Process Abstraction

2023-24 COMP3230A

Contents

- What is a “process”?
- How to represent a “process”?
  - Resources use by a process
  - Process states
- Important data structures
- Operations on processes

Learning Outcome

- ILO 2a - explain how OS manages processes/threads and discuss the mechanisms and policies in efficiently sharing of CPU resources.

Reading & Reference

- Required Reading
  - Operating Systems: Three Easy Pieces by Arpaci-Dusseau et. al
    - Chapter 4, Abstraction: The Process
      - http://pages.cs.wisc.edu/~remzi/OSTEP/cpu-intro.pdf
    - Chapter 5, Interlude: Process API
      - http://pages.cs.wisc.edu/~remzi/OSTEP/cpu-api.pdf

- Reference
  - Chapter 3 of Operating Systems, 3rd edition by Deitel et. al

Process vs. Program

- Program itself is a lifeless thing

- What is a Process?
  - A process is a program in execution
    - **An instance** of a program running in a computer

  - A process is an entity that can be assigned to and executed on a CPU

  - A unit of activity characterized by
    - the execution of a sequence of instructions,
    - with an execution state, and
    - an associated set of system resources

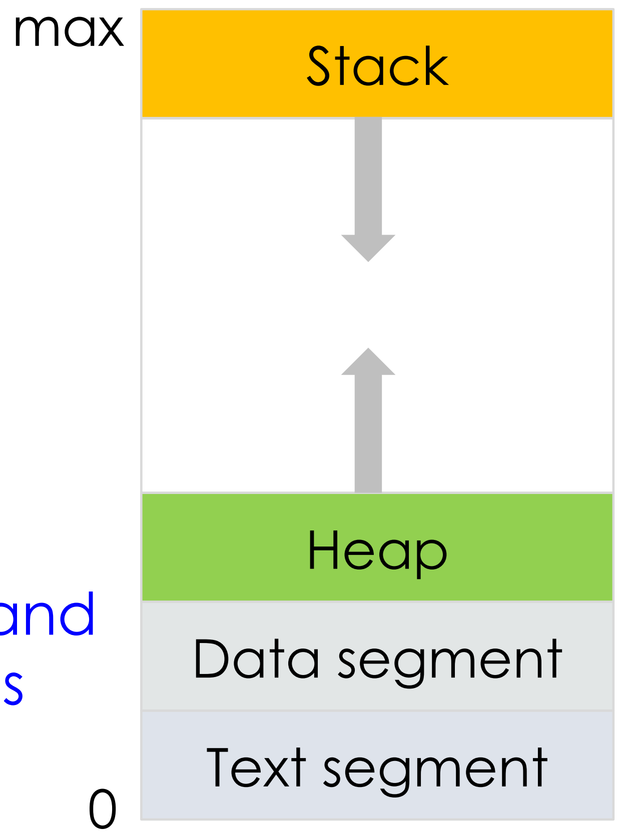
Process – an abstraction

- To represent a running program, the OS needs to keep track of the following information:

		Examples
The memory that the process can access (or reference) is part of the process	Memory	Program code Data
	Resources in use	I/O in use Physical memory
During execution, process updates/ stores data in CPU registers, e.g., program counter, stack pointer, etc.	Execution state	Register set Current process state

Process – Address Space

- The process's view of its memory is called the **address space**, which is a range of memory locations (or a range of memory addresses)
- Process address space consisting of a few "regions":



Stores local variables, arguments to function, return value for active procedure calls

Where dynamically allocated memory is placed

Stores global and static variables

Stores the program code that the processor executes

Process – Process States

- In the process execution life cycle, it moves through a series of discrete process states.

