# Processes

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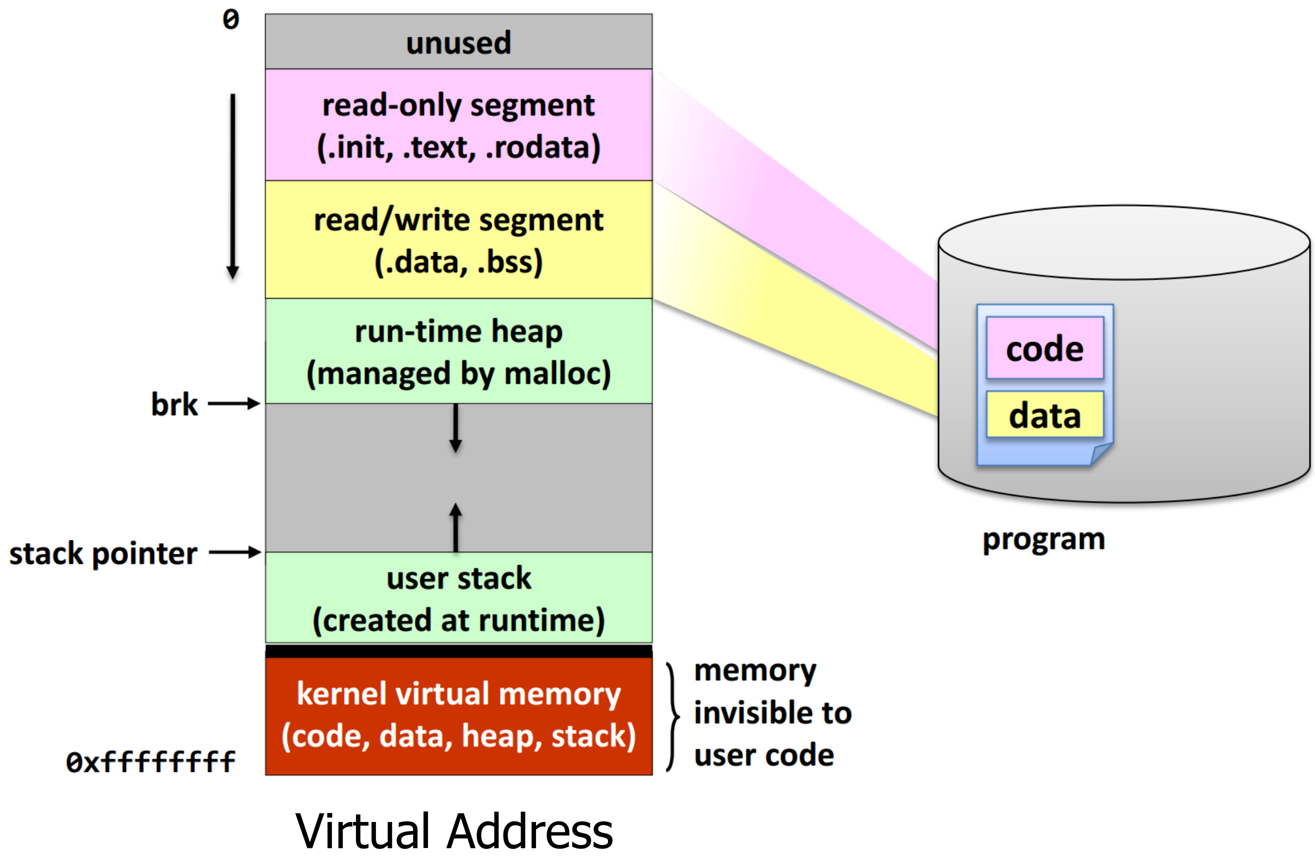
# Q & A (1)

- **Where were 'string literals' stored?**



# Q & A (2)

- What happen to this code?

```
int main(void)
{
    char c;

    while(read(0, &c, 1) != 0)
        write(1, &c, 1);
    exit(0);
}
```

