Operating Systems

Processor Virtualization via Process Abstraction (Lecture-2)

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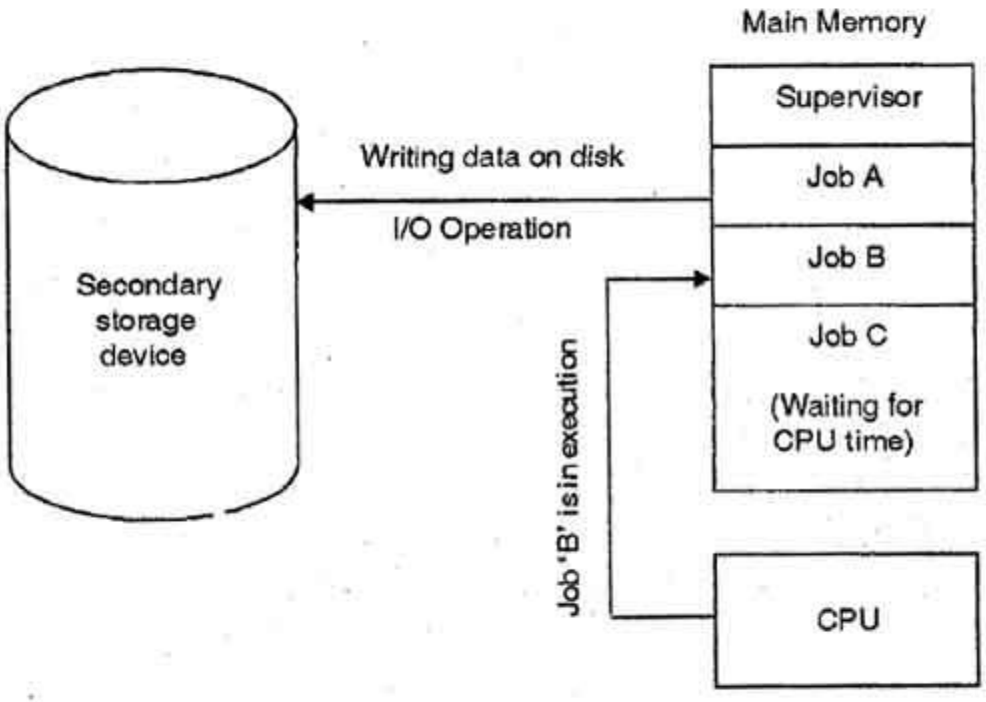
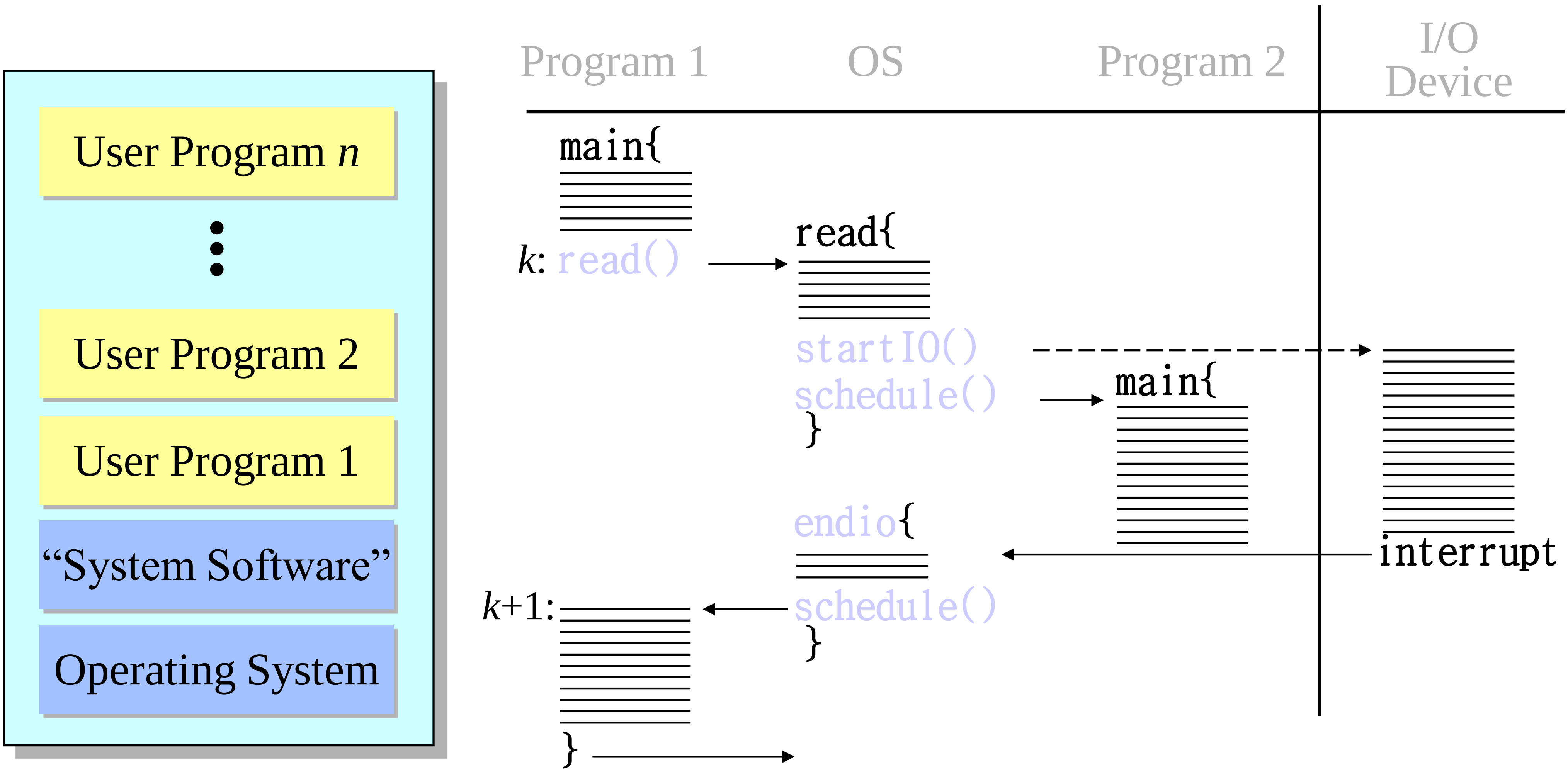
Multiprogrammed Operating Systems

- Idea: Switch between multiple jobs based on I/O requests.

