

# OS 2024 Lab 2

## shell

Due Date: 2025/11/28 17:00 (before lab2 course finishes)

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# **1.Introduction**

## **2.Requirements**

## **3.Grading**

### **1.1 Shell introduction**

### **1.2 Basic functionality**

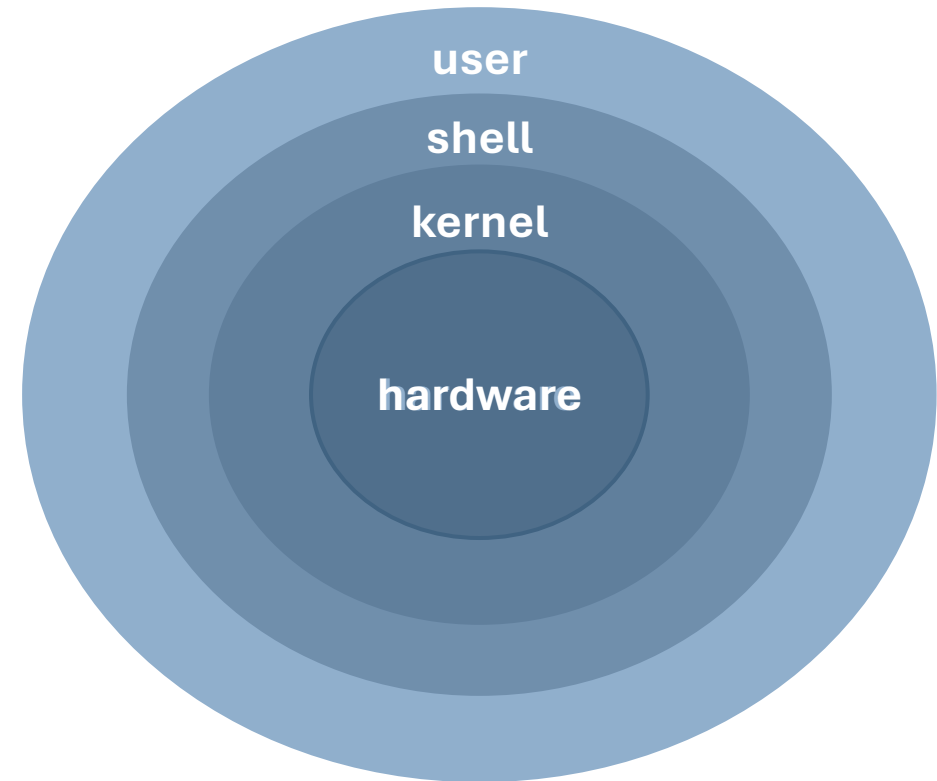
- **Built-in commands**
- **External commands**

### **1.3 Advanced functionality**

- **Redirection**
- **Pipe**

# Shell

It is an **intermediary between the user and the kernel**, allowing the user to control the computer through commands.



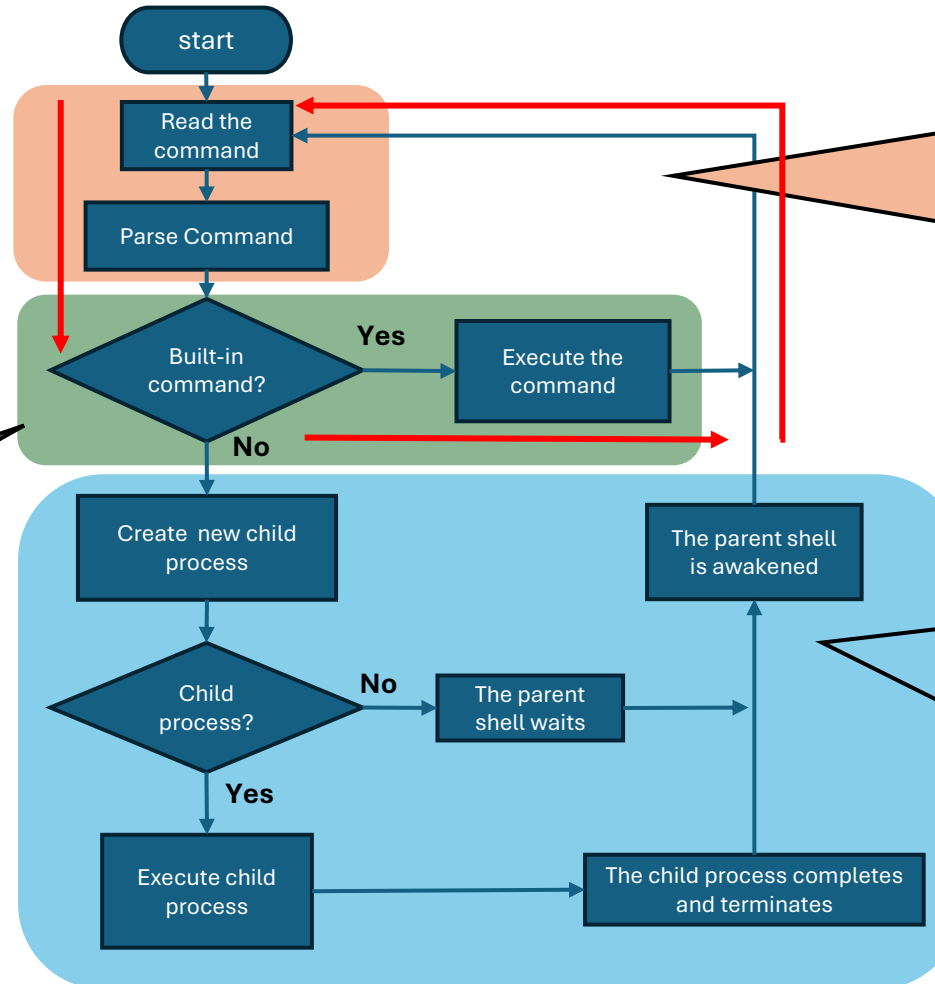
System architecture diagram

# Flow diagram - basic functionality

Command : cd Desktop/oslab/

```
timatm@timatm-VirtualBox:~$ cd Desktop/oslab/  
timatm@timatm-VirtualBox:~/Desktop/oslab$
```