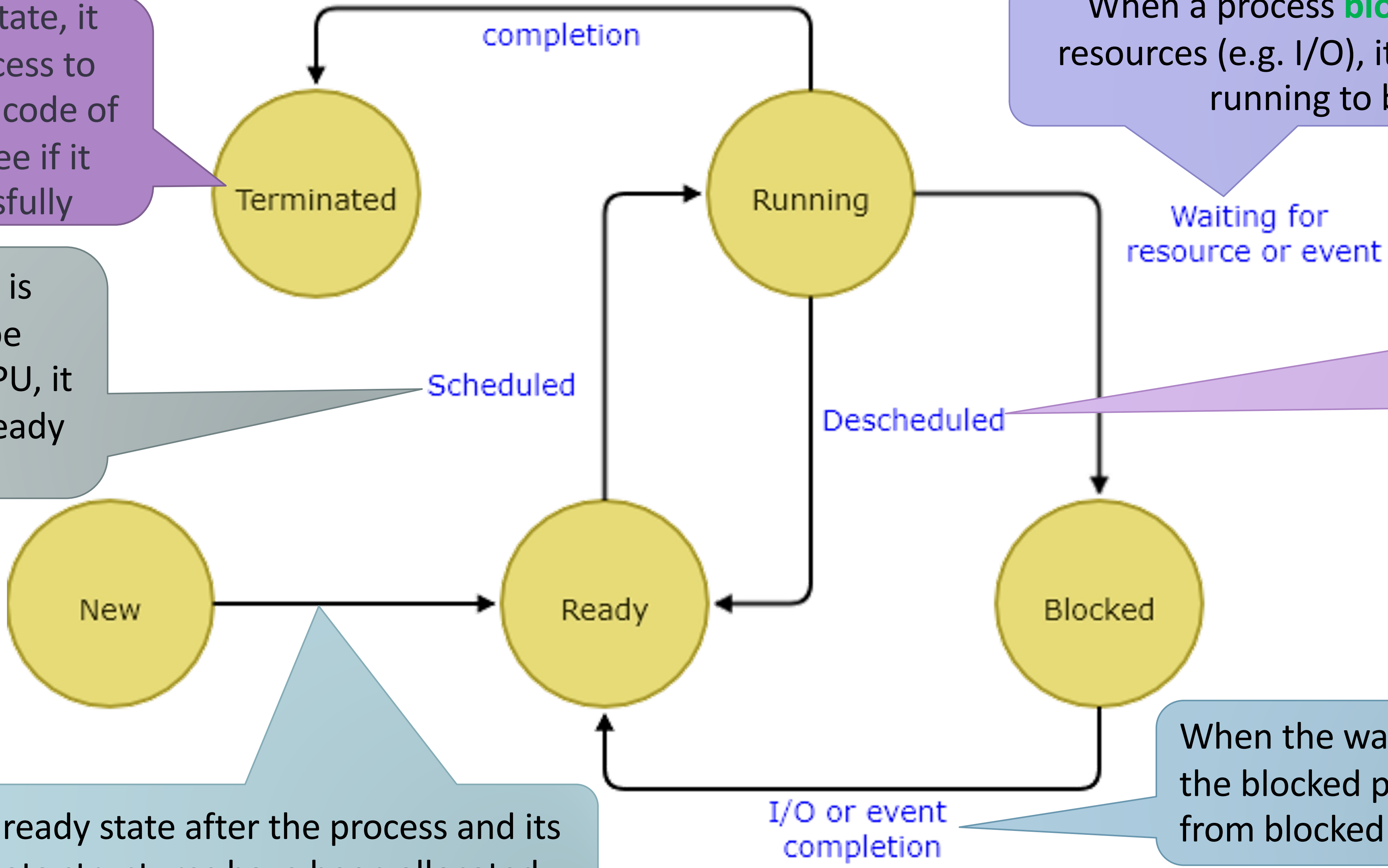
- Process state - an indicator of the nature of the current activity of a process
  - **new (initial)**: The process is just being created
  - **running**: The process is executing on a processor
  - **blocked**: The process is **waiting for** some event (e.g., I/O or communication) to happen before it can proceed
  - **ready**: The process **is ready to run** on a processor and **is waiting** to be assigned to a processor
  - **terminated (final / zombie)**: The process has finished execution but has not yet been cleaned up; *why not just discard it?*

Life Cycle of a Process

With terminated state, it allows parent process to examine the return code of the process and see if it executed successfully