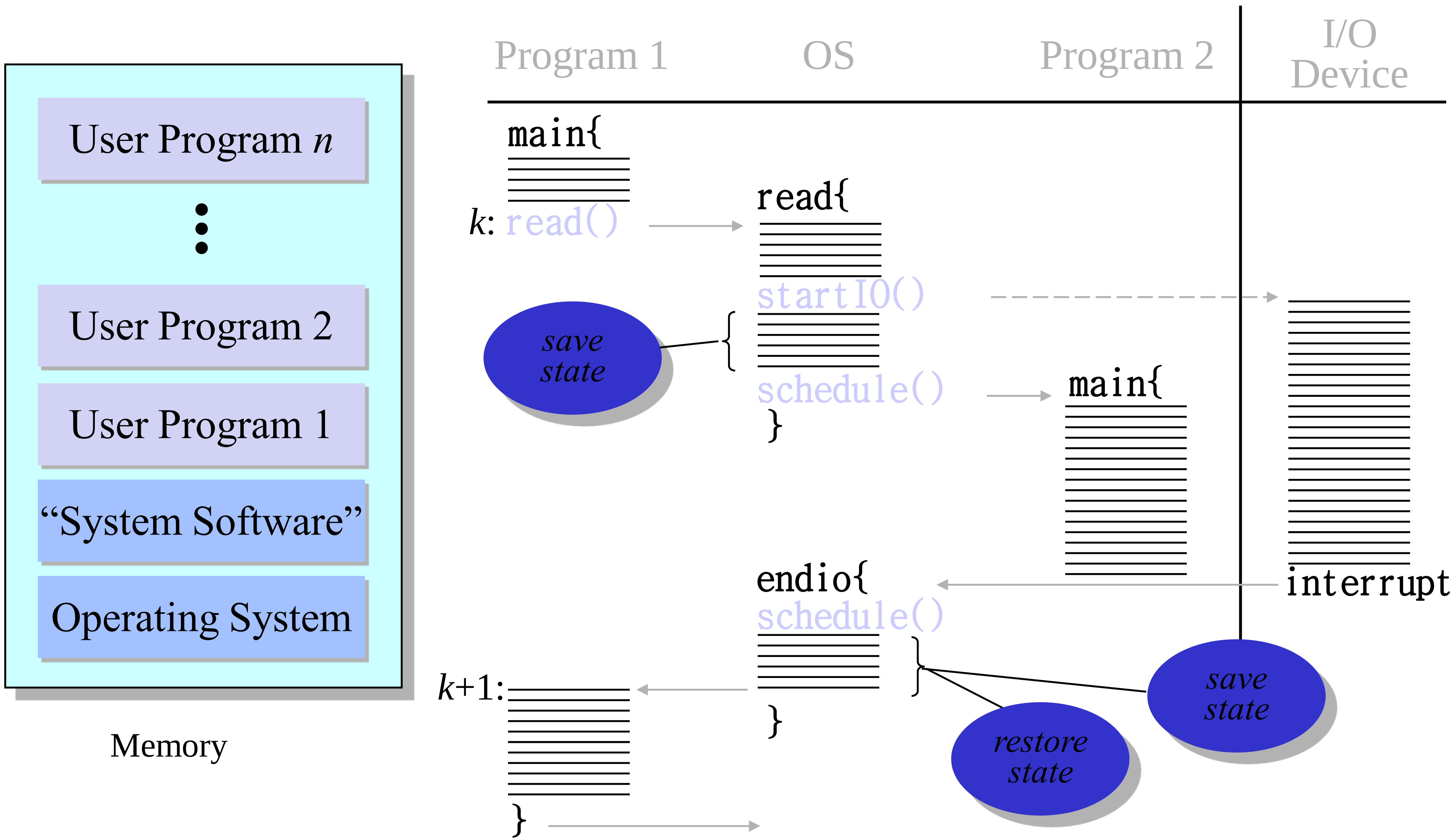


Multiprogramming (‘65-‘80)

Keep several jobs in memory and multiplex CPU between jobs

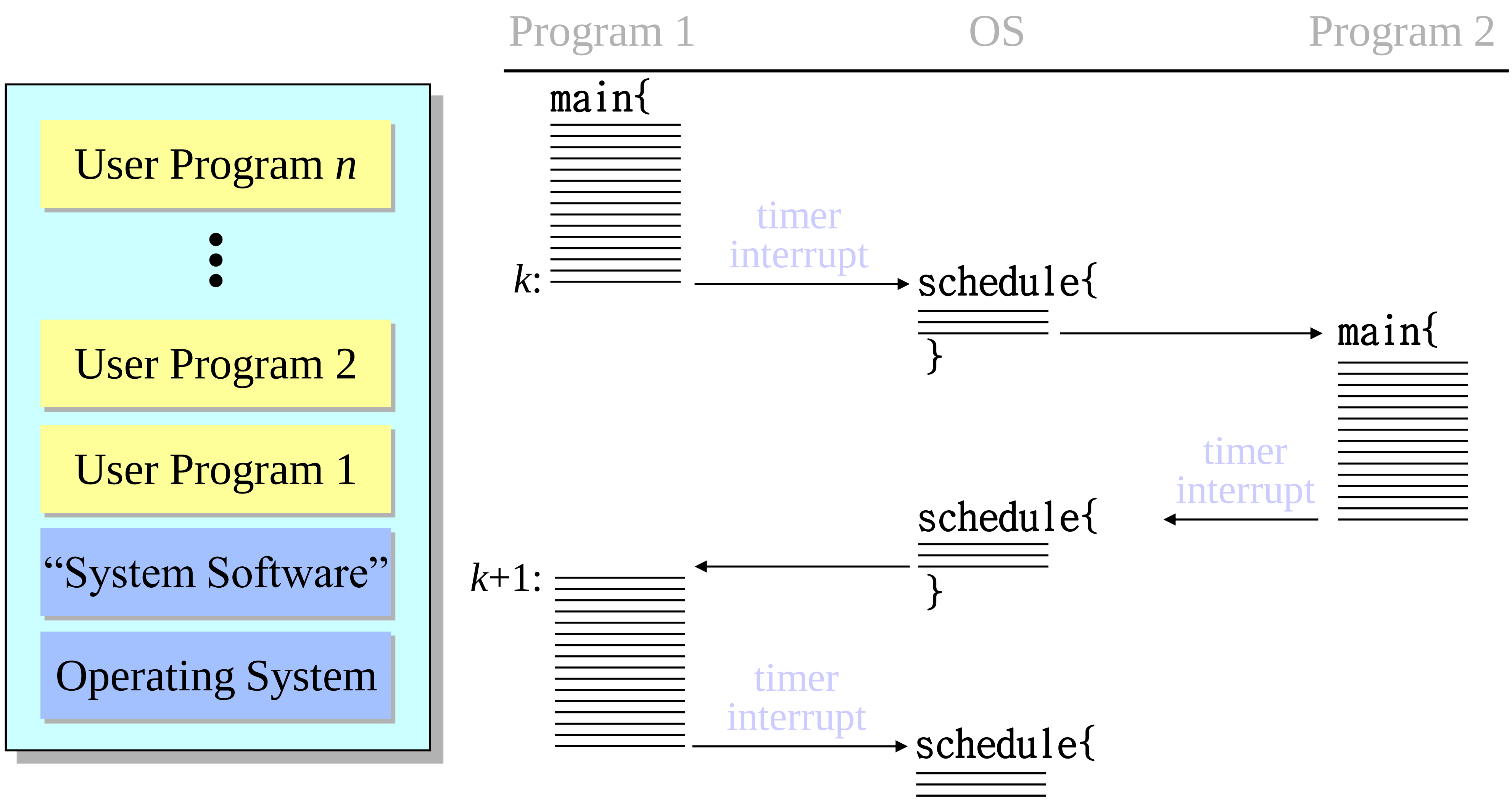


Context Switching

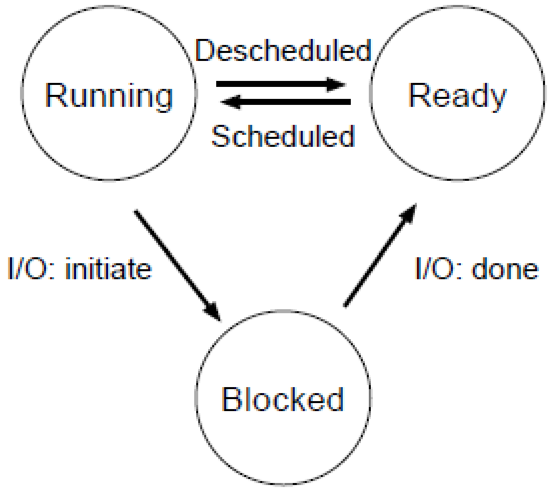


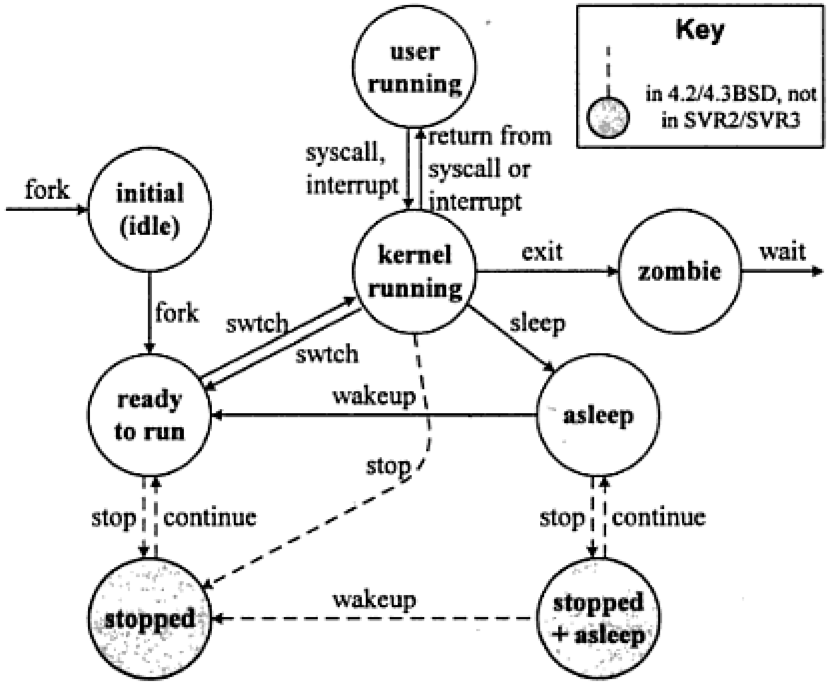
Timesharing Operating Systems (‘70-)