**Built-in command**



**Parse the command given by the user**

**Determine whether it is a built-in command. If so, execute the built-in function.**

**If it is an external command, call fork() and exec() to execute the external command.**

# Flow diagram - basic functionality

Command : cd Desktop/oslab/

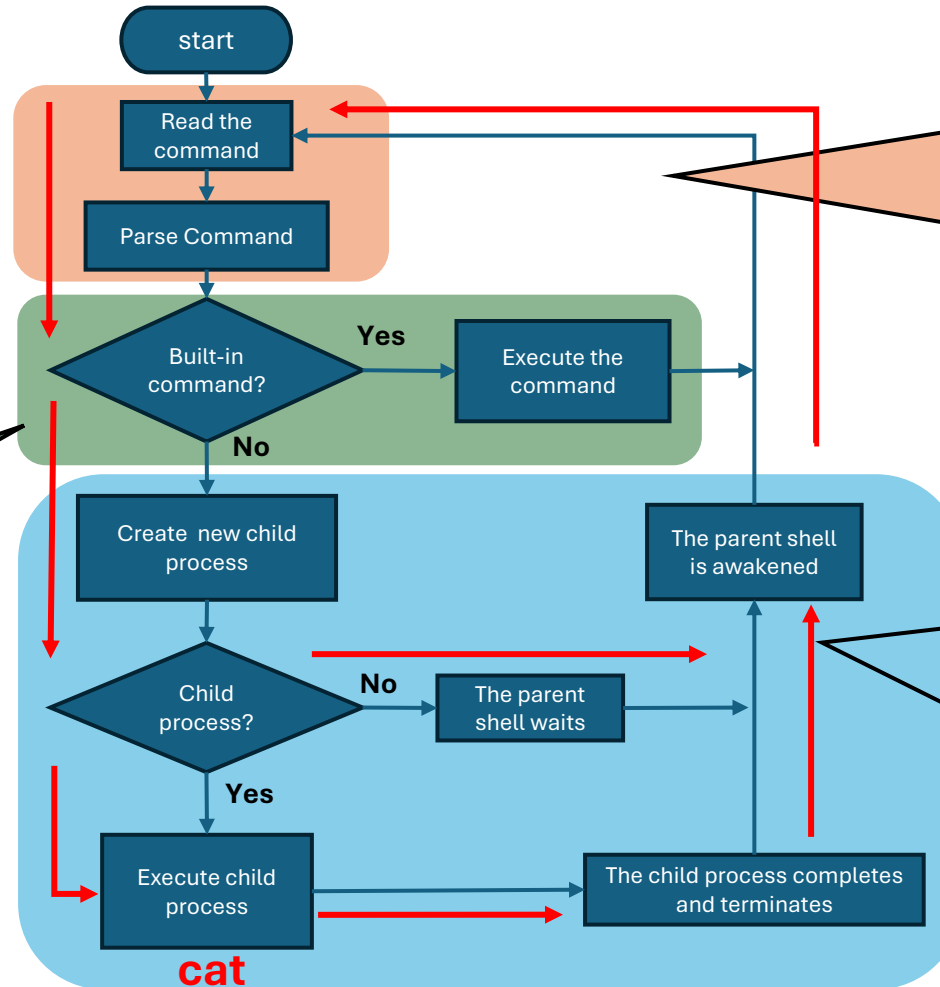
```
timatm@timatm-VirtualBox:~$ cd Desktop/oslab/
timatm@timatm-VirtualBox:~/Desktop/oslab$
```

Command : cat test.txt

```
timatm@timatm-VirtualBox:~/Desktop/oslab$ cat test.txt
I love OS lab
```

**External command**

Determine whether it is a built-in command. If so, execute the built-in function.



Parse the command given by the user

If it is an external command, call fork() and exec() to execute the external command.

# What are Built-in commands?

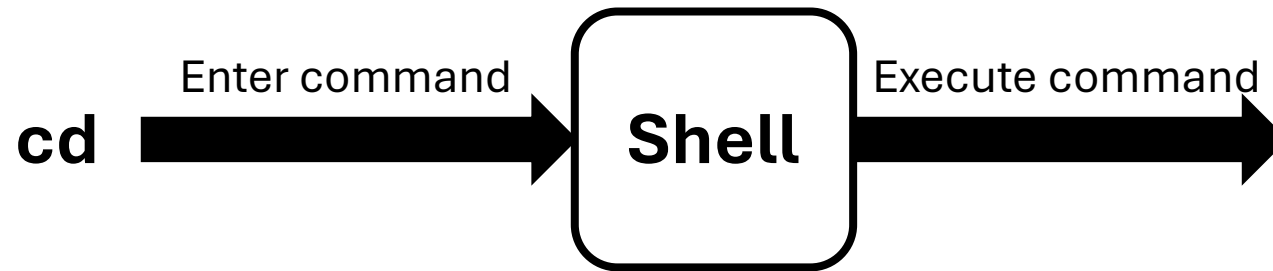
- Part of the shell (Bash, Zsh, etc.)
- Executed by the shell, no new process created
- Generally efficient and faster than external commands
- Commands like `cd`, `echo`, `pwd`, and `exit`.

# What are External commands?

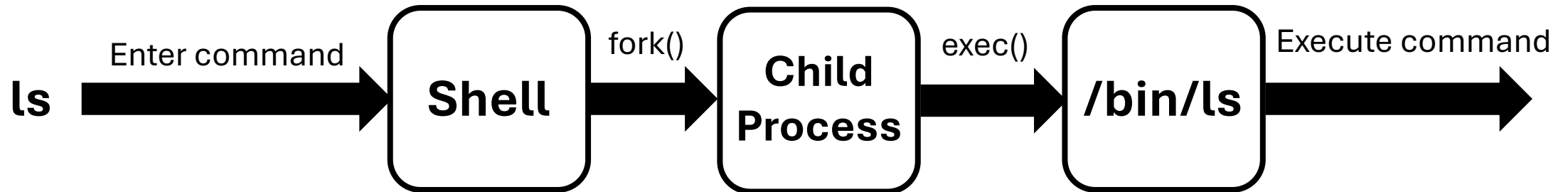
- Programs outside the shell (like `/bin/ls`, `/usr/bin/find`, etc.)
- Executed by the shell, but new processes are created to run them
- Typically slower than built-in commands due to process creation overhead
- Commands like `ls`, `grep` and `cat`

# Command type

- Built-in Command



- External Command



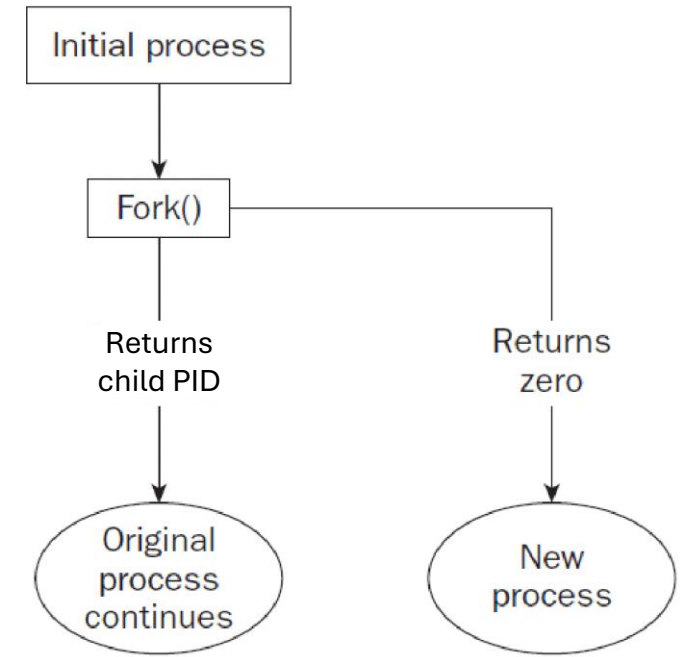
# Fork

```
int
main(void)
{
    pid_t pid;

    if (signal(SIGCHLD, SIG_IGN) == SIG_ERR) {
        perror("signal");
        exit(EXIT_FAILURE);
    }
    pid = fork();
    switch (pid) {
        case -1:
            perror("fork");
            exit(EXIT_FAILURE);
        case 0:
            puts("Child exiting.");
            exit(EXIT_SUCCESS);
        default:
            printf("Child is PID %jd\n", (intmax_t) pid);
            puts("Parent exiting.");
            exit(EXIT_SUCCESS);
    }
}
```

