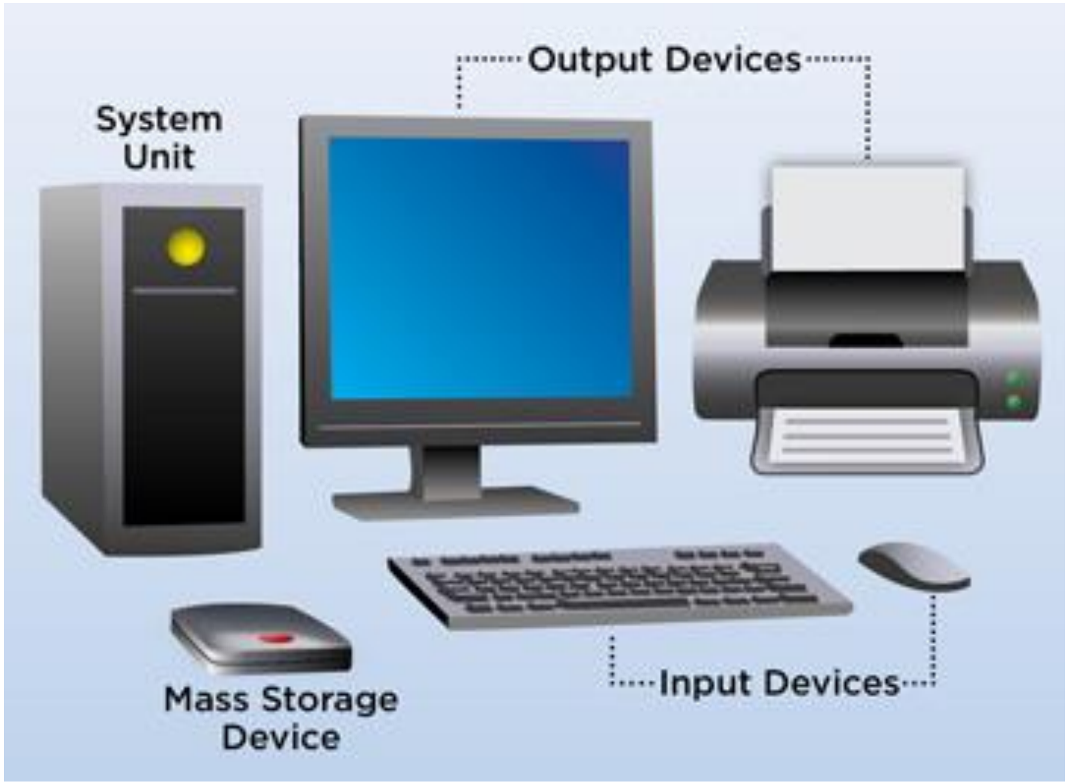
Lecture 1
OS Introduction

Bo Tang @ 2021, Spring

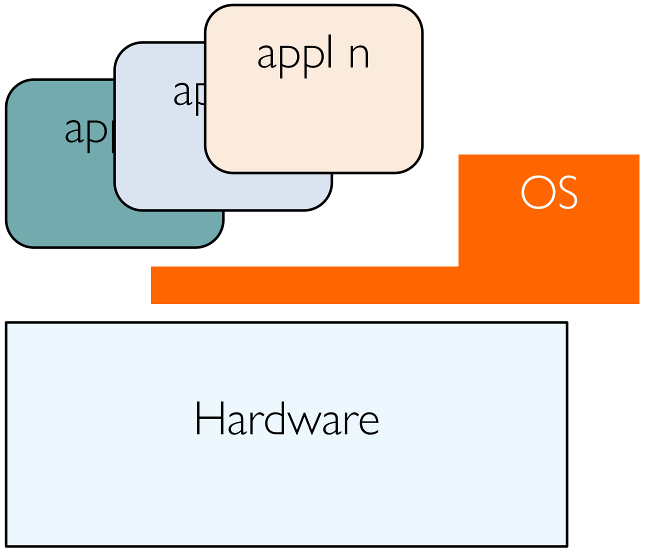
What is a Computer



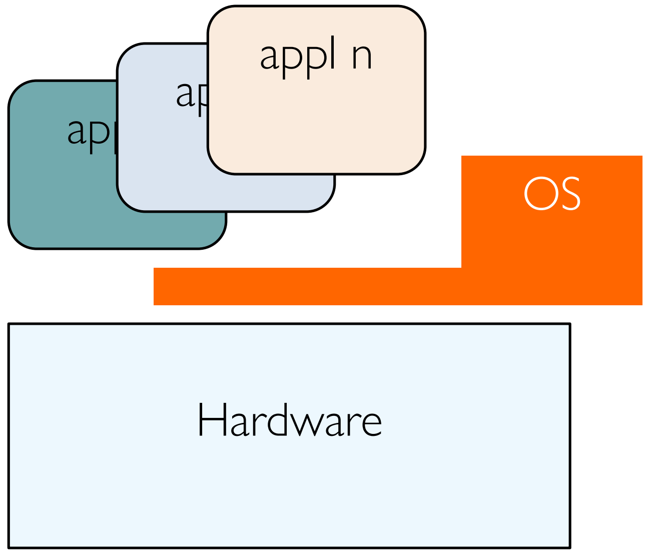
Print “Hello CS302” in a Computer?

How do we do?

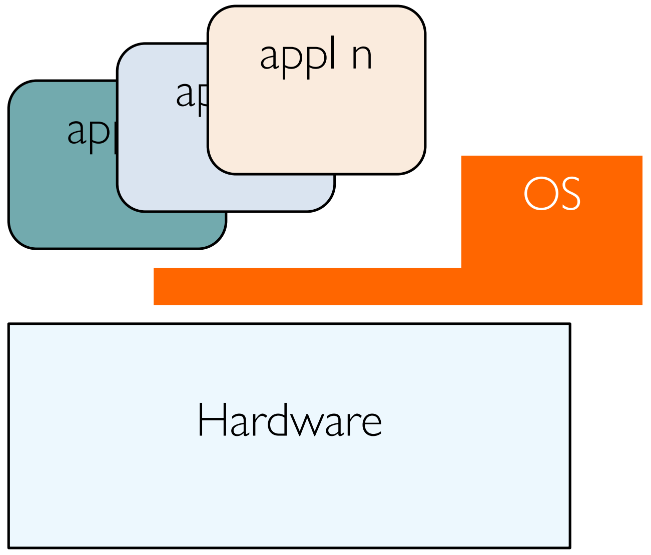
Different Levels of OS course: use it



Different Levels of OS course: play it



Different Levels of OS course: design it



Stanford / CMU OS Course

Learning OS concepts by Coding them

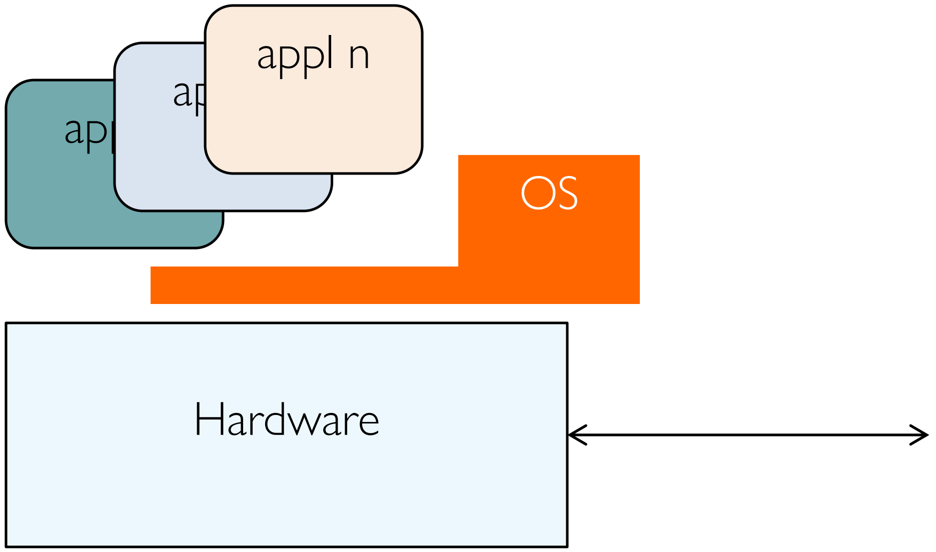
绝知此事要躬行

Our Roadmap

- What is an OS?
- What does an OS do?
- OS basics
- What is a process?
- What is a shell?
- What is a system call ?
- OS components