A timer interrupt is used to multiplex CPU among jobs



Process State Transitions

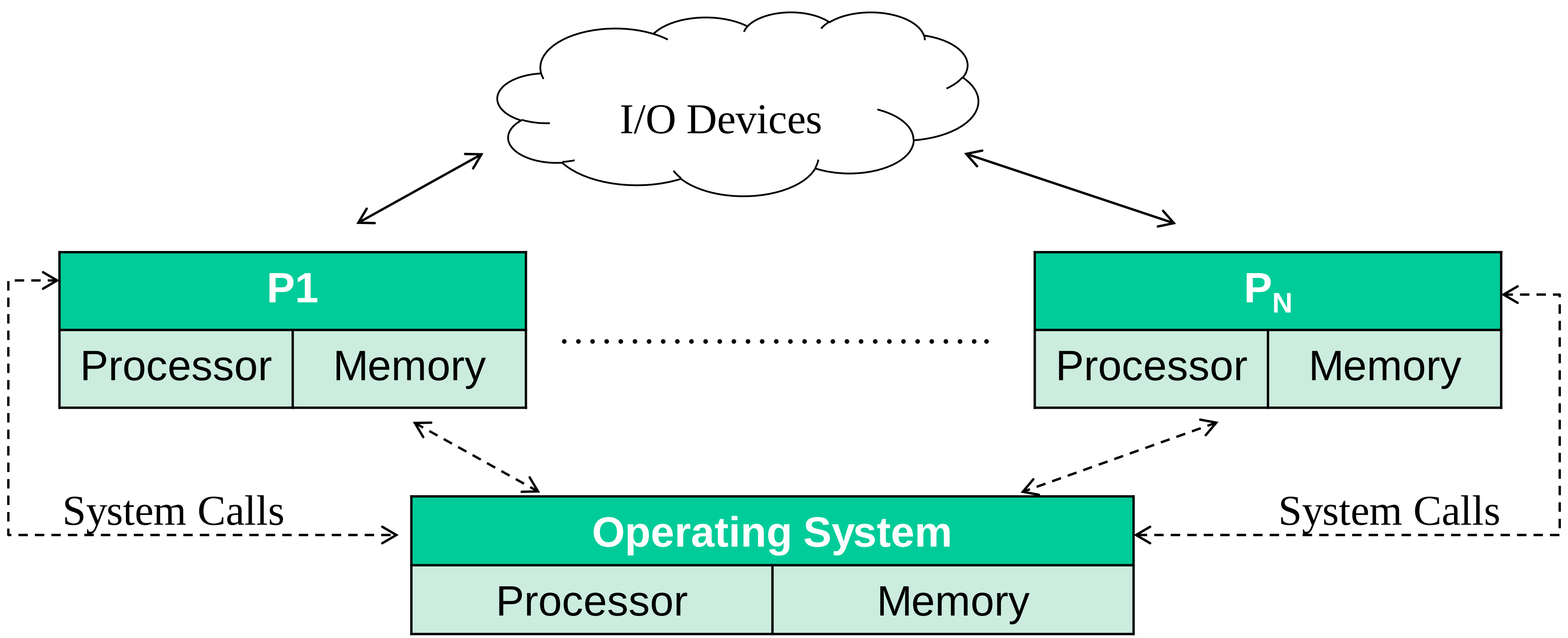




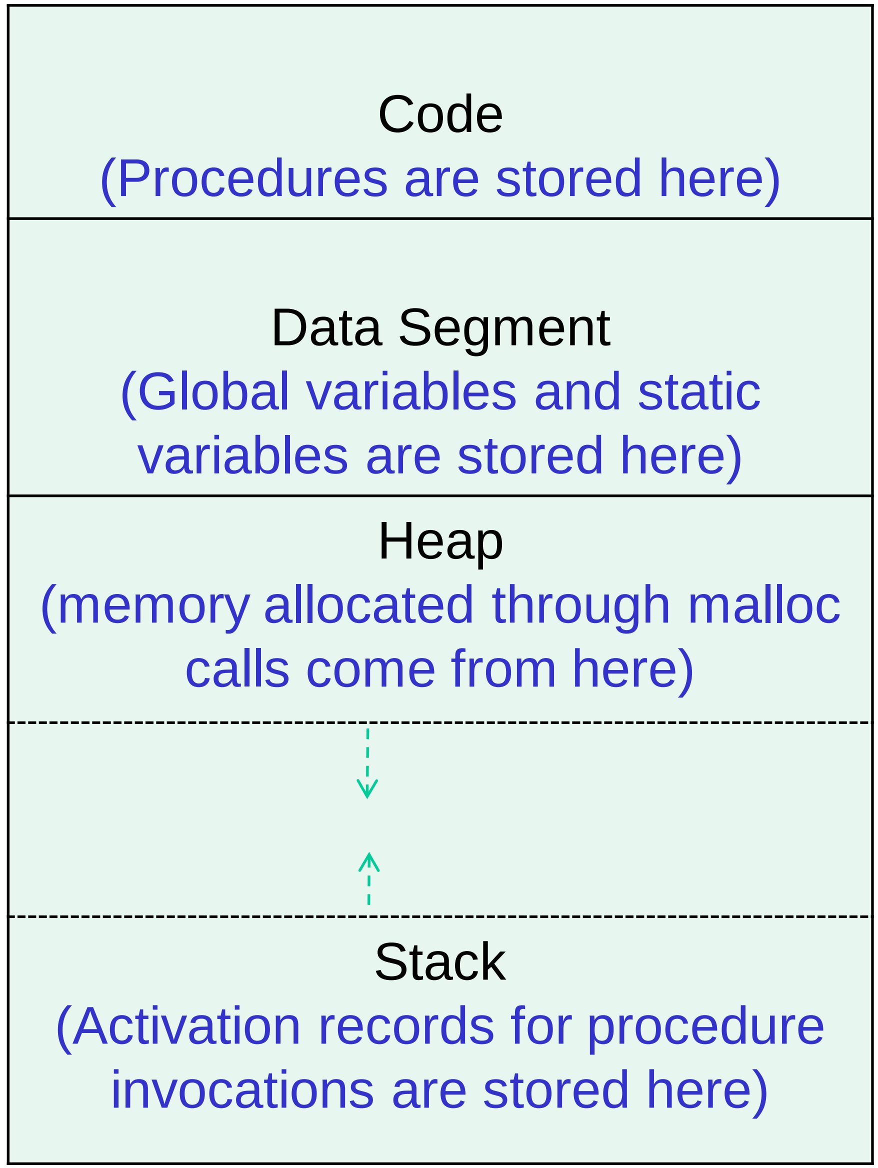
Scheduling Policy: Among the available ready-to-run processes which one should be allocated CPU in the next time slice.