} **child process**

} **parent process**



***Fork() diagram***

# Execvp

## Using `execvp()`

The following example searches for the location of the `ls` command among the directories specified by the `PATH` environment variable, and passes arguments to the `ls` command in the `cmd` array.

```
#include <unistd.h>

int ret;
char *cmd[] = { "ls", "-l", (char *)0 };
...
ret = execvp ("ls", cmd);
```

## **NOTE:**

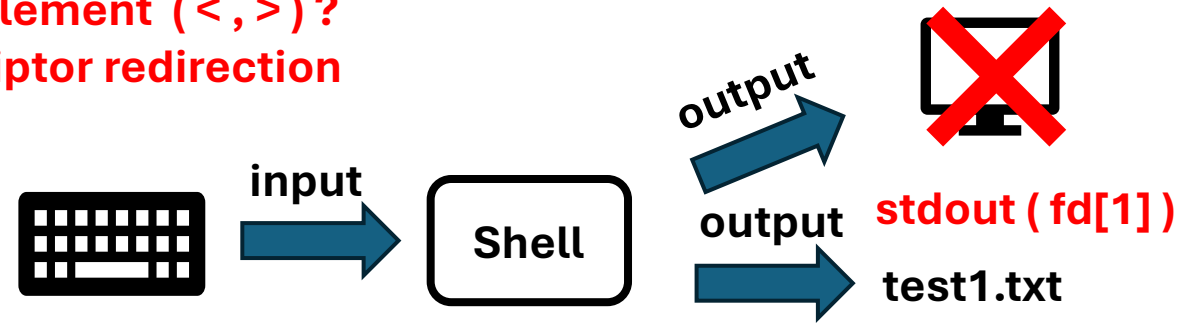
- In order to allow students to practice `fork()`, the use of `system()` is prohibited in this lab.

# Shell advanced functionality

Command : `cat test.txt > test1.txt`

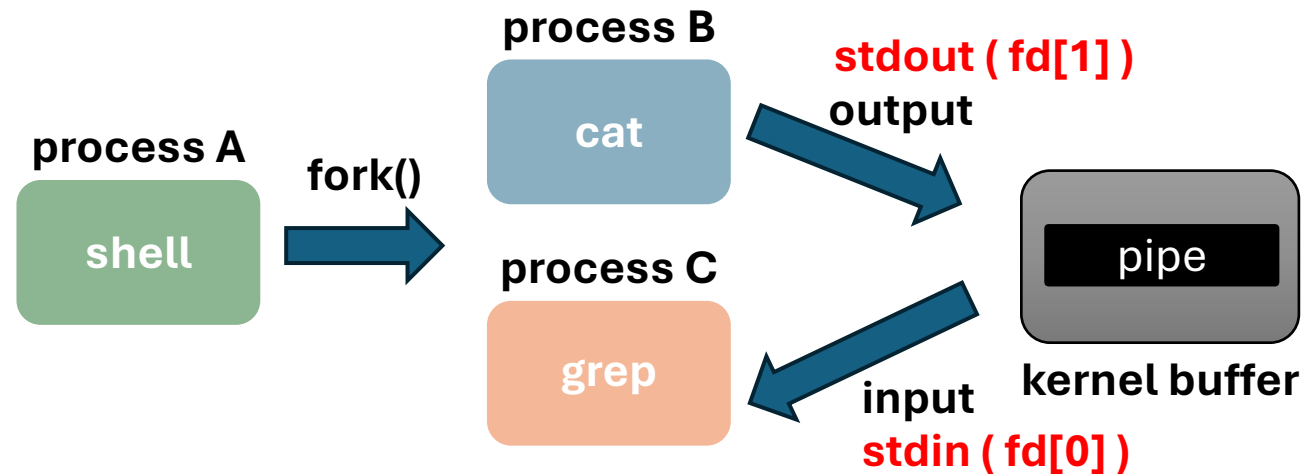
```
timatm@timatm-VirtualBox:~/Desktop/oslab$ cat test.txt > test1.txt
timatm@timatm-VirtualBox:~/Desktop/oslab$ cat test1.txt
I love OS lab
```

How to implement (`<`, `>`)?  
→ file descriptor redirection



Command : `cat test1.txt | grep lab`

```
timatm@timatm-VirtualBox:~/Desktop/oslab$ cat test1.txt | grep lab
I love OS lab
```



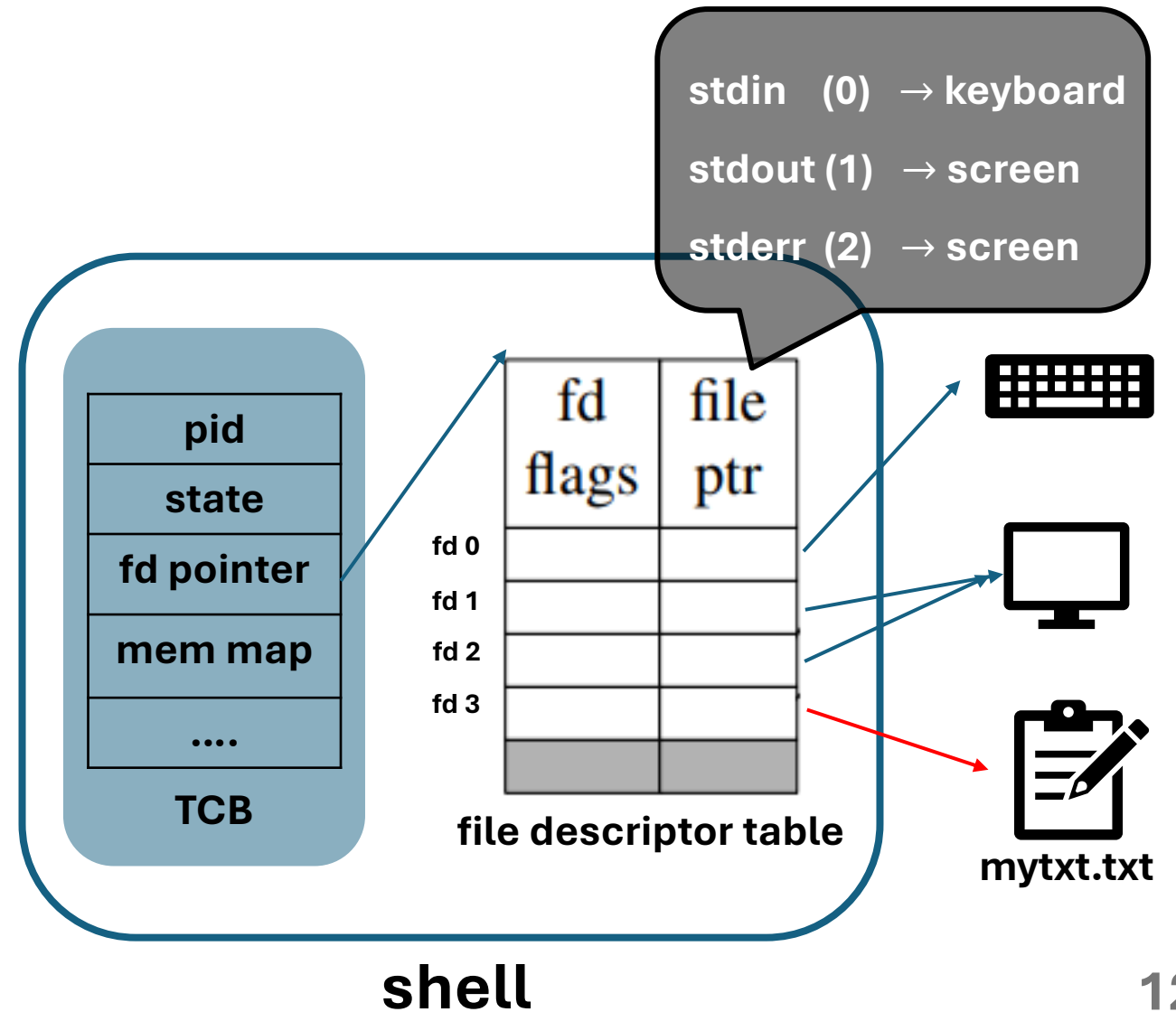
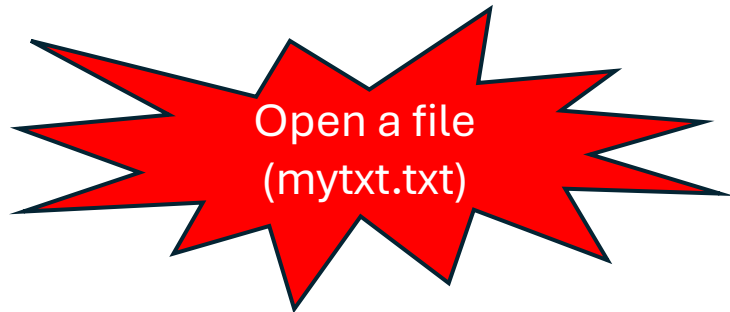
# File descriptor