What is an OS

- Special layer of software that provides application software access to hardware resources:
  - Convenient abstraction of complex hardware device
  - Protected access to shared sources
  - Security and authentication
  - Communication among logical entities

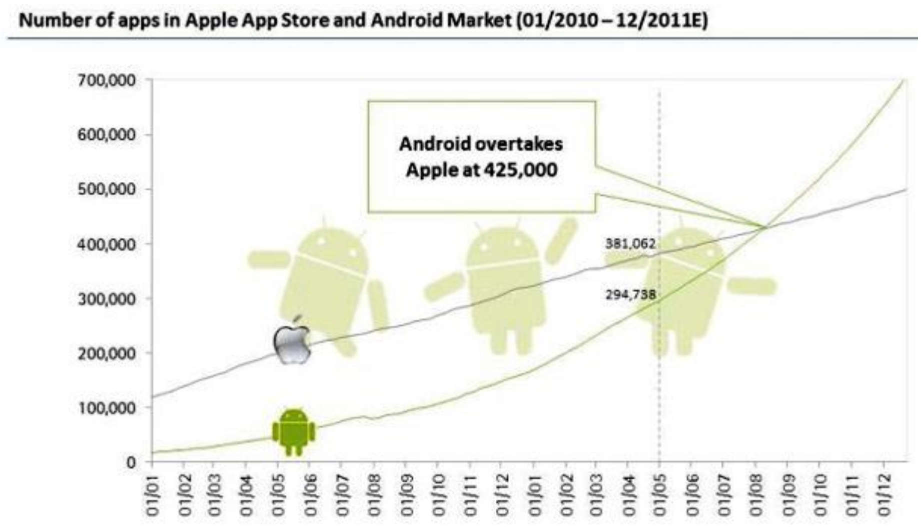


An OS

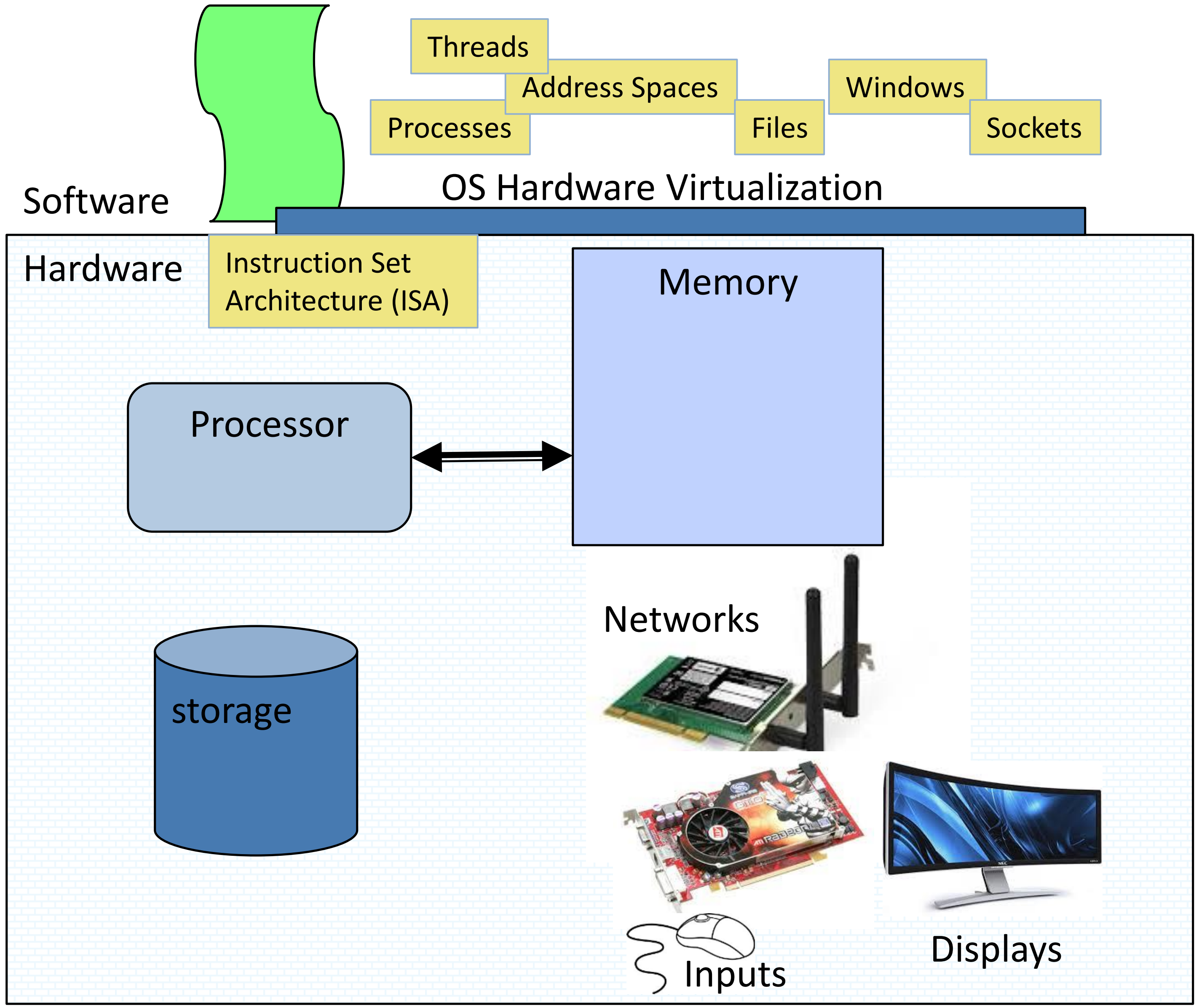
- Includes a program
  - called "**kernel**" (e.g., kernel.exe), which manages all the physical devices (e.g., CPU, RAM and hard disk)
  - exposes some functions as system calls for others to configure the kernel or build things (e.g., C library) on top
- Includes some more programs
  - called "**drivers**", which handles the interaction between the kernel and the external devices (e.g., keyboard)
  - called a "**shell**", which renders a simple command-line user interface with a full set of commands
  - …
- Includes some "optional" programs
  - GUI, Browser, Paintbrush, …