Virtualization 1.0

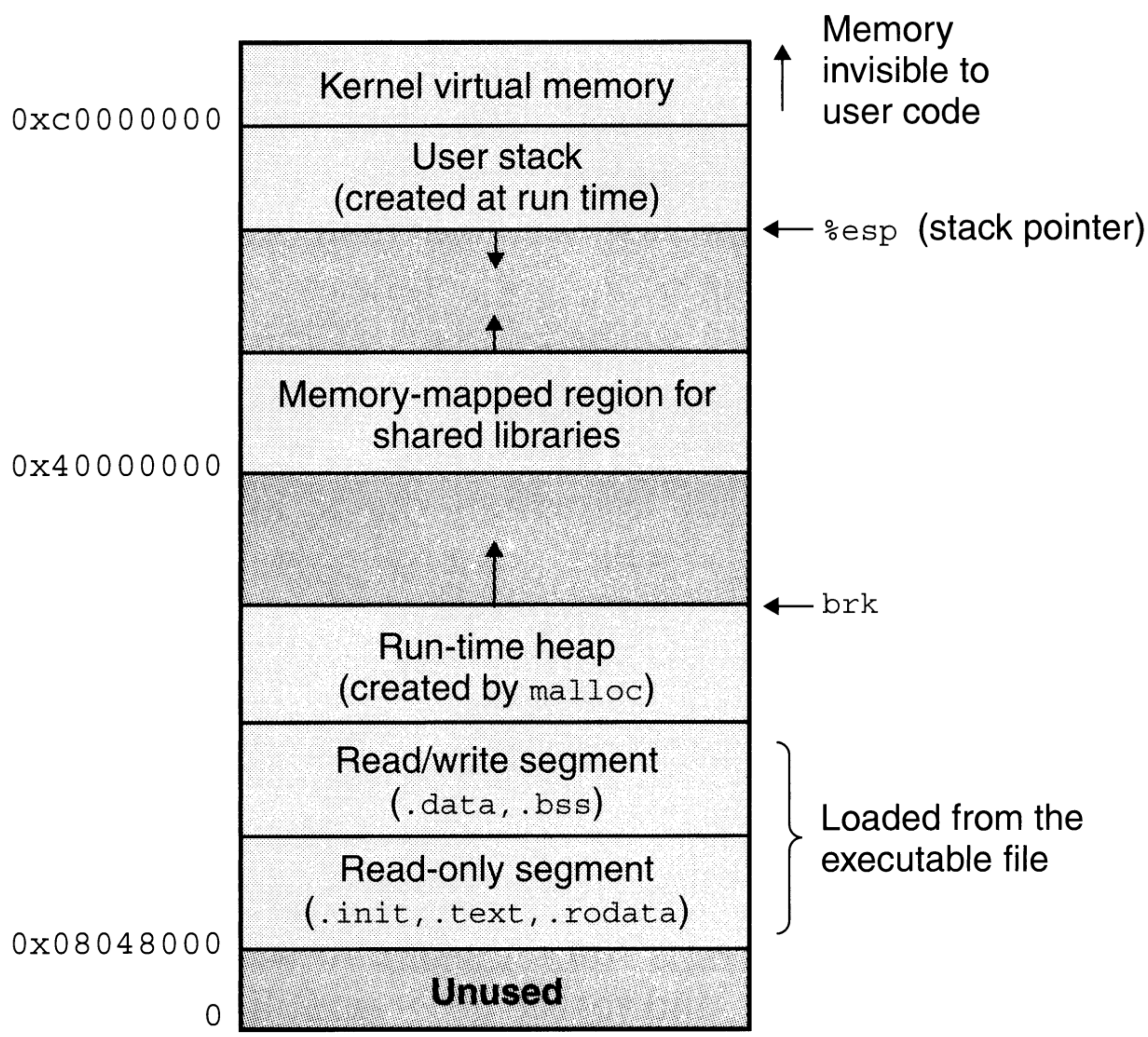
- Goal: Give every program a virtual PC
- Every process
  - Gets an illusion that it has an entire processor for itself (via multiplexing CPU over time)
  - Complete memory address space available (via Virtual Memory)
- However: Indirect interference between processes is possible



Storage Lay-out of a Program



Virtual Address Space Layout of a Linux Process



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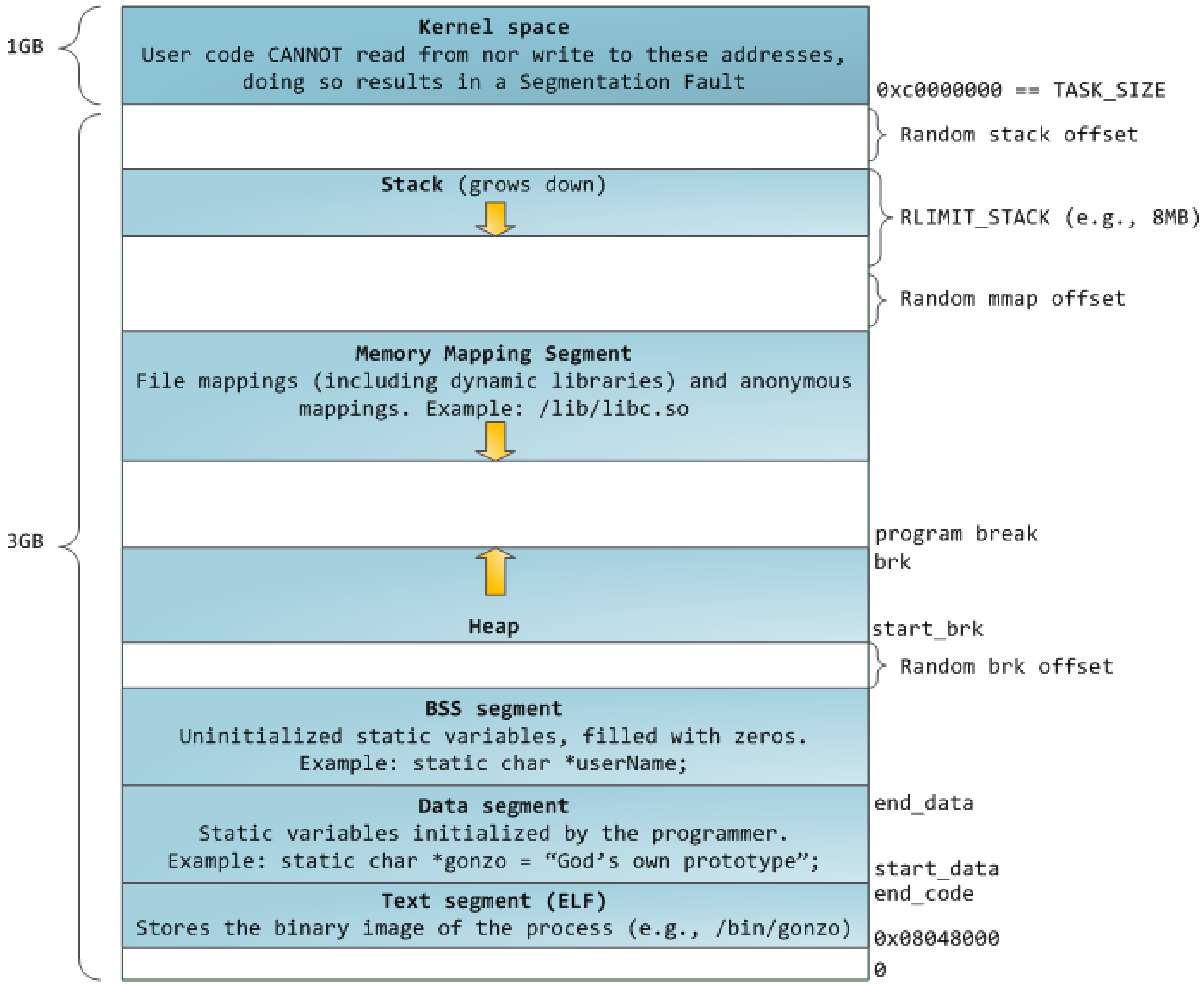
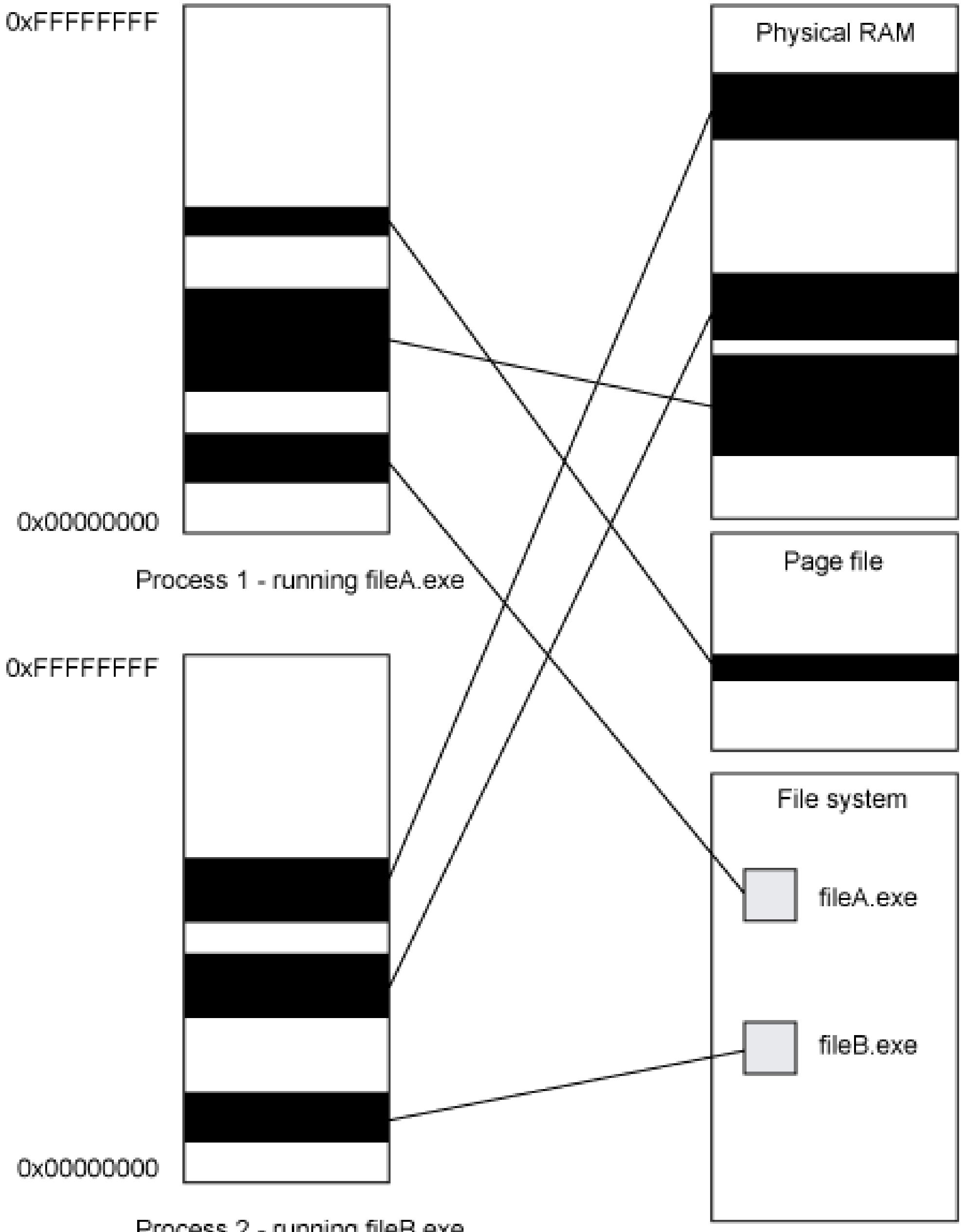