## Task Control Block (TCB):

A data structure **used by the OS to manage processes/threads.**

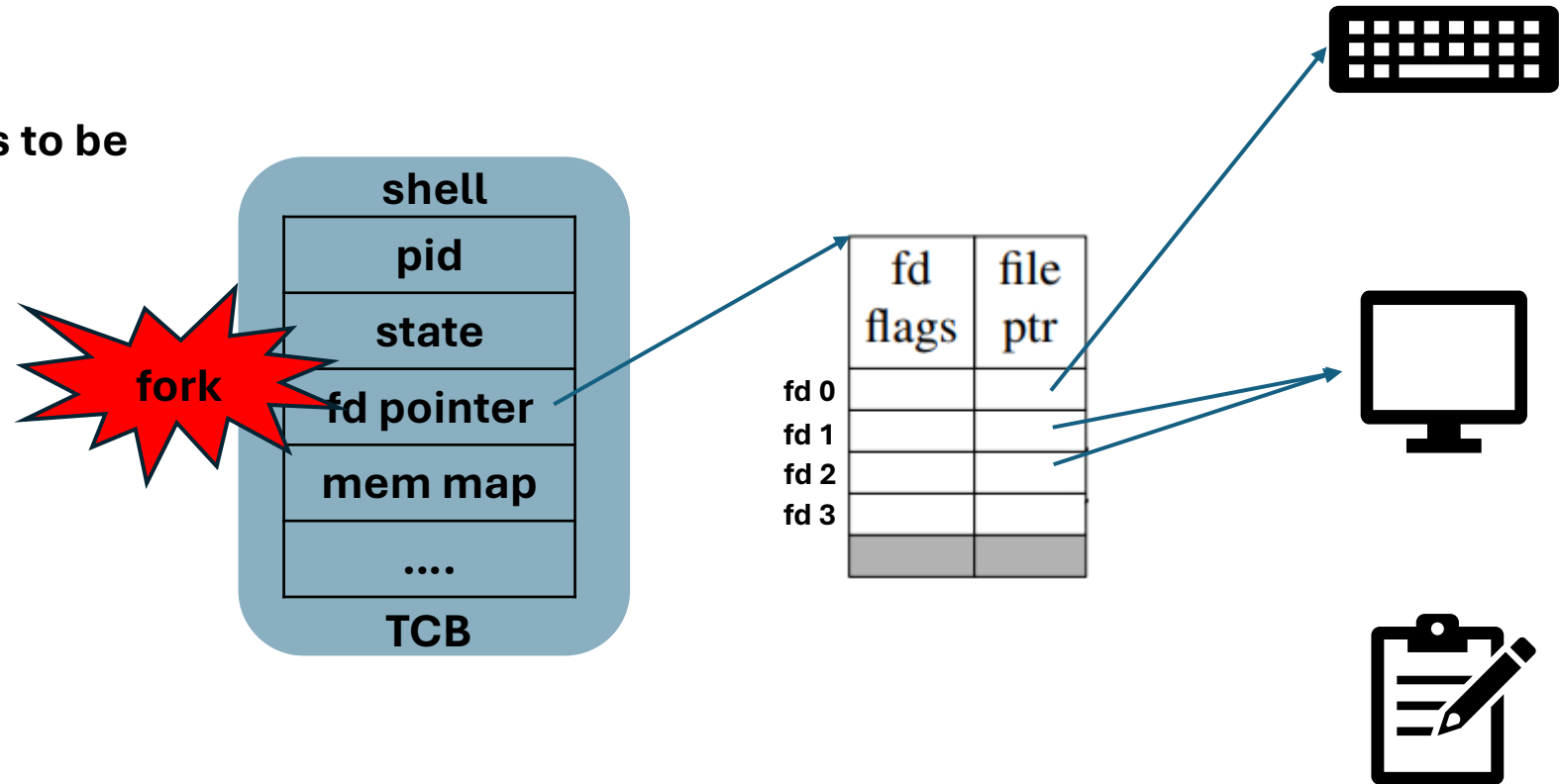
## File descriptor table:

A table unique to each process, **mapping file descriptors (small integers) to open files, sockets, or other resources.**