- ‘₩n’ is termination character in stdin and stdout

# Processes (1)

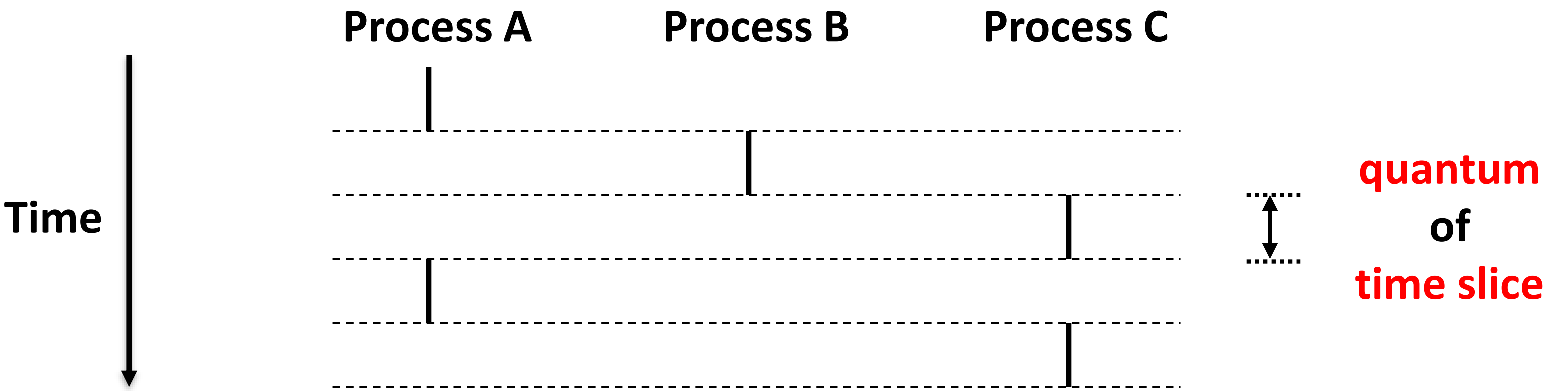
- **What's difference among**
  - Program
  - Process
  - Processor
- **Process**
  - **An instance of a program in execution**
  - 'Context' + 'Resource'

# Processes (2)

- **Process provides each program with two key abstractions:**
  - Logical control flow
    - Each program seems to have exclusive use of the CPU
  - Private address space
    - Each program seems to have exclusive use of main memory
- **How are these illusions maintained?**
  - Process executions interleaved (multitasking).
  - Address space managed by virtual memory system.

# Logical Control Flows

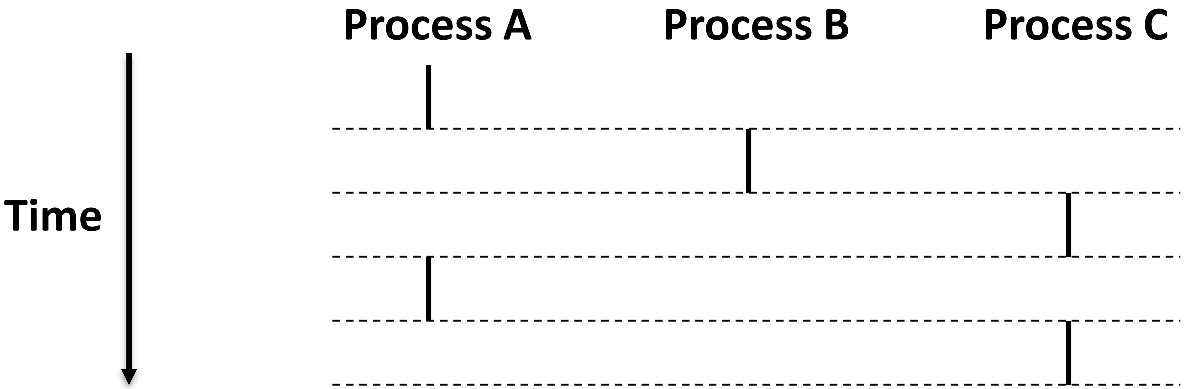
- Each process has its own logical control flow



# Concurrent Processes (1)

## Definition

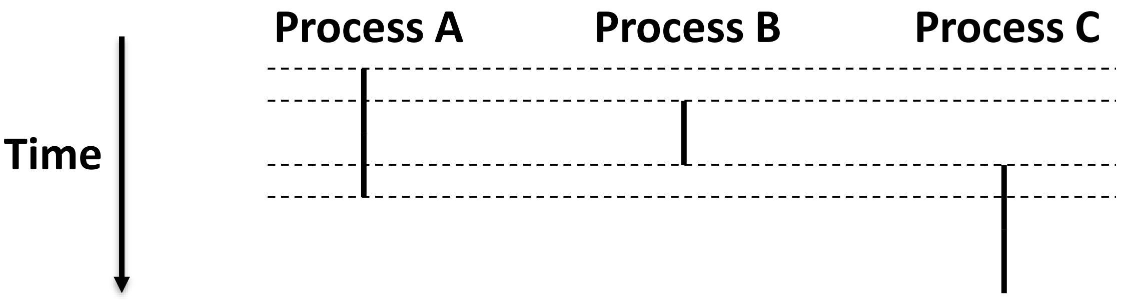
- Two processes run concurrently (are concurrent) if their flows overlap in time.
- Otherwise, they are sequential.
- Examples (running on single core):
  - Concurrent: A & B, A & C
  - Sequential: B & C