What does an OS do

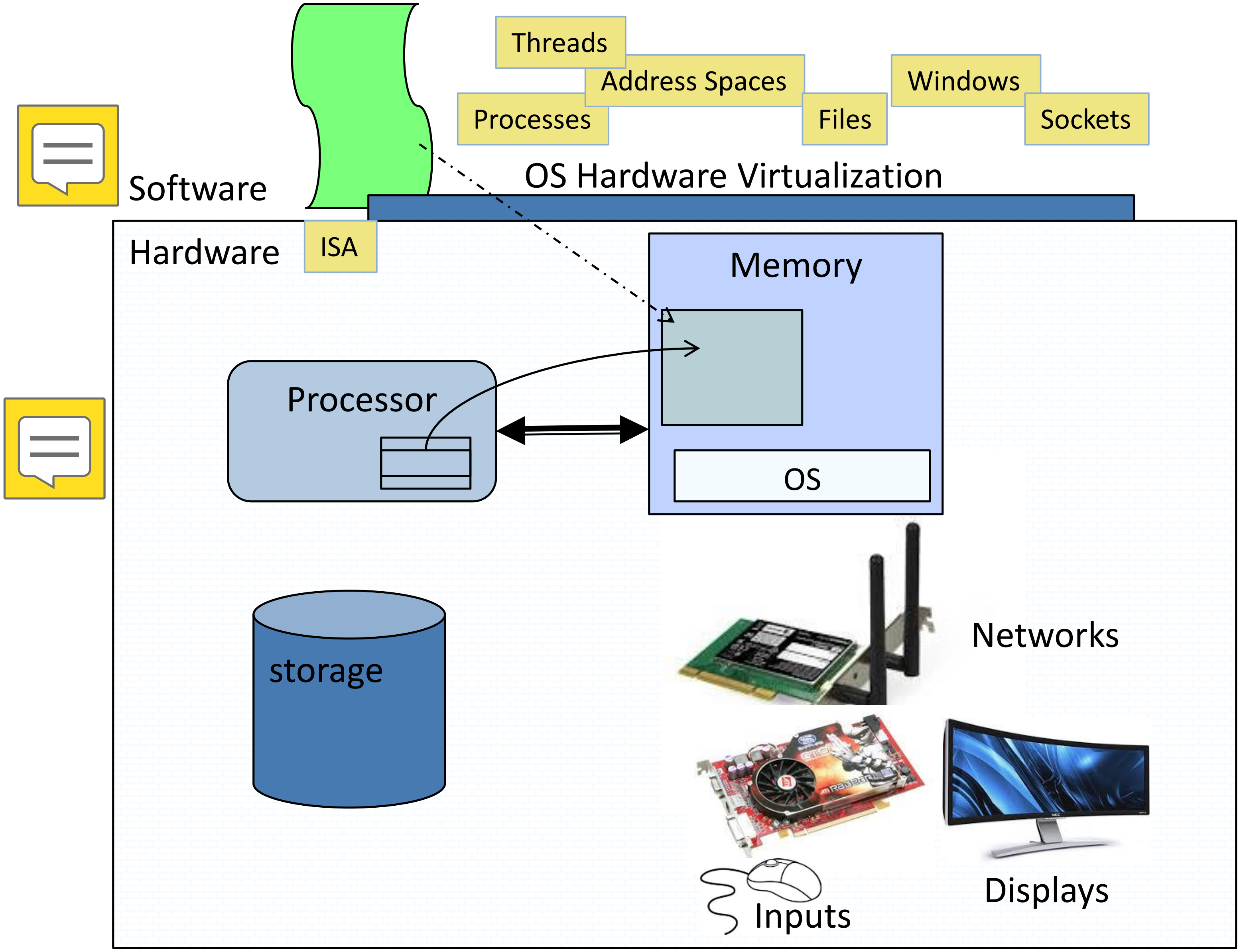
- Provide abstractions to apps
  - File systems
  - Processes, threads
  - VM, containers,
  - …
- Manage resources:
  - Memory, CPU, Storage,
  - …
- Achieves the above by implementing specific algorithms and techniques
  - Scheduling
  - Concurrency
  - …