# File descriptor ( after fork() )

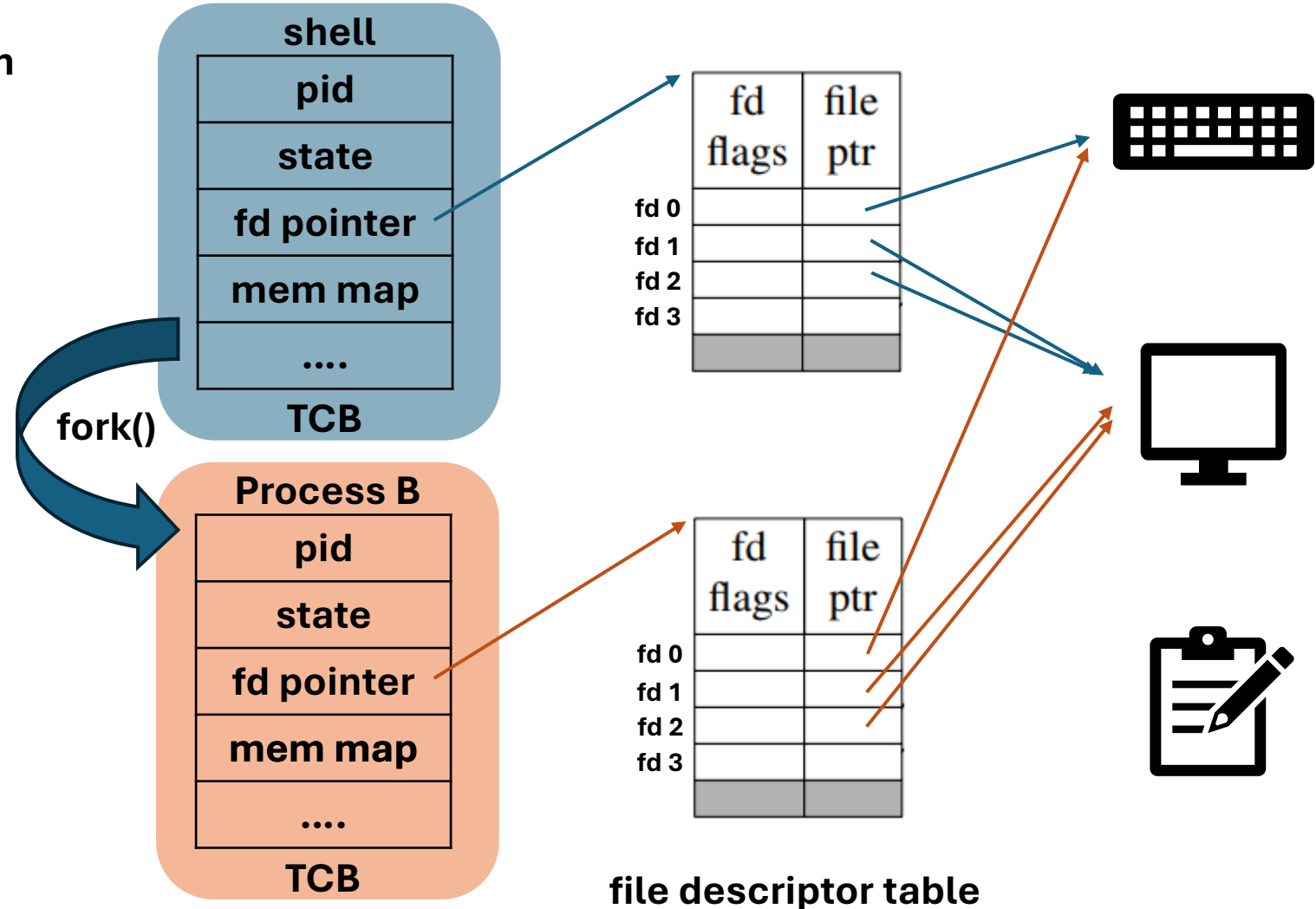
- The right side is the architecture of the original shell
- When an external command is to be executed, fork() is called



file descriptor table

# File descriptor ( after fork() )

- The child process creates its own TCB and file descriptor table

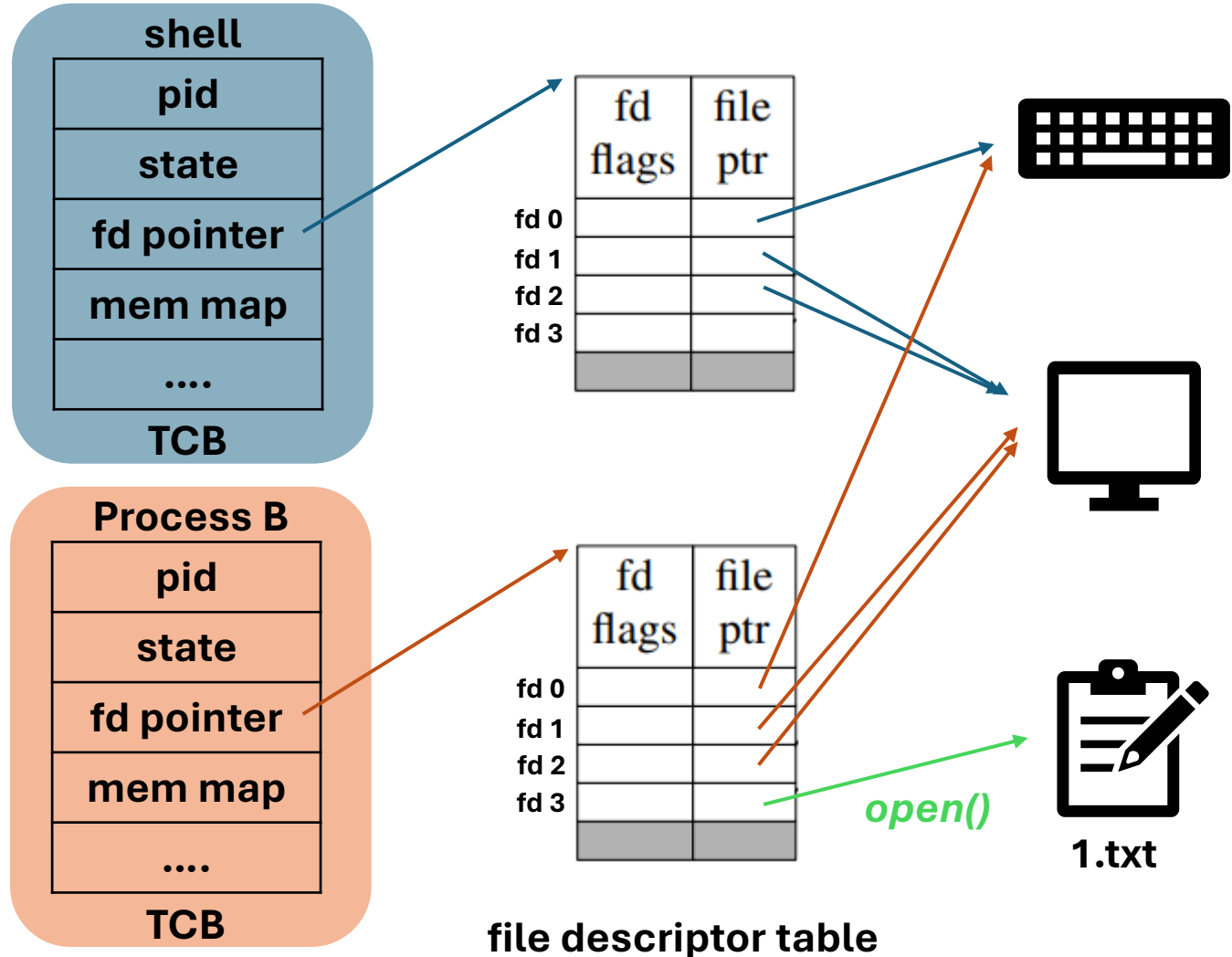


# Redirection

Implementation redirection (>) operation :