Taken from: http://duartes.org/gustavo/blog/post/anatomy-of-a-program-in-memory

Virtual Address Space versus Physical Address Space



Taken From: http://www.ibm.com/developerworks/aix/library/j-nativememory-aix/index.html

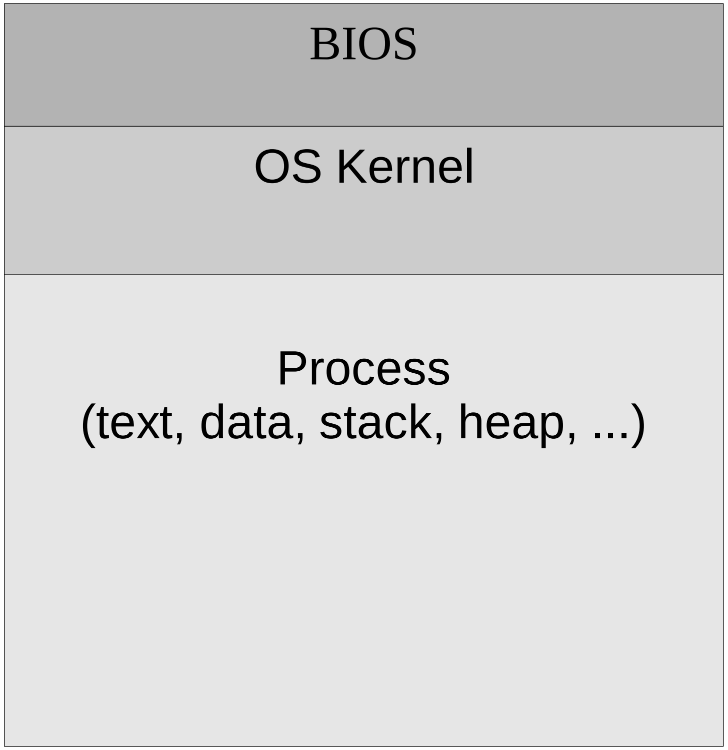
Virtualizing a Processor

- Goal
  - We would like to run multiple programs on a single CPU (may be more).
  - Each program should get an illusion that it has the entire CPU for itself.
    - In other words, provide each program a separate virtual CPU.
- Possible Tradeoff: Virtual CPU may run a bit slower than the underlying Physical CPU.
- Idea: A program relinquishes the CPU in either of the following two scenarios
    - Has to wait on an I/O request
    - Already used the allocated time slice (time multiplexing)

Process Abstraction

- A process is a dynamic object which can be created and destroyed using an OS API (aka system calls).
- The state of the process and its dynamics (or evolution) are a function of the static program from which it is created.
- Simply Put: A process is a program in execution.
  - A program is a static entity whereas a process is a dynamic entity.
- Process State: text/code, data, bss, stack, heap, CPU registers, program counter, …, anything else!
- As a process executes its state keep evolving.

Memory Map

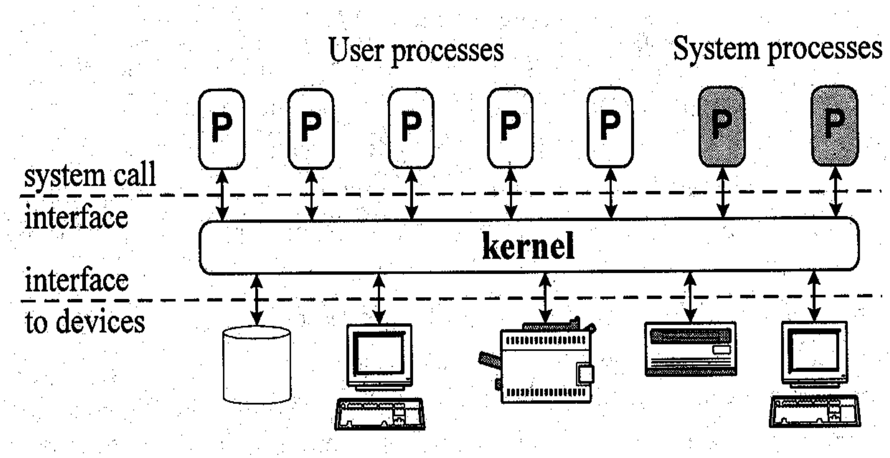


Per Process Kernel Data Structures

- u-area (accessible only when the process is currently running)
  - Process control block – Stores the hardware context when the process is not running
  - Open file descriptor tables
  - CPU and other resource usage statistics
  - Per kernel stack
  - …………
- proc structure (accessible at any time)
  - Process id
  - Location of the kernel address map for the u-area of this process
  - Current process state (like READY, STOPPED, BLOCKING, …)
  - ………..