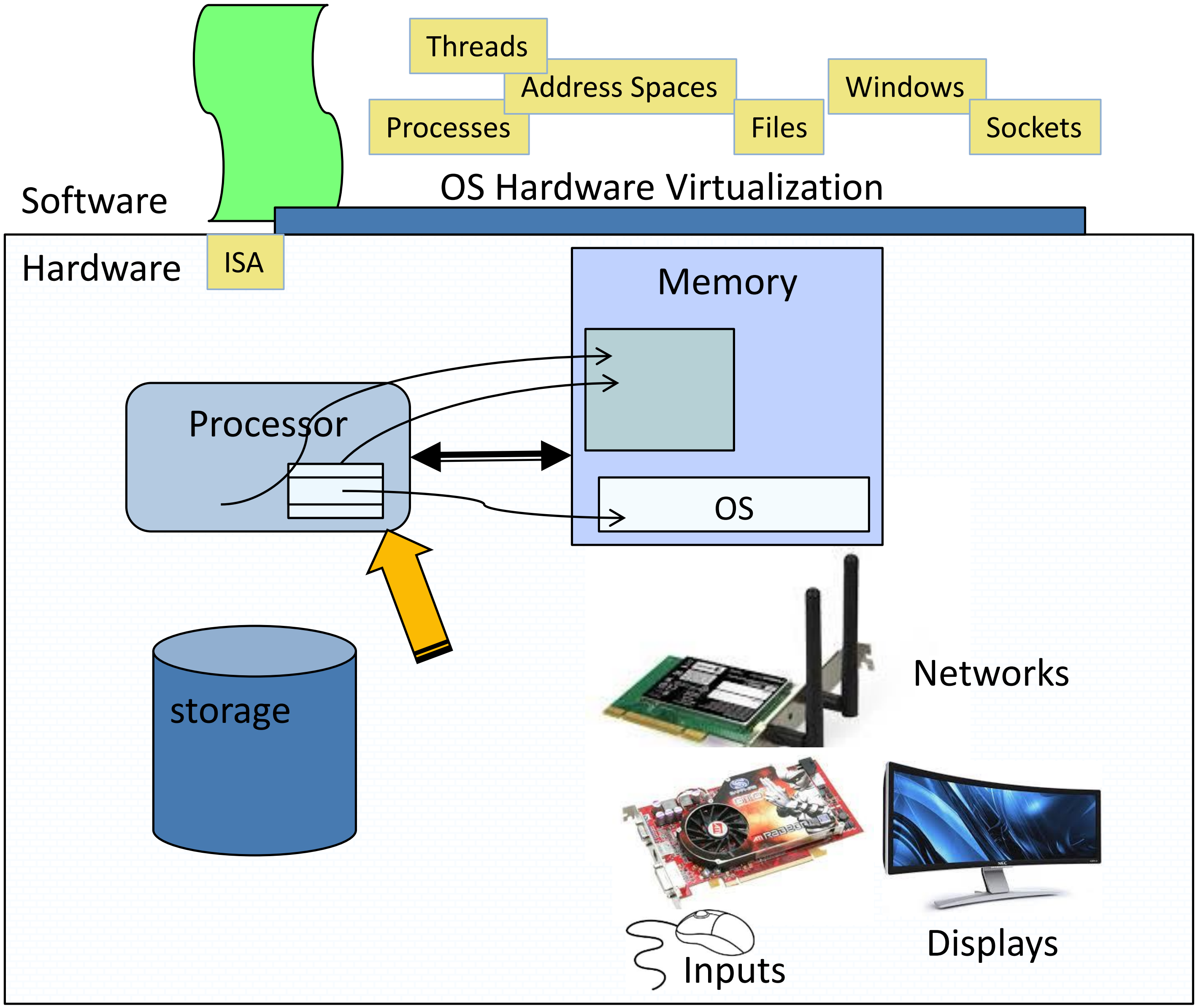
OS basics: "Virtual Machine" Boundary



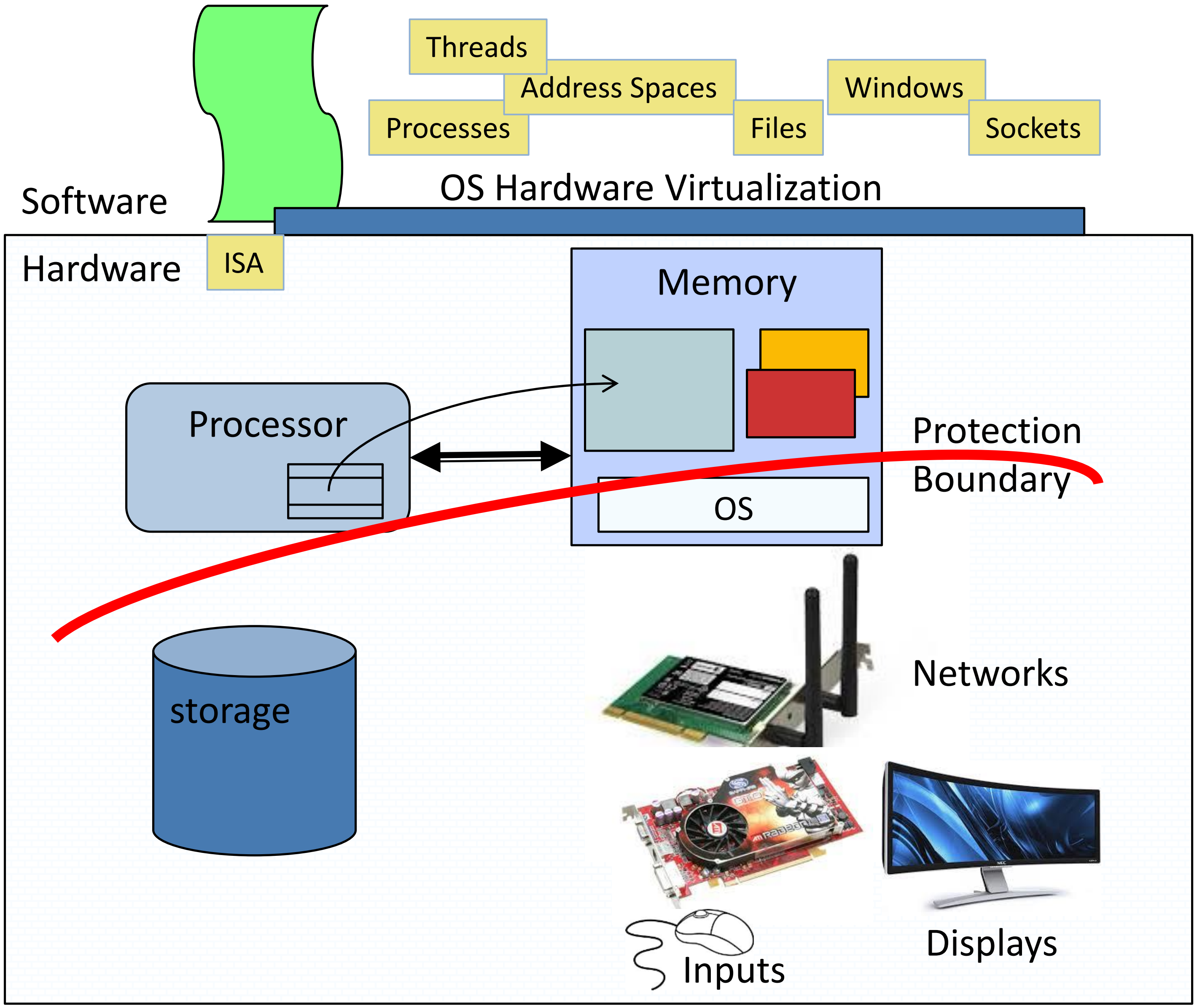
OS basics: Program and Process



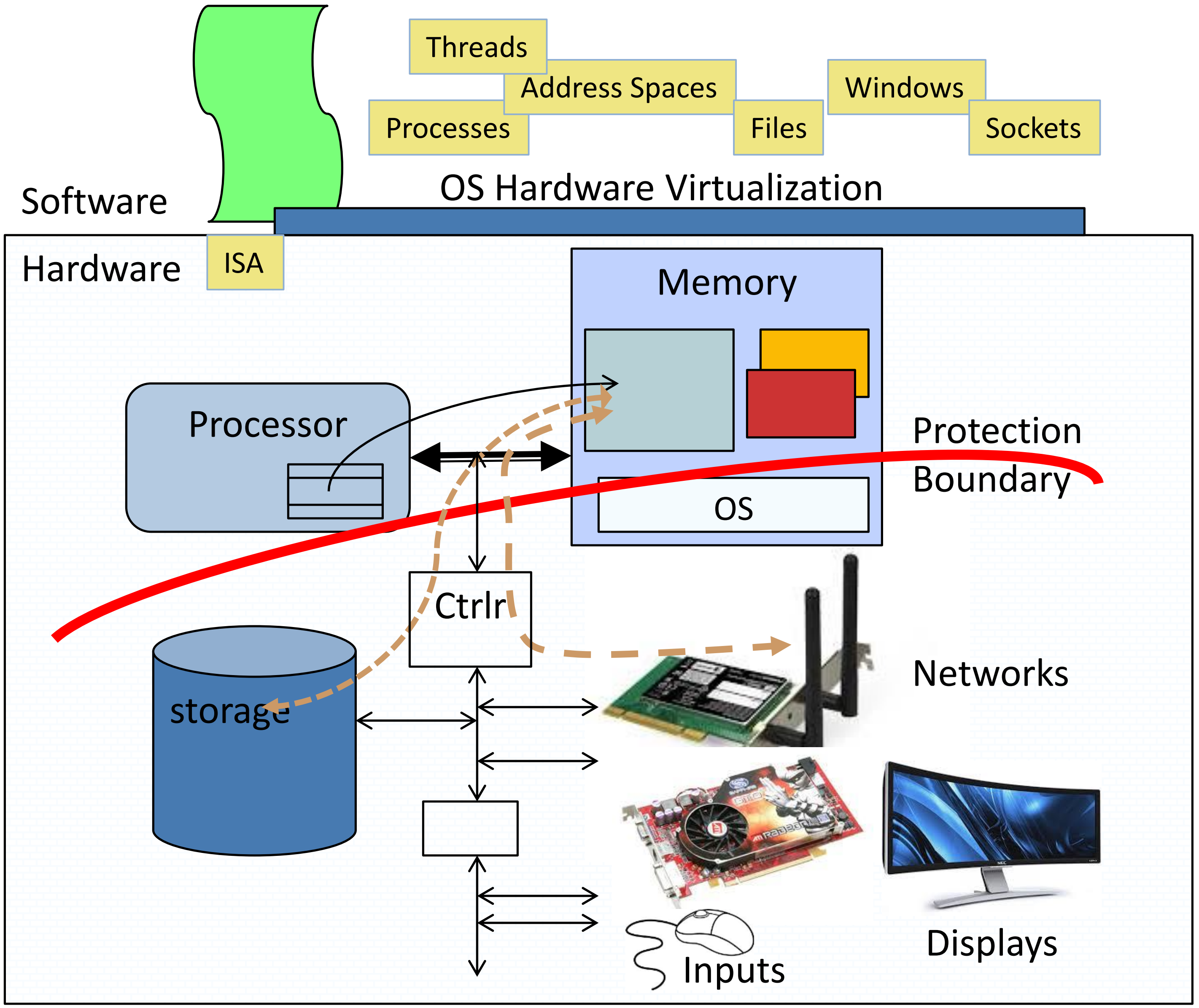
OS basics: Context Switch



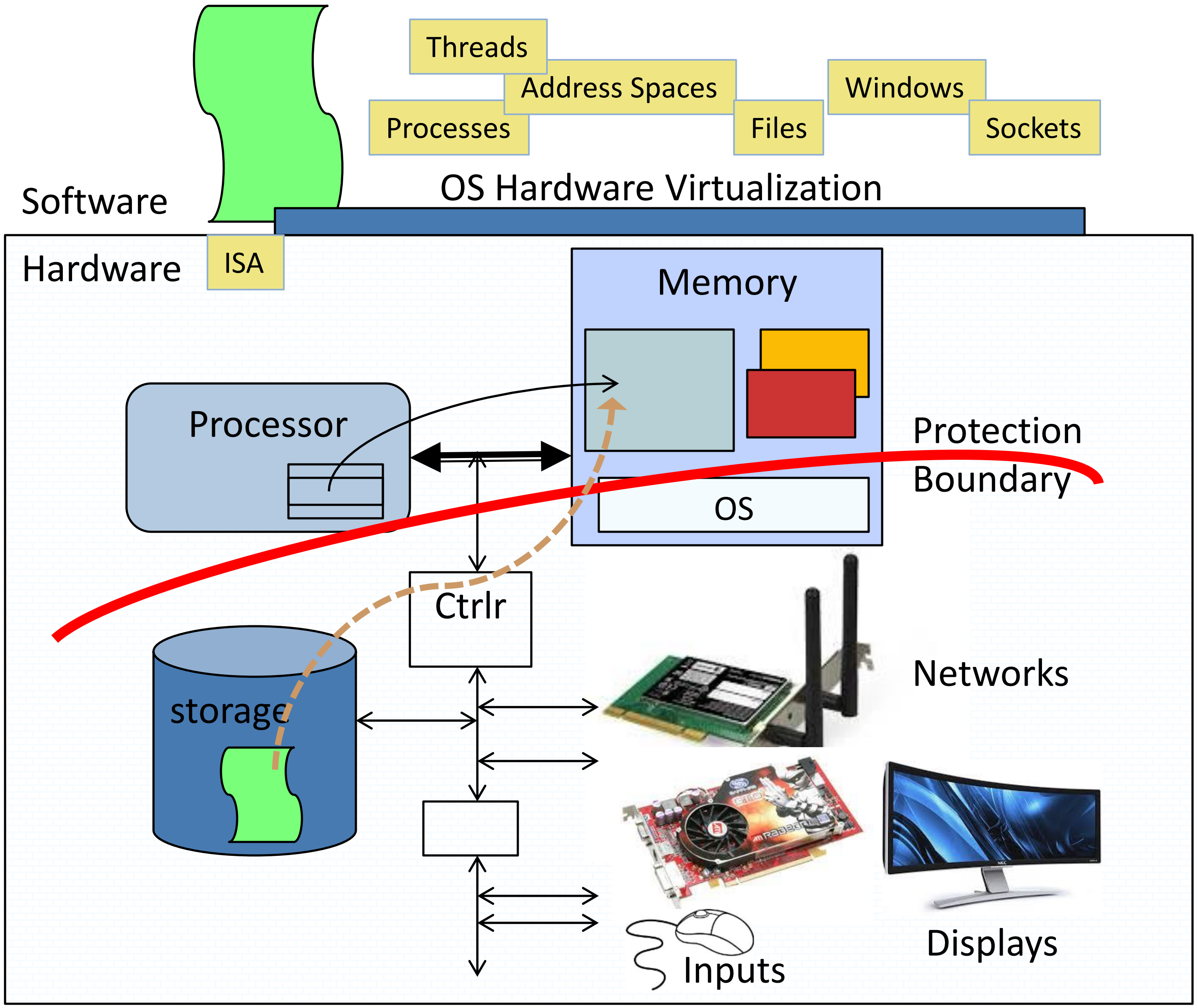
OS basics: Scheduling, Protection



OS basics: IO


Threads
Address Spaces
Windows
Processes
Files
Sockets
Software
OS Hardware Virtualization
Hardware
ISA
Memory
Processor
Protection
Boundary
OS
Ctrlr
storage
Networks
Displays
Inputs

OS basics: loading



What is a process

- A process is an execution instance of a program.
  - More than one process can execute the same program code

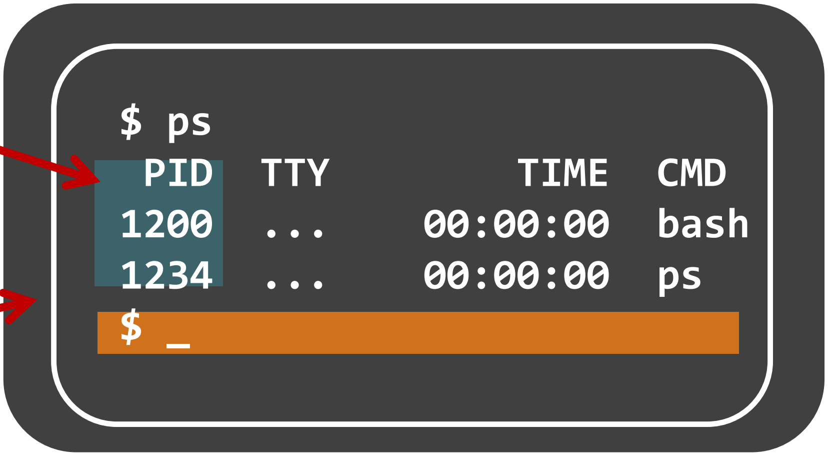
- Consider the following two commands:

Command A	`ls -R /`	Recursively print the directory entries, starting from the directory '/'
Command B	`ls -R /home`	Recursively print the directory entries, starting from the directory '/home'

They are 2 different processes

Process vs. Program

- A process has states concerning the execution. E.g.,
  - Which line of codes it is running
  - How much time left before returning the CPU to others
- Linux commands about processes
  - ps: "process status", it can report a vast amount of information about every process in the system
    - Try "ps -ef"



```
$ ps
  PID  TTY        TIME   CMD
 1200  ...    00:00:00   bash
 1234  ...    00:00:00   ps
$ _
```