`ls > 1.txt`

- **Open the file that needs to be redirected**
- Use `dup2()` to redirect the stdin and stdout of the process

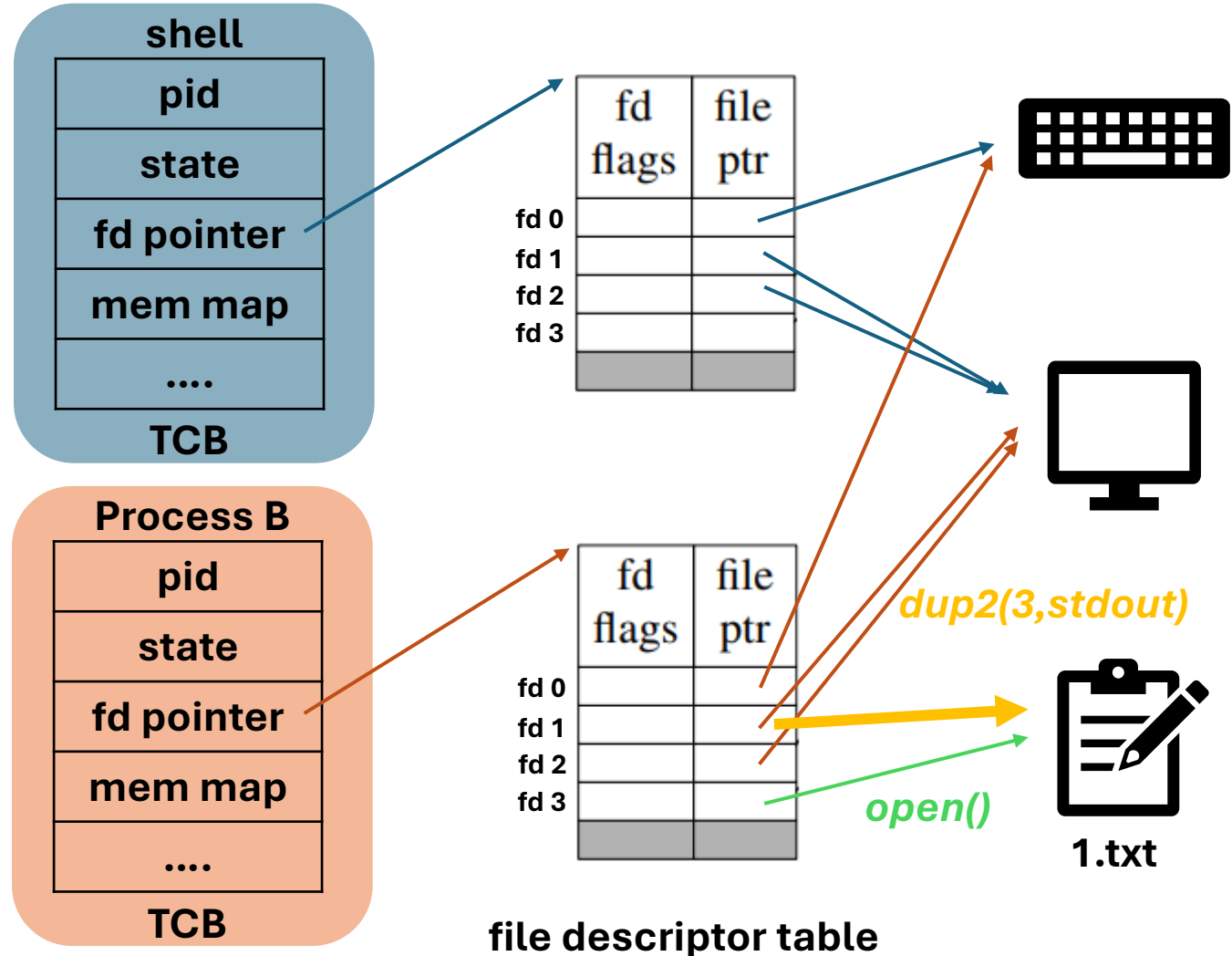


# Redirection

Implementation redirection (>) operation :

`ls > 1.txt`

- Open the file that needs to be redirected
- Use `dup2()` to redirect the `stdin` and `stdout` of the process



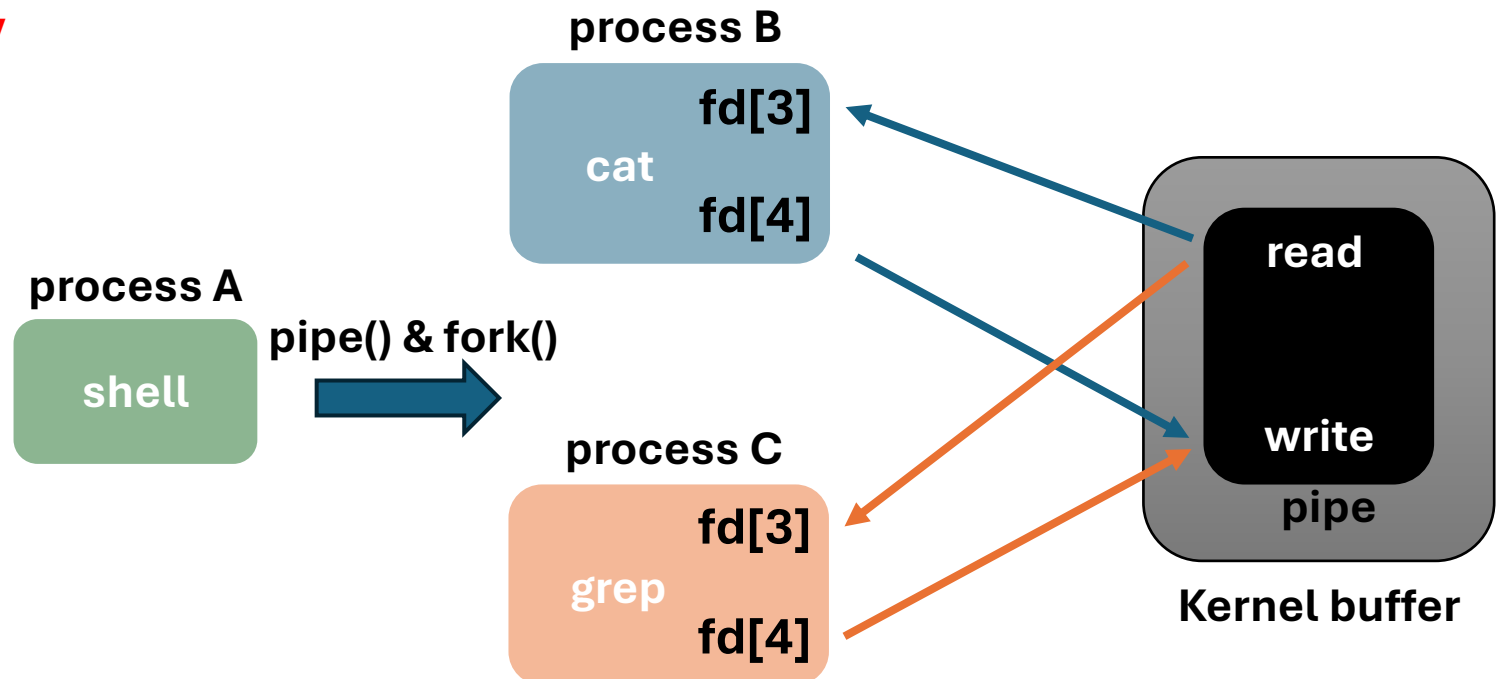
# Pipe

Implementation pipe (|) operation :

```
cat test1.txt | grep lab
```

- Use pipe() and fork() to point the file descriptor to read and write respectively
- Close unused file descriptors
- Use dup2() to redirect stdin and stdout

After pipe() and fork()?