Process Abstraction

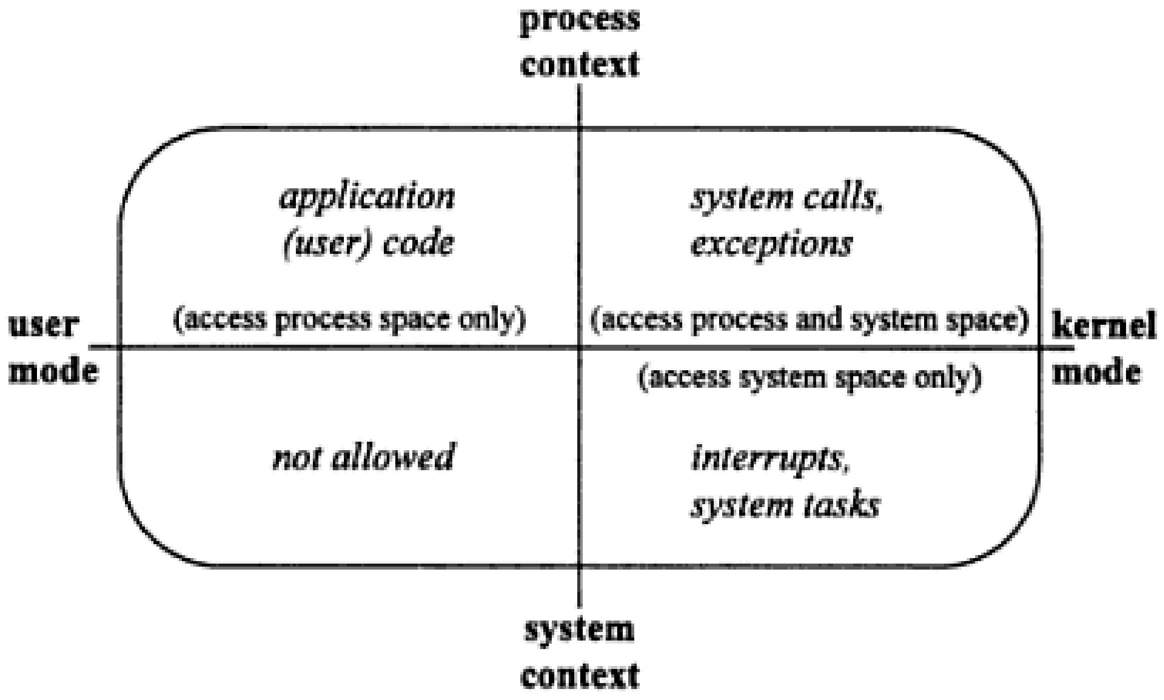
- Every process should get
  - a virtual CPU for itself
  - a complete virtual memory address space
- Different processes may run different instances of the same program
  - E.g., Two Firefox processes are fired from the same program.
- Every process gets a unique identifier (pid)



- init
- kswapd
- …

Mode, Space and Context

- User Mode vs Kernel Mode
  - Realized using processor modes
- User Space vs System Space
- Process Context vs System Context



Unresolved Issues

1. Kernel isolation
2. Process isolation
3. Address space isolation

Process Creation

Parent

pid = 3456

```
main()
{
  pid=fork();
  if (pid == 0)
     ChildProcess();
  else
     ParentProcess();
}

void  ChildProcess()
{
  .....
}

void  ParentProcess()
{
  .....
}
```

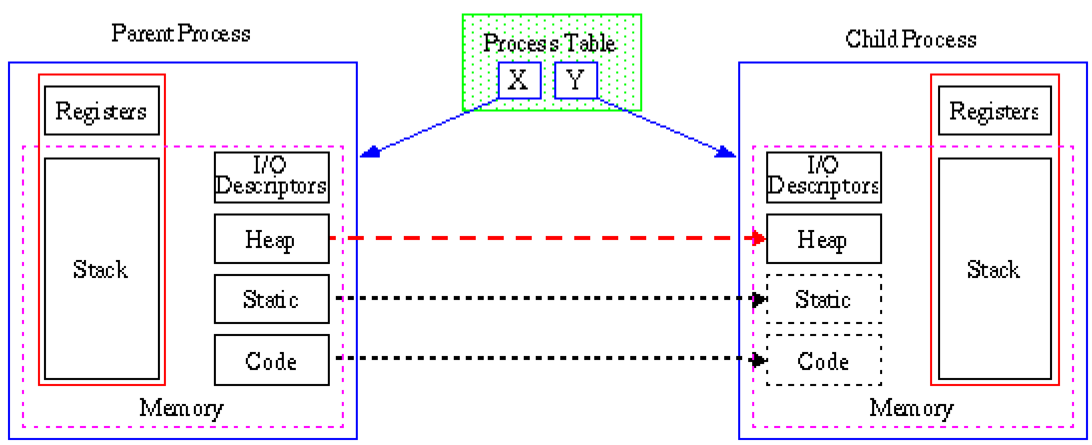
Child

pid = 0

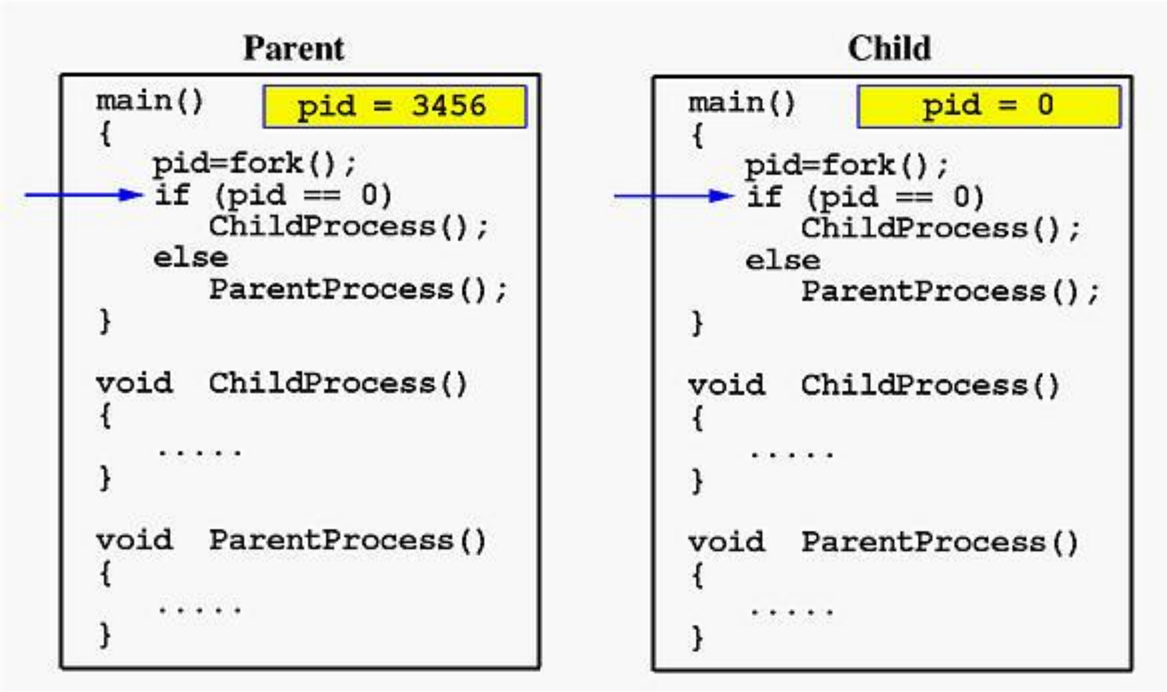
```
main()
{
  pid=fork();
  if (pid == 0)
     ChildProcess();
  else
     ParentProcess();
}

void  ChildProcess()
{
  .....
}

void  ParentProcess()
{
  .....
}
```