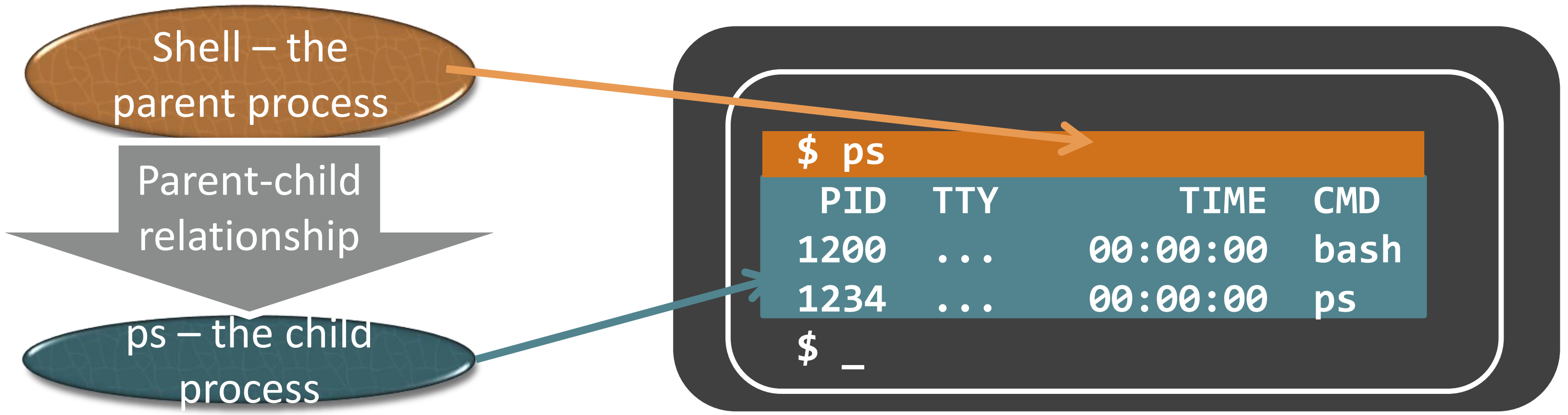
This column shows the unique identification number of a process, called **Process ID**, or PID for short.

By the way, this is called **shell**.

  - top: it allows users to monitor processes and system resource usage on Linux. It is interactive!

What is a Shell?

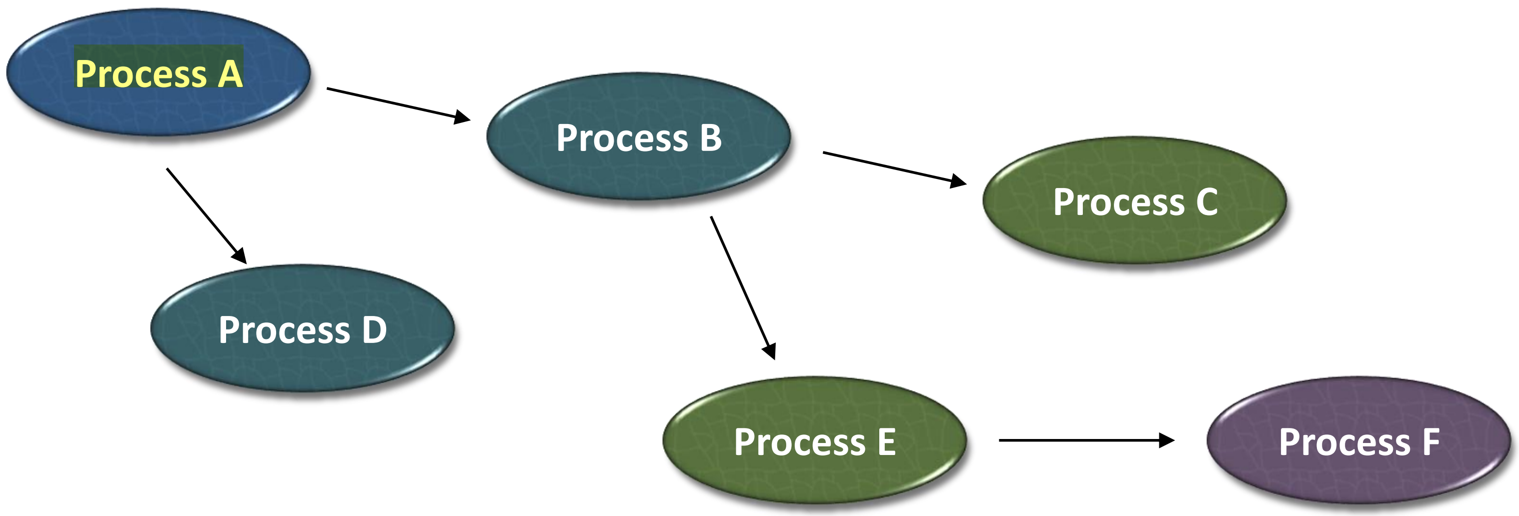
- A shell is a program, you open a "terminal", which actually launches a "shell" process
    - Bash in linux
- Written in C
    - use `getchar()` (to get your command "**ps**")
    - syntax checking
    - invoke a function `fork()` (a **system call**) to create a new process
        - i.e., becoming a **child process** of the shell.
    - Ask the the child process to `exec()` the program "**ps**".



```
$ ps
  PID  TTY         TIME  CMD
 1200  ...     00:00:00  bash
 1234  ...     00:00:00  ps
$ _
```

Process hierarchy

- Process relationship
  - A parent process will have its child processes.
  - Also, a child process will have its child processes.
  - This forms a **tree hierarchy**.



E.g., "Process E" is the shell and "Process F" is "**ps**".

What is a system call?

- System call
  - is a function call.
  - exposed by the **kernel**.
  - abstract away most low-level details.
    - Do you know how to read an input from keyboard?

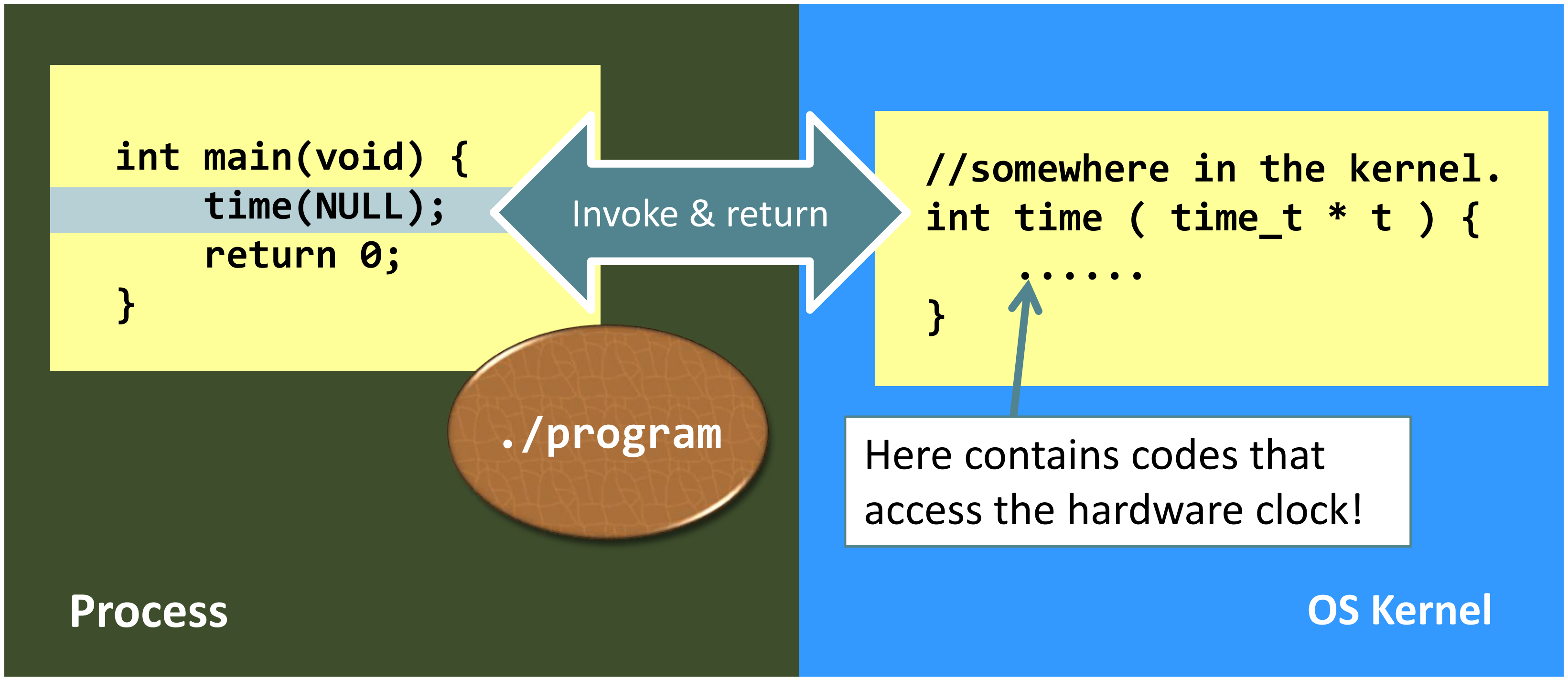
```
int add_function(int a, int b) {
    return (a + b);
}

int main(void) {
   int result;
   result = add_function(a,b);
   return 0;
}

// this is a dummy example…
```

Function implementation.