# Concurrent Processes (2)

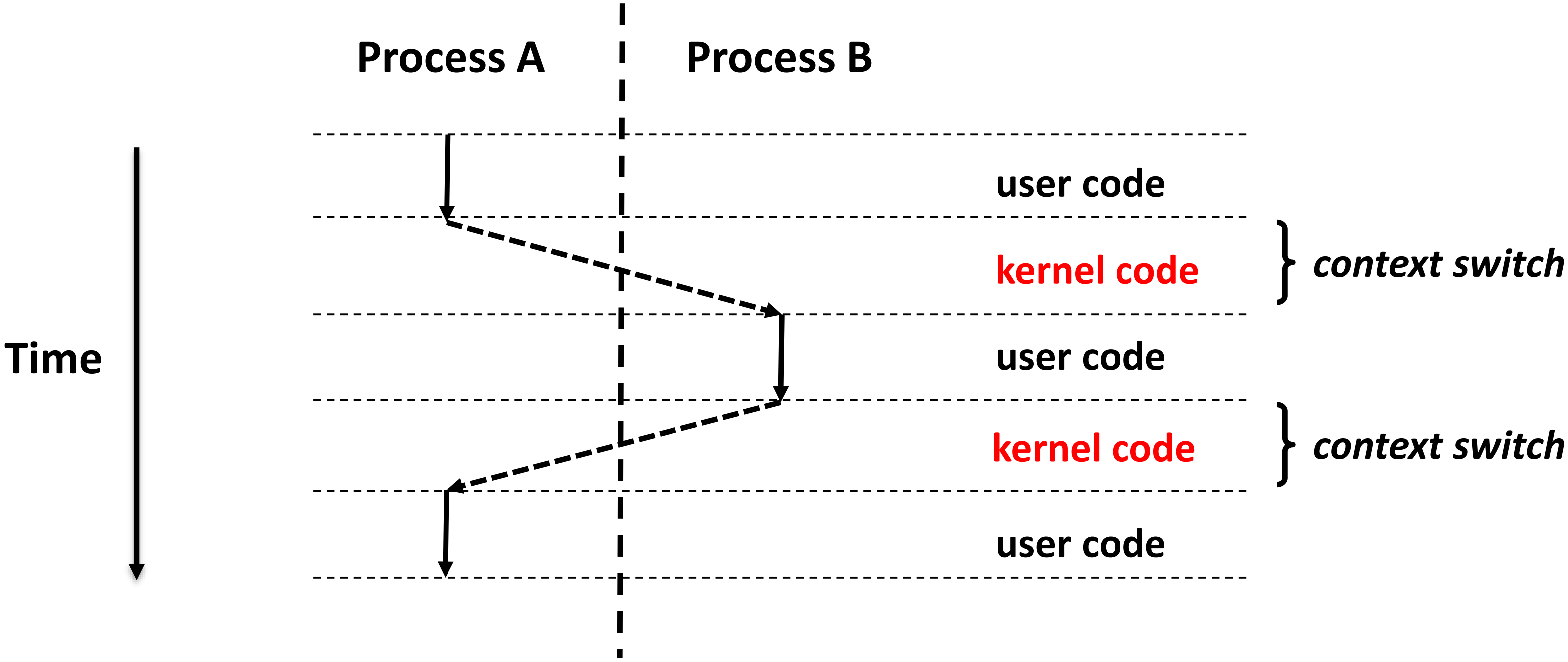
## User View of Concurrent Processes

- Control flows for concurrent processes are physically disjoint in time
- However, we can think of concurrent processes are running in parallel with each other



# Context Switching

- Control flow passes from one process to another via a context switch



# Creating a New Process

- **pid_t fork(void)**
  - Creates a new process (child process) that is identical to the calling process (parent process)
  - Returns 0 to the child process
  - Returns child's **pid** to the parent process