Process Creation



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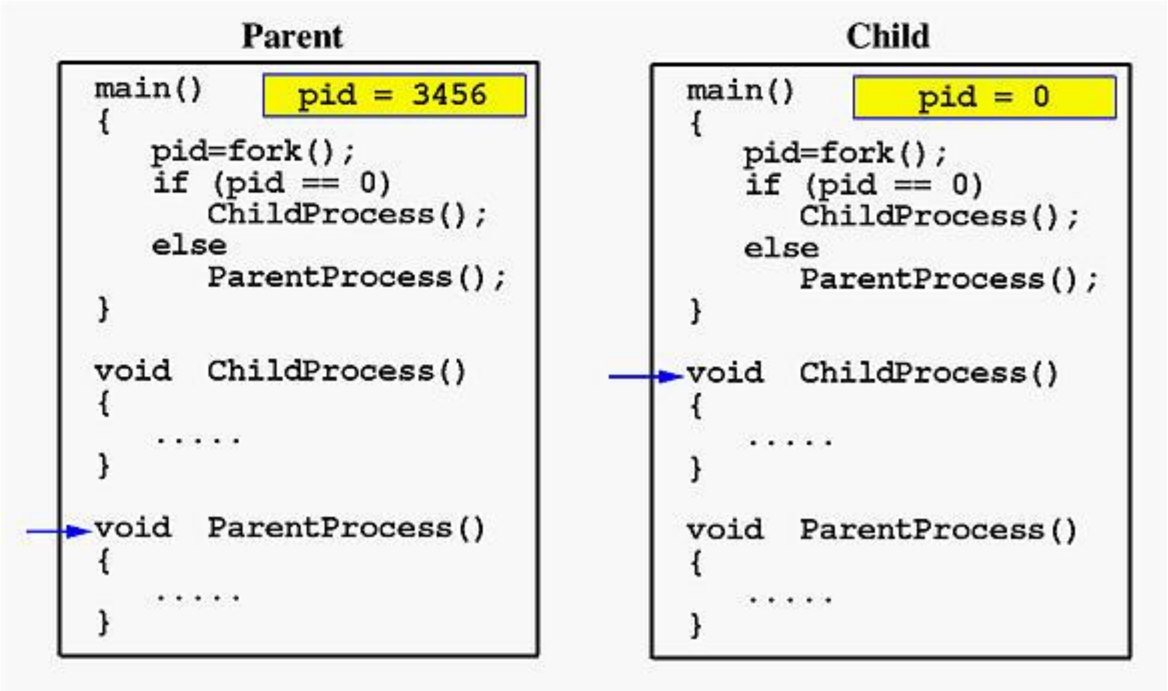
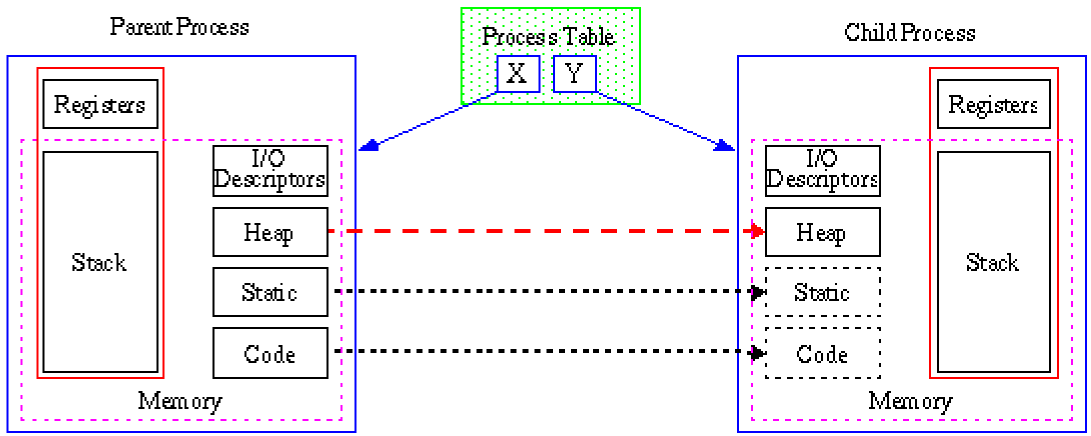
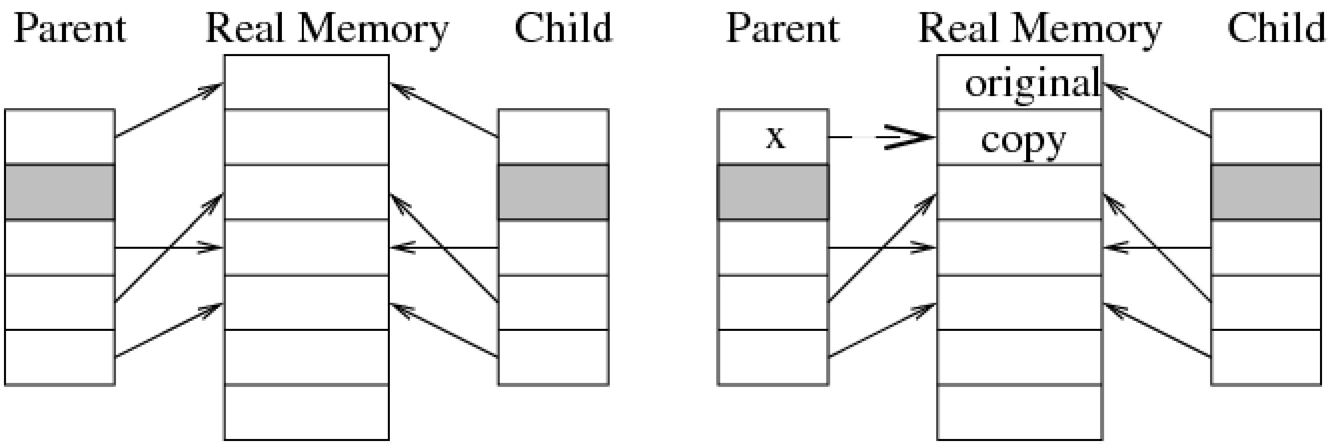