# Pipe

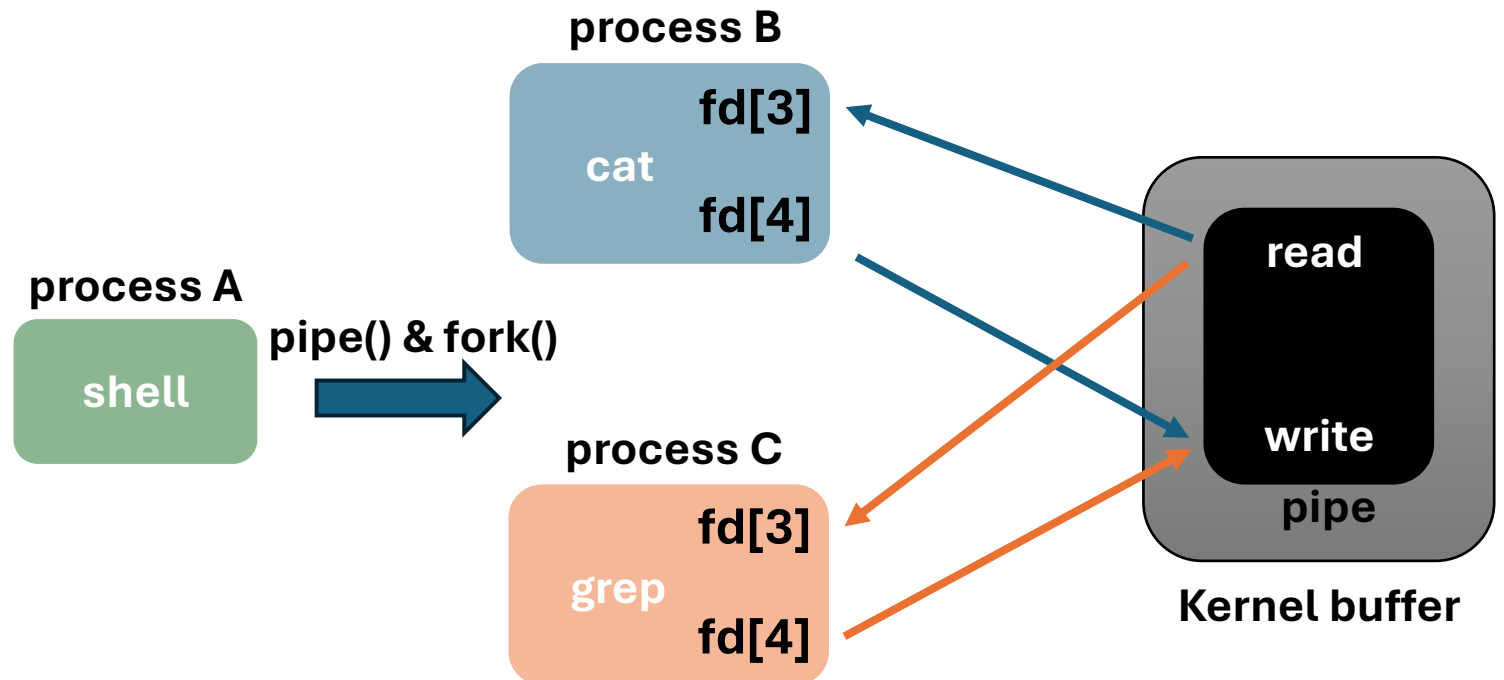
Implementation pipe (|) operation :

```
cat test1.txt | grep lab
```

- Use pipe() and fork() to point the file descriptor to read and write
- **Close unused file descriptors**
- Use dup2() to redirect stdin and stdout

Close redundant mapping

- Close read of processB
- Close write of processC

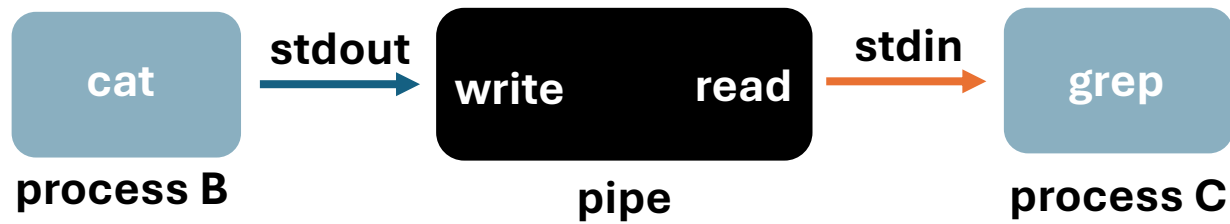


# Pipe

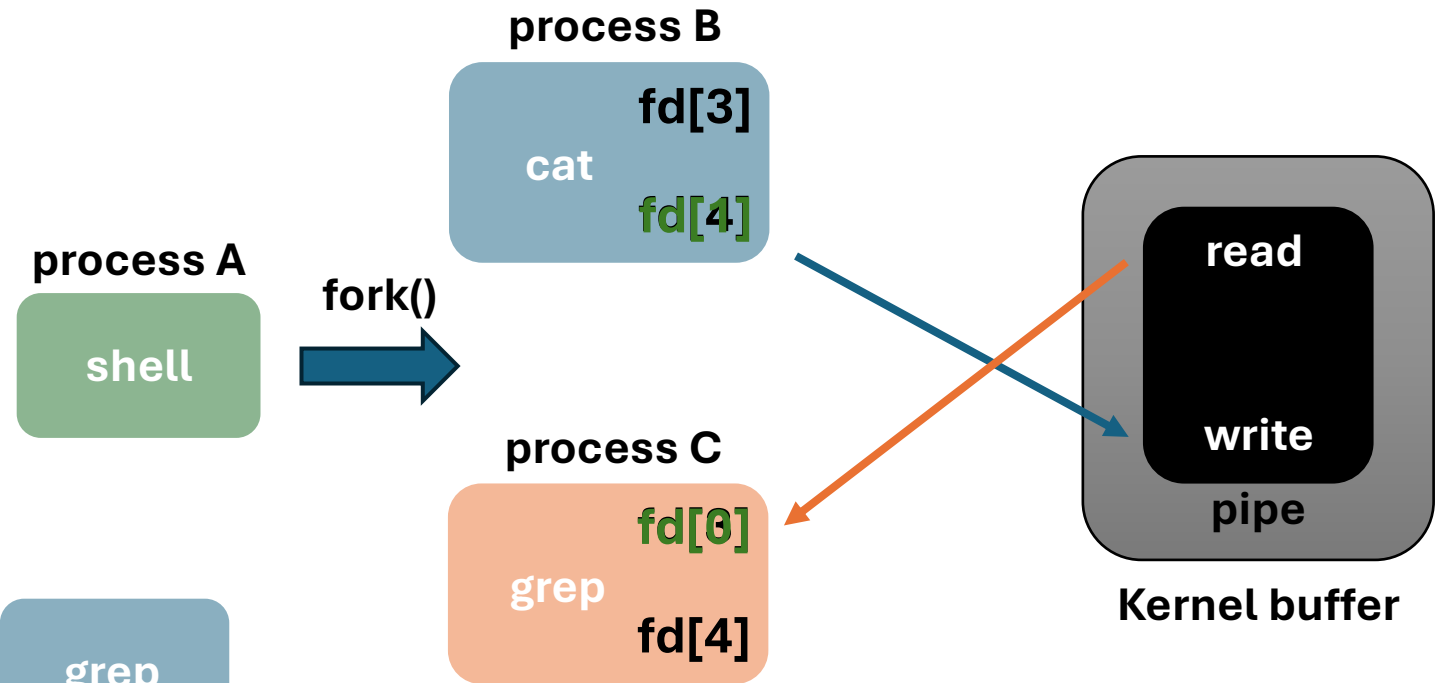
Implementation pipe (|) operation :