This is a function call.

Interacting with the OS

How to measure the time cost of your program?



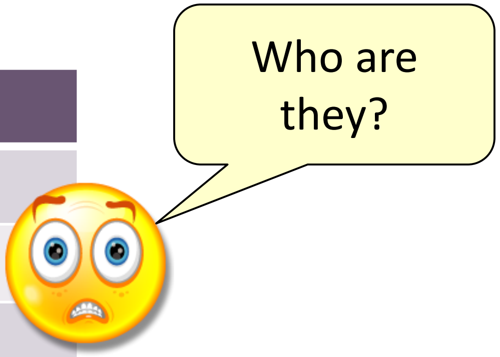
```
int main(void) {
    time(NULL);
    return 0;
}
```

```
//somewhere in the kernel.
int time ( time_t * t ) {
    ......
}
```

System calls

- Categorizing system calls:
  - Process, File system, Memory, Security, Device
- How can we know if a “function” is a system call
  - Read the man page “syscalls” under linux
- Pop quiz
  - Which of the following is/ are system call(s)?

Name	Yes/No?
`printf() & scanf()`	No
`malloc() & free()`	No
`fopen() & fclose()`	No
`mkdir() & rmdir()`	Yes
`chown() & chmod()`	Yes

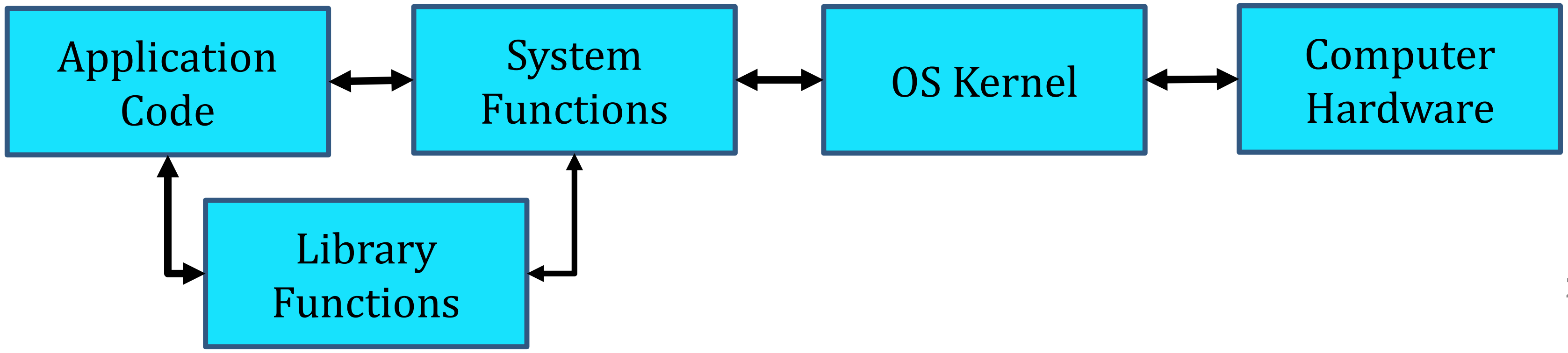


System calls VS Library function calls

- Take **fopen()** as an example.
  - **fopen()** invokes the system call **open()**.
  - So, why people invented **fopen()**?
  - Because **open()** is too primitive and is not programmer-friendly!

Library call	`fopen(“hello.txt”, “w”);`
System call	`open(“hello.txt”, O_WRONLY | O_CREAT | O_TRUNC, 0666);`

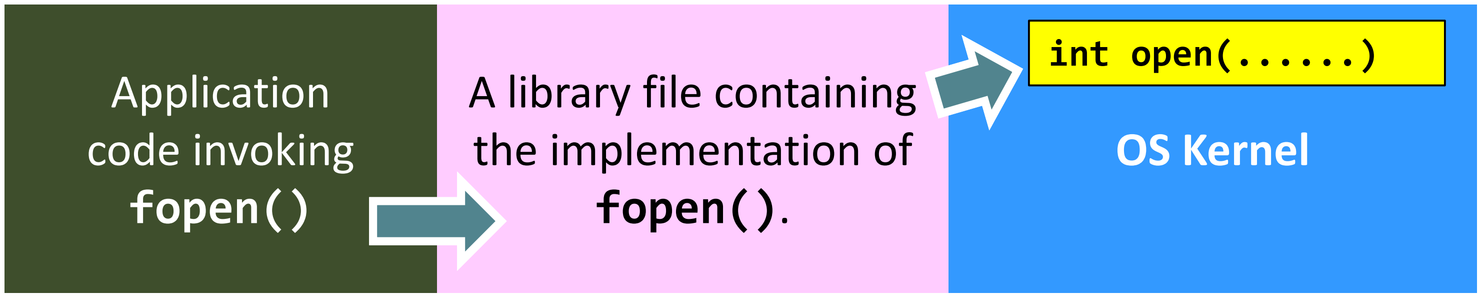
- Function calls:



System calls VS Library function calls

- Library functions are usually compiled and packed inside an object called the **library file.**
  - In Windows: .DLL – dynamically linked library.
  - In Linux: .SO – shared objects.

- Big picture:

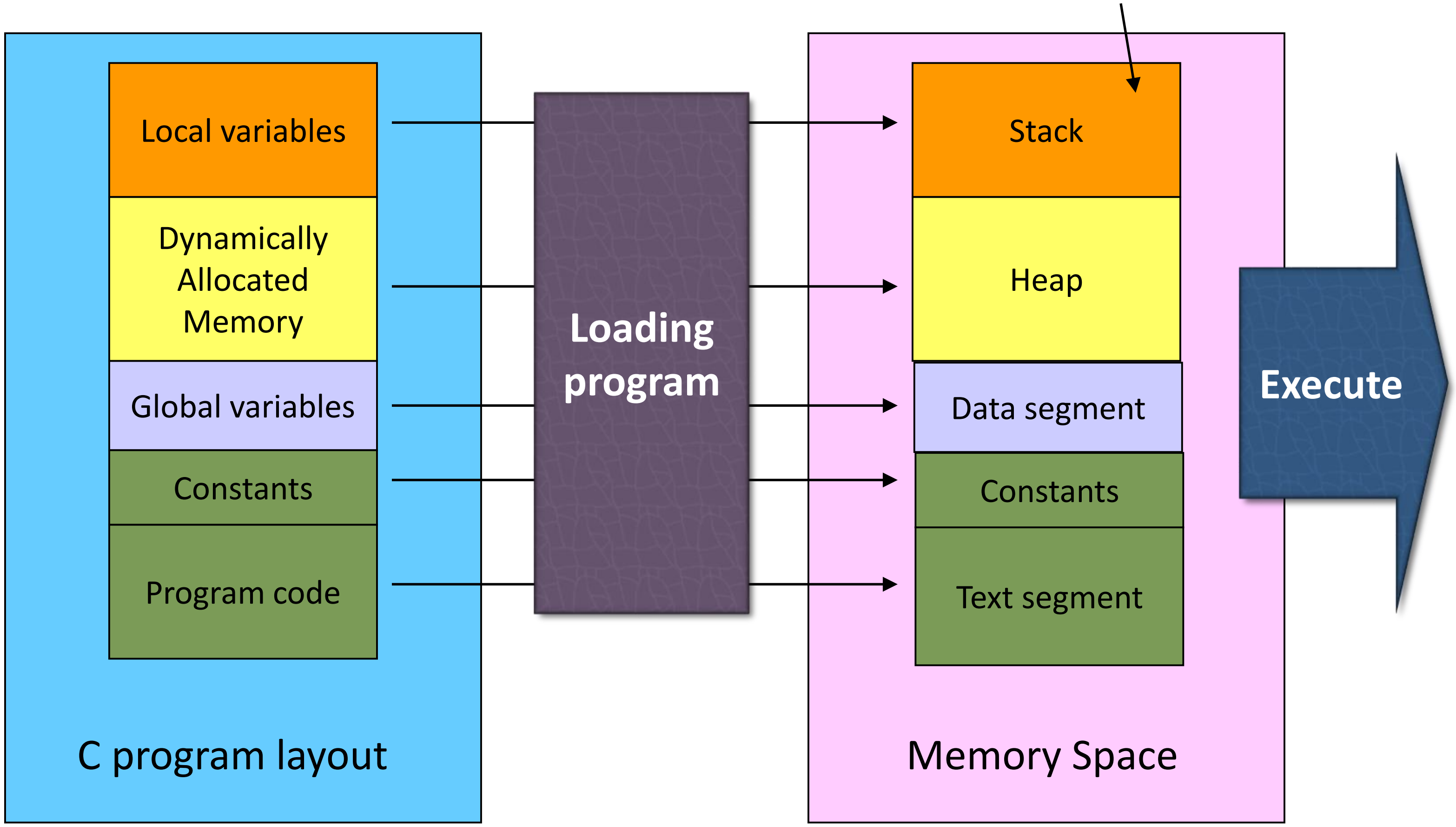

Application code invoking **fopen()**
A library file containing the implementation of **fopen()**.
int open(......)
OS Kernel

What will we learn about Process

- System calls
  - How to program a simple, bare-bone shell?
- Lifecycle and Scheduling
  - How to create processes?
  - How to handle the death of the processes?
  - Which process shall get the core next?
- Signals
  - How to suspend a process?
  - A virus? We can make a program to play a song whenever you type **Ctrl+C**?
- Synchronization
  - How processes can cooperate to do useful work together?

The Memory of a Process

BTW, this arrangement is called s_ _ _ _ _ _ _ _ _ _ _ _ _!

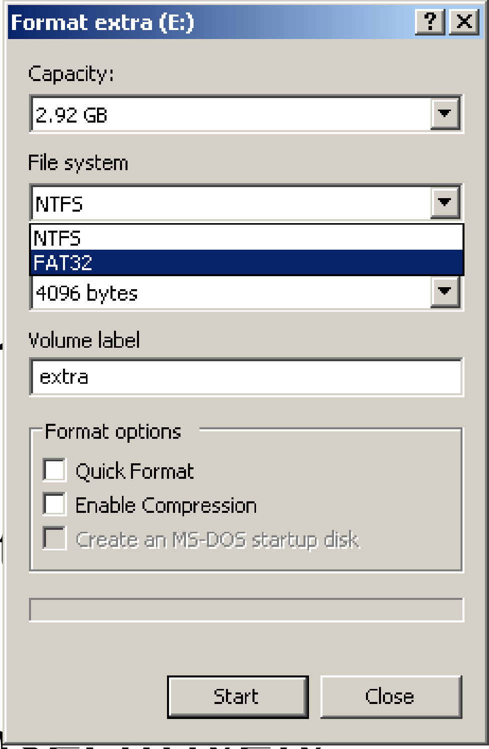


What will we learn about Memory

- Virtual memory
  - Your process virtually owns all your machine’s RAM
- Memory-related functions
  - E.g., how to write “**`malloc()`**”?
- Stack overflow
  - Why & when?
- RAM = 256MB
  - **`malloc(16MB)`**
  - How much free memory left?

File System

- Have you heard of…
  - FAT16, FAT32, NTFS, Ext3, Ext4, BtrFS, Juliet
  - They are all file systems.
  - It is about how to organize your files in the s



Format extra (E:)

Capacity: 2.92 GB

File system: NTFS

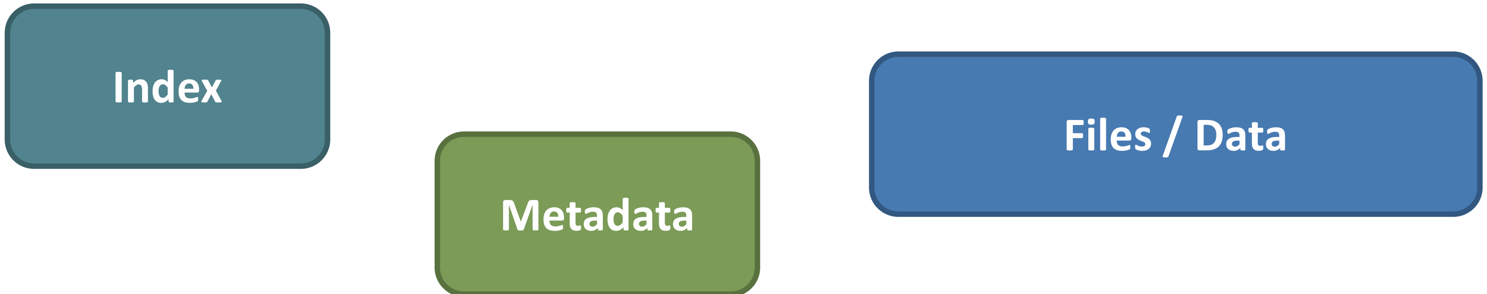
NTFS
FAT32

4096 bytes

Volume label: extra

Format options
- [ ] Quick Format
- [ ] Enable Compression
- [ ] Create an MS-DOS startup disk

- If a FS just lays your files one-by-one, consecutively, tightly, in your hard disk, is it good?
  - What if you increase the size of your file?
  - What's the performance of searching for a file? O(?)
  - BTW, how to deal with directories?



FS vs OS

- Each disk can have multiple FSs
- An OS may understand different FSs

Windows XP supports	Linux supports
NTFS, FAT32, FAT16, ISO9660, CIFS	NTFS, FAT32, FAT16, ISO9660, CIFS, Ext2, Ext3, etc…

Linux supports far more FS-es than any versions of Windows

What will we learn about File System

- How to deal with directories?
- Implementation of some famous FS-es.
- Why does a file system perform badly?
- How to undelete a file?

More…

- Form programmer to a system programmer
- From system programming to programming a operating system
  - Multi-threading
  - Booting
  - Architectural Conscious OS programming
  - Lock-free programming
  - I/O
  - Virtualization

Thank You!