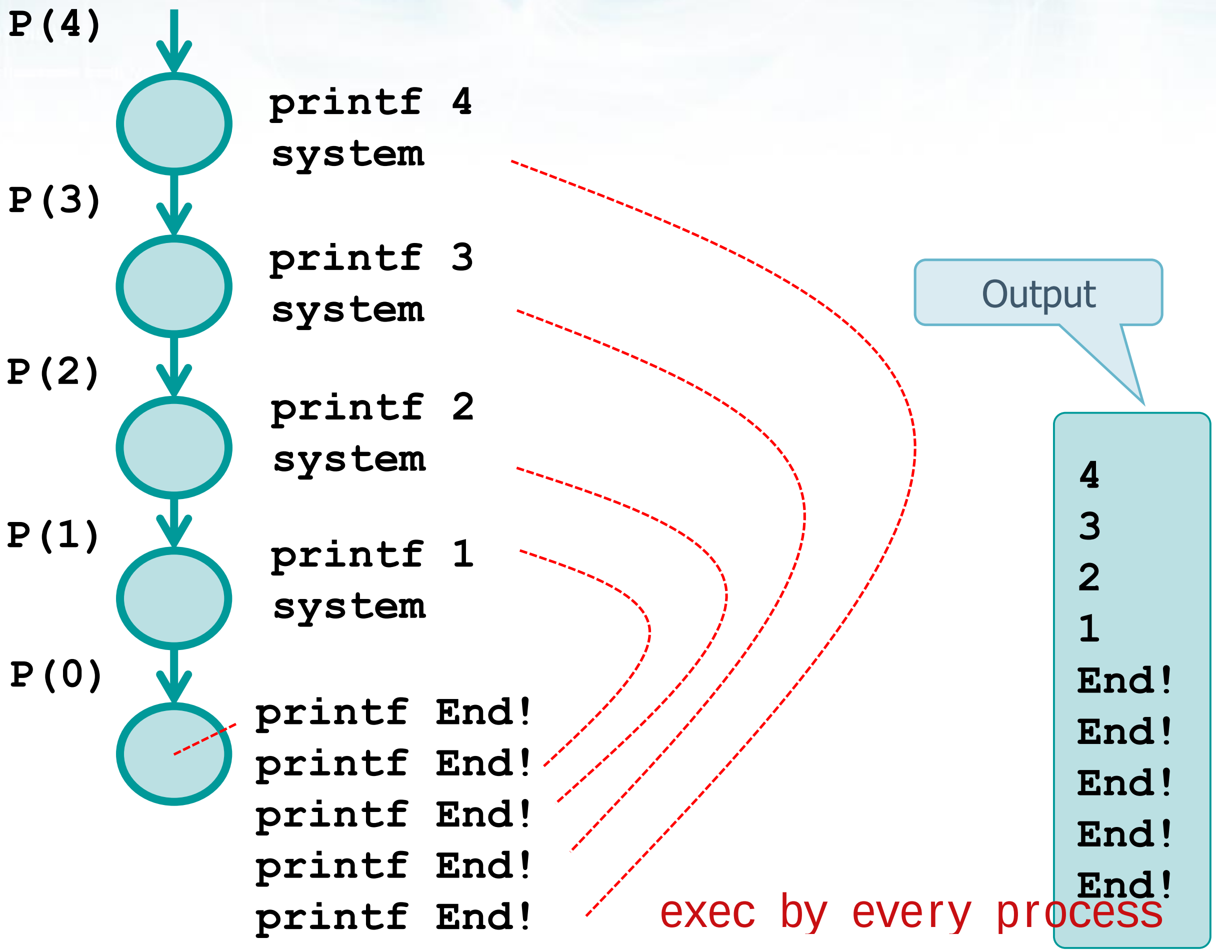
Run with n=4

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

int main(int argc, char ** argv){
  int n;
  char str[10];
  n = atoi (argv[1]);
  if (n>0) {
    printf ("%d\n", n);
    sprintf (str, "%s %d", argv[0], n-1);
    system (str);
  }
  printf("End!\n");
  return (1);
}
```

recursive

Solution



```
4
3
2
1
End!
End!
End!
End!
End!
```

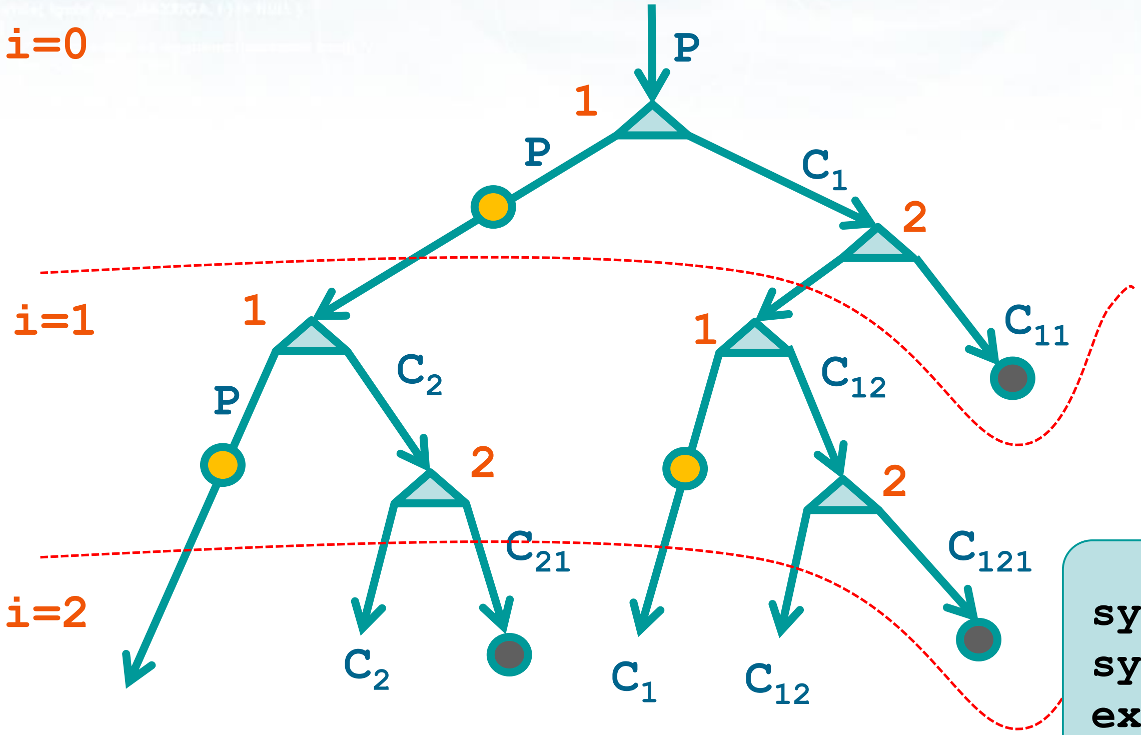
Exercise

- Draw the process generation tree of the following C code segment
- What does it display?
- Why?

Exercise

```
#include ...
int main () {
  char str[100];
  int i;
  for (i=0; i<2; i++){
    if (fork()!=0) {
      sprintf (str, "echo system with i=%d", i);
      system (str);
    } else {
      if (fork()==0) {
        sprintf (str, "exec with i=%d", i);
        execlp ("echo", "myPgrm", str, NULL);
      }
    }
  }
  return (0);
}
```

Exercise



● echo system with i=%d

● exec echo with i=%d

Output

```
system with i=0
system with i=1
exec with i=1
exec with i=0
system with i=1
exec with i=1
```

Which order?