Process Creation



Copy-on-Write



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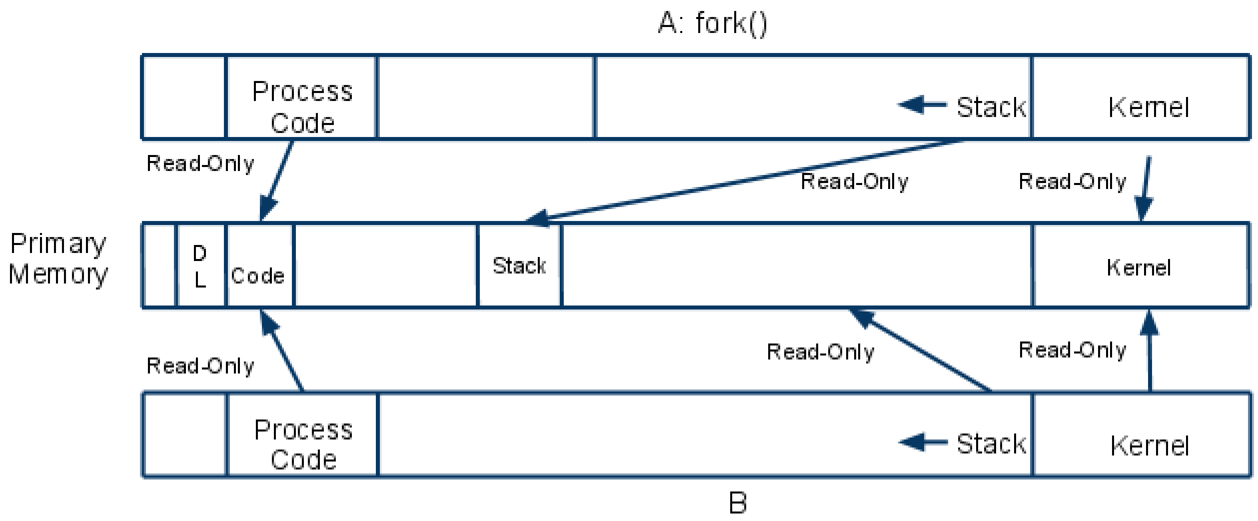
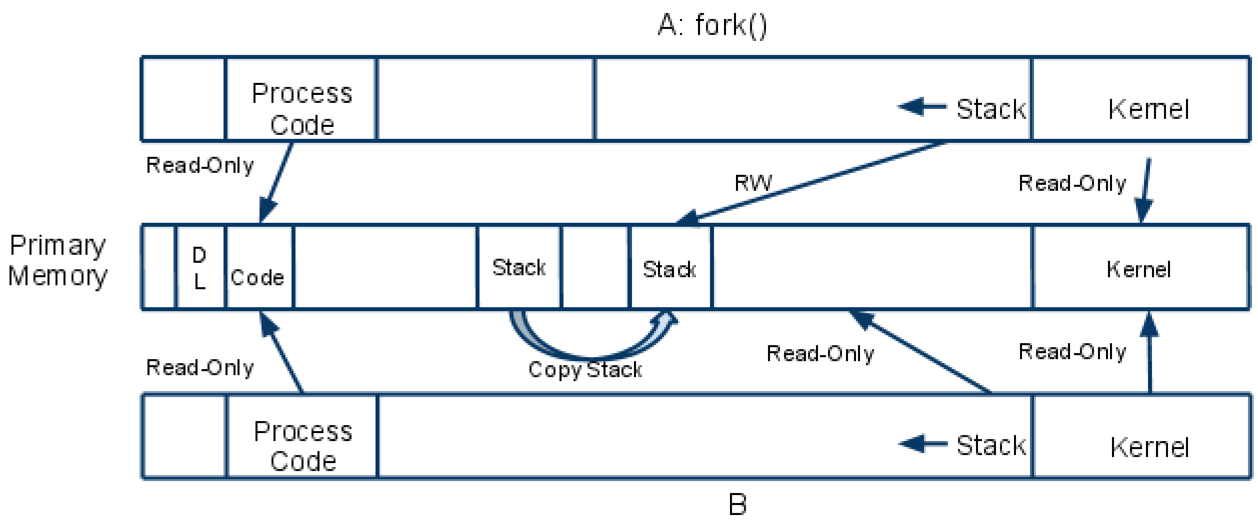
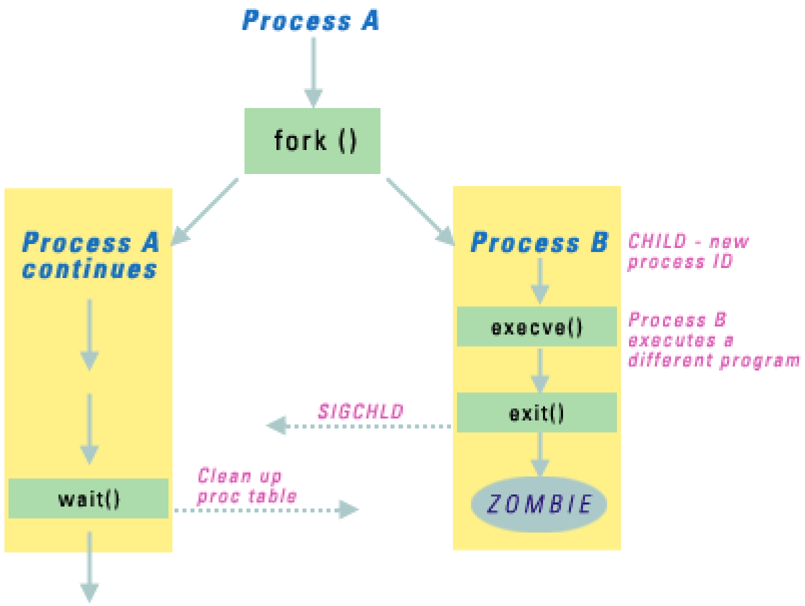


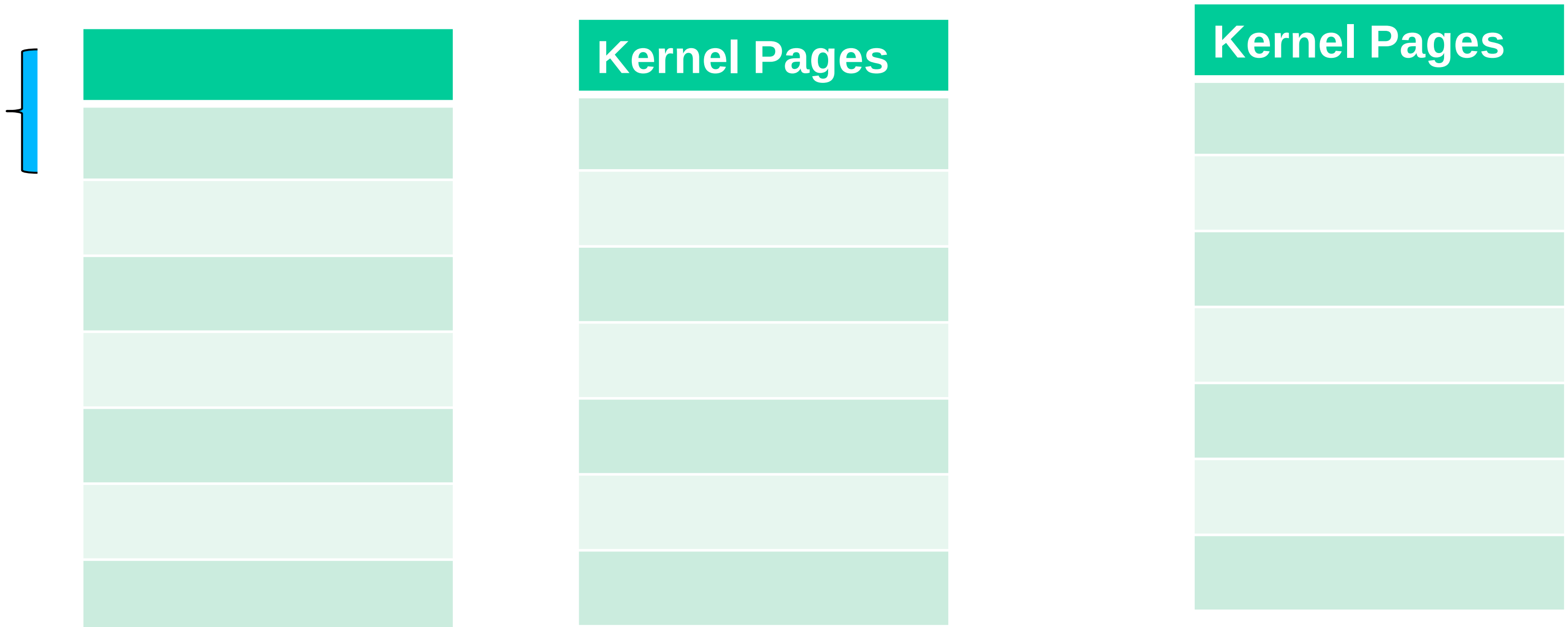


execve



Process A
fork ()
Process A continues
wait()
Clean up proc table
SIGCHLD
Process B
CHILD - new process ID
execve()
Process B executes a different program
exit()
ZOMBIE

Copy-on-Write



Tying it All Together: The Unix Shell

```
while(! EOF) {
read input
handle regular expressions
int pid = fork();           // create a child
if(pid == 0) {              // child continues here
    exec("program", argc, argv0, argv1, ...);
}
else {                      // parent continues here
...
}
```

- Translates <CTRL-C> to the kill() system call with SIGKILL
- Translates <CTRL-Z> to the kill() system call with SIGSTOP
- Allows input-output redirections, pipes, and a lot of other stuff that we will see later