`cat test1.txt | grep lab`

- Use pipe() and fork() to point the file descriptor to read and write
- Close unused file descriptors
- Use dup2() to redirect stdin and stdout



After redirection?



# 1. Introduction

## 2. Requirements

## 3. Grading

2.1 Built-in command `cd` implementation

2.2 External commands implementation

2.3 Redirection implementation

2.4 Pipe implementation (**bonus**)

# Input format

## 1. Only 3 special operators: |, < and > .

- No quotation marks ( " or ' ), e.g., "string", 'string'

## 2. All the cmds, args, operators will be separated by space char.

- 指令(cmd), 引數(arg), 特殊符號(operator) 都會用空白符號隔開

## 3. Input redirection (<) only show up after last command.

- Input redirection 的檔名一定會接在 < 後面，且如果有，一定會緊接在第一個指令後面

## 4. Output redirection (>) only show up after last command.

- Output redirection 的檔名一定會接在 > 後面，且如果有，一定會緊接在最後一個指令後面

格式

```
>>> $ cmd args < infile | cmd args | cmd args > outfile
```

範例 1

```
>>> $ cd Desktop/oslab/
```

範例 2

```
>>> $ cat test1.txt > out.txt
```

範例 3

```
>>> $ cat test1.txt | grep lab
```

# Data structure

```
struct cmd_node {
    char **args;
    int length;
    char *in_file, *out_file;
    int in ,out
    struct cmd_node *next;;
}
```

```
struct cmd {
    struct cmd_node *head;
    int pipe_num;
}
```

```
>>> $ cd Desktop/oslab/
```

cmd

```
head
pipe_num = 1
```

cmd\_node

```
args[0] = cd
args[1] = Desktop/oslab/
length = 2
in_file = out_file = NULL
in = 0 , out = 1
next = NULL
```

```
>>> $ cat test1.txt > out.txt
```

cmd

```
head
pipe_num = 1
```

cmd\_node

```
args[0] = cat
args[1] = test1.txt
length = 2
in_file = NULL
out_file = out.txt
in = 0 , out = 1
next = NULL
```

# Data structure

```
struct cmd_node {  
    char **args;  
    int length;  
    char *in_file, *out_file;  
    int in ,out  
    struct cmd_node *next;  
}
```

```
struct cmd {  
    struct cmd_node *head;  
    int pipe_num;  
}
```

```
>>> $ cat test1.txt | grep lab
```

cmd

head —————→  
pipe\_num = 2

cmd\_node

args[0] = cat  
args[1] = test1.txt  
length = 2  
in\_file = out\_file = NULL  
in = 0 , out = 4  
next —————→

cmd\_node

args[0] = grep  
args[1] = lab  
length = 2  
in\_file = out\_file = NULL  
in = 3 , out = 1  
next = NULL

## 2.1 Built-in command cd implementation

- **Objective:** Complete the **cd** function so the program can execute this built-in command, and you can take **pwd** function as the reference.
  - **NAME** cd - change the working directory  
**SYNOPSIS** cd [directory]
  - **NAME** pwd - print name of current working directory  
**SYNOPSIS** pwd
- **Function to complete:**
  - cd() in /src/builtin.c

```
oslab@PC:~$ cd ./path/to/directory
```

```
oslab@PC: path/to/directory$
```

```
oslab@PC: path/to/directory$ pwd
```

```
/home/path/to/directory
```

## 2.1 Built-in command cd implementation

- **Test case & expected result**

```
>>> $ pwd
/oslab2
>>> $ cd ./shell
>>> $ pwd
/oslab2/shell
>>> $
```

## 2.2 External command implementation

- **Objective:** The **spawn\_proc** function forks a child process to execute an external command, while the parent process waits for the child to finish.
- **Function to complete:**
  - spawn\_proc() in shell.c
- **Test case & expected result**

```
>>> $ ls
builtin.o demo.txt makefile my_shell.c src
command.o include my_shell shell.o
>>> $
```

```
>>> $ cat test1.txt
Today is os' Day.
I am a student in CSIE.
I love os, you love os.
I am going to score 100 point.
Have a nice os' Day.
>>> $
```

## 2.3 Redirection implementation

- **Objective:** Complete **the redirection** function to manage input and output redirection for both built-in and external commands.
- **Function to complete:**
  - redirection() in shell.c
- **Test case & expected result**

```
>>> $ cat test1.txt > out.txt
>>> $ cat out.txt
Today is os' Day.
I am a student in CSIE.
I love os, you love os.
I am going to score 100 point.
Have a nice os' Day.
>>> $
```

## 2.4 Pipe implementation (bonus)

- **Objective:** Complete the **fork\_cmd\_node** function to manage the execution of multiple commands connected by pipes. Ensure proper handling of data flow and error management between the processes.
- **Function to complete:**
  - `fork_cmd_node()` in `shell.c`
- **Test case & expected result**

```
>>> $ cat test1.txt | tail -2  
I am going to score 100 point.  
Have a nice os' Day.  
>>> $
```

# 1.Introduction

## 2.Requirements

## 3.Grading

requirement	points
2.1 Built-in command cd implementation	2
2.2 External command	2
2.3 Redirection for external commands	3
2.4 Pipe implementation(bonus)	1
<b>Answer 3 questions about your code</b>	<b>3</b>

# Precautions

- Due Date: **2025/11/28 17:00 (before lab2 course finishes)**
- You should implement lab2 with **C** language.
- You will get **two folders ( include & src )** and **three files ( demo.txt & makefile & my\_shell.c )** from **os\_2025\_lab2\_template**
- You can modify makefile as you want, but make sure your **makefile** can compile your codes and create the executable successfully.