When a process is dispatched to be executed by the CPU, it transitions from ready to running

When a process **blocks waiting** for resources (e.g. I/O), it transitions from running to blocked



OS decides to switch a process from running to ready

When the waiting event occurred, the blocked process transitions from blocked to ready

Switch to the ready state after the process and its associated data structures have been allocated

Process Control Block

- To manage a process, OS makes use of a **data structure** to maintain information about a process
  - Process Control Block (**PCB**) or Process Descriptor

- PCB typically includes
  - Process identification number (PID) - **a unique ID**
  - Current **process state**
  - Program counter - indicates the address of **next** instruction
  - **Register context** - a snapshot of the register contents in which the process was last running before it **transitioned** out of the running state
  - Scheduling information - process priority, pointers to scheduling queues, etc.

Process Control Block (2)

- Credentials - determines the resources this process can access
- Memory Management information - concerning memory areas allocated to the process
- Accounting information - CPU usage statistics, time limits, etc.
- A pointer to the process's parent process
- Pointers to the process's child processes
- Pointers to allocated resources

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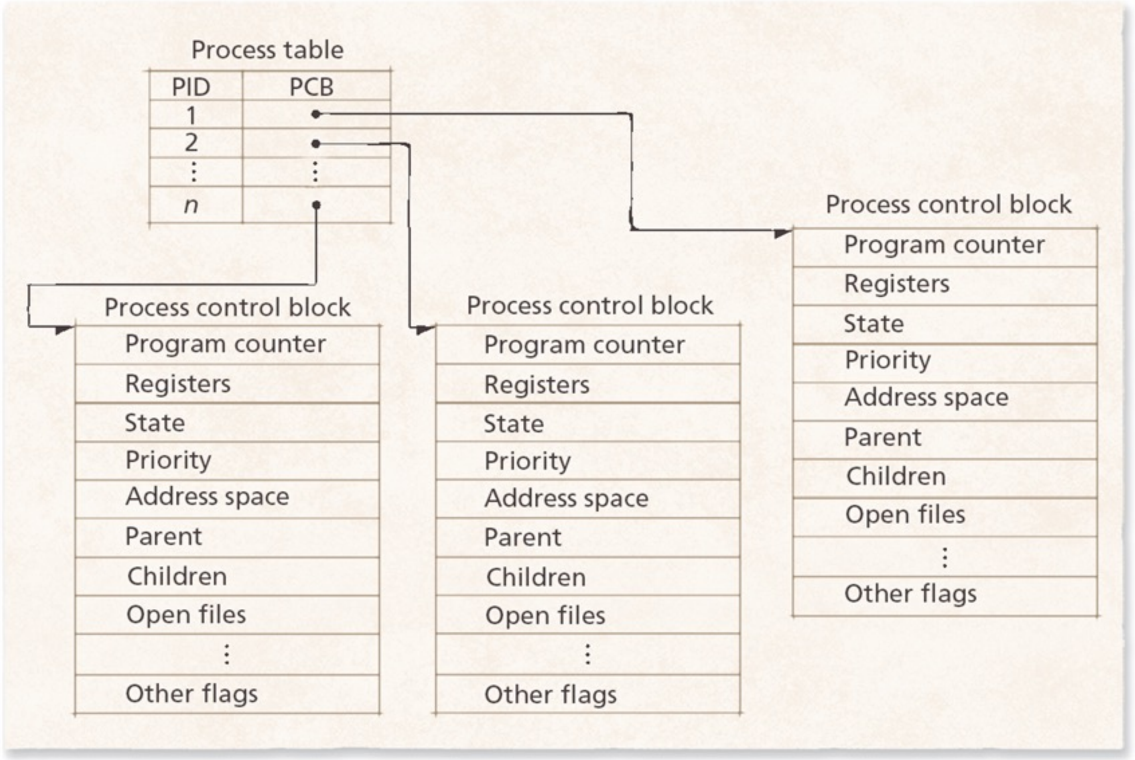
Example: Linux process descriptor
struct *task_struct*
in /usr/src/linux/include/linux/sched.h
at around 450 lines of statements