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

**Fork is interesting (and often confusing) because it is called *once* but returns *twice***

# Fork Example (1)

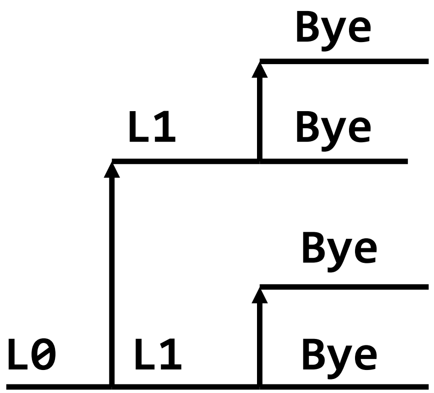
- **Key points**
  - Parent and child both run **same code**
    - Distinguish parent from child by **return value** from **fork()**
  - Start with same state, but each has private copy.
    - Share file descriptors, since child inherits all open files.

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

# Fork Example (2)

- **Key points**
  - Both parent and child can continue forking.

```
void fork2()
{
    printf("L0\n");
    fork();
    printf("L1\n");
    fork();
    printf("Bye\n");
}
```



# Destroying a Process

- void exit (int status)
  - Exits a process.
    - Normally returns with status 0
  - **atexit()** registers functions to be executed upon exit.

```
void cleanup(void) {
   printf("cleaning up\n");
}

void fork6() {
   atexit(cleanup);
   fork();
   exit(0);
}
```

# Synchronizing with Children

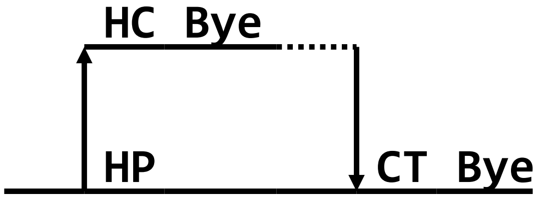
- **pid_t wait (int *status)**
  - suspends current process until one of its children terminates.
  - return value is the **pid** of the child process that terminated.
  - if **status != NULL**, then the object it points to will be set to a status indicating why the child process terminated.

- **pid_t waitpid (pid_t pid, int *status, int options)**
  - Can wait for specific process
  - Various options

# Wait Example (1)

```
void fork9() {
   int child_status;

   if (fork() == 0) {
      printf("HC: hello from child\n");
   }
   else {
      printf("HP: hello from parent\n");
      wait(&child_status);
      printf("CT: child has terminated\n");
   }
   printf("Bye\n");
   exit();
}
```



# Wait Example (2)

- **If multiple children completed,**
  - will take in arbitrary order.
  - Can use macros **WIFEXITED** and **WEXITSTATUS** to get information about exit status.

```
void fork10() {
    pid_t pid[N];
    int i, child_status;
    for (i = 0; i < N; i++)
        if ((pid[i] = fork()) == 0)
            exit(100+i); /* Child */
    for (i = 0; i < N; i++) {
        pid_t wpid = wait(&child_status);
        if (WIFEXITED(child_status))
            printf("Child %d terminated with exit status %d\n",
                   wpid, WEXITSTATUS(child_status));
        else
            printf("Child %d terminate abnormally\n", wpid);
    }
}
```

# Waitpid Example

```
void fork11()
{
    pid_t pid[N];
    int i;
    int child_status;
    for (i = 0; i < N; i++)
        if ((pid[i] = fork()) == 0)
            exit(100+i); /* Child */
    for (i = 0; i < N; i++) {
        pid_t wpid = waitpid(pid[i], &child_status, 0);
        if (WIFEXITED(child_status))
            printf("Child %d terminated with exit status %d\n",
                   wpid, WEXITSTATUS(child_status));
        else
            printf("Child %d terminated abnormally\n", wpid);
    }
```

# Zombies (1)

- **Idea**
  - When a process terminates, still consumes system resources.
    - Various tables maintained by OS
  - Called a “zombie”
    - Living corpse, half alive and half dead
- **Reaping**
  - Performed by parent on terminated child.
  - Parent is given exit status information.
  - Kernel discards the terminated process.
- **What if parent doesn’t reap?**
  - If any parent terminates without reaping a child, then child will be reaped by init process.
  - Only need explicit reaping for long-running processes.
    - e.g. shells and servers

# Zombies (2)

```c
void fork7()
{
  if (fork() == 0) {
    /* Child */
    printf("Terminating Child, PID = %d\n",
            getpid());
    exit(0);
  } else {
    printf("Running Parent, PID = %d\n",
            getpid());
    while (1); /* Infinite loop */
  }
}
```

```
linux> ./forks 7 &
[1] 6639
Running Parent, PID = 6639
Terminating Child, PID = 6640
linux> ps
  PID TTY          TIME CMD
 6585 ttyp9    00:00:00 tcsh
 6639 ttyp9    00:00:03 forks
 6640 ttyp9    00:00:00 forks <defunct>
 6641 ttyp9    00:00:00 ps
linux> kill 6639
[1]    Terminated
linux> ps
  PID TTY          TIME CMD
 6585 ttyp9    00:00:00 tcsh
 6642 ttyp9    00:00:00 ps
```

- **ps** shows child processes as “defunct”
- Killing parent allows child to be reaped

# Running New Programs (1)

- **int execl (char *path, char *arg0, …, NULL)**
  - loads and runs executable at **path** with arguments **arg0**, **arg1**, …
    - **path** is the complete path of an executable
    - **arg0** becomes the name of the process
      - » Typically **arg0** is either identical to **path**, or else it contains only the executable filename from path.
    - "real" arguments to the executable start with **arg1**, etc.
    - list of args is terminated by a **(char *) 0** argument.
  - returns –1 if error, otherwise doesn't return!
- **int execv (char *path, char *argv[])**
  - argv : null terminated pointer arrays

# Running New Programs (2)

- Example: running /bin/ls

```
main() {
    if (fork() == 0) {
        execl("/bin/ls", "ls", "/", 0);
    }
    wait(NULL);
    printf("completed\n");
    exit();
}
```

```
main() {
    char *args[] = {"ls", "/", NULL};
    if (fork() == 0) {
        execv("/bin/ls", args);
    }
    wait(NULL);
}
```

# Summary

- **Process abstraction**
  - Logical control flow
  - Private address space

- **Process-related system calls**
  - `fork()`
  - `exit()`, `atexit()`
  - `wait()`, `waitpid()`
  - `execl()`, `execle()`, `execv()`, `execve()`, …

# Lab. Exercise 1 (1)

- **Make the following program:**
  - main
    - fork()
    - if child
      - exec()
      - [$ ls -al /sys/kernel/debug]
    - if parent
      - wait()
      - get the child's return value
      - print the child's pid and the value

# Lab. Exercise 2 (1)

- **Make the following program**

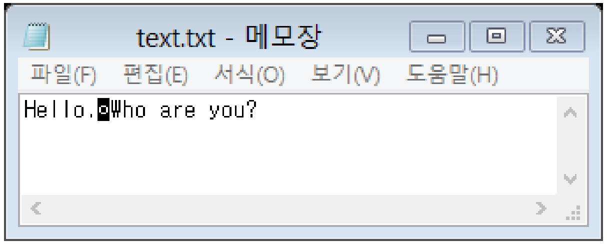
| | Unix | Dos |
|---|---|---|
| Newline | <LF> | <CR> <LF> |
| <TAB> char | 8 consecutive <space> -> <TAB> | <TAB> -> 4 consecutive <space> |

- If input file is Unix format, convert it to the dos-format
- If input file is Dos format, convert it to the Unix-format

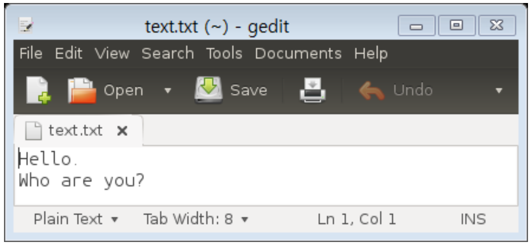
# Lab. Exercise 2 (2)

- **Make the following program**

| | Unix | Dos |
|---|---|---|
| Newline | <LF> | <CR> <LF> |
| <TAB> char | 8 consecutive <space> -> <TAB> | <TAB> -> 4 consecutive <space> |



```
Hello.◙Who are you?
```



```
Hello.
Who are you?
```

# Lab. Exercise 2 (3)

- **Make the following program**

| | Unix | Dos |
|---|---|---|
| Newline | <LF> | <CR> <LF> |
| <TAB> char | 8 consecutive <space> -> <TAB> | <TAB> -> 4 consecutive <space> |

- ./convert [input_file]
- You should name the output file as [input_file].out
- You cannot use fopen, fread, fwrite and fclose
  - Instead, use open, read, write and close
- Test file is uploaded at project page
  - http://csl.skku.edu/SSE2033S16/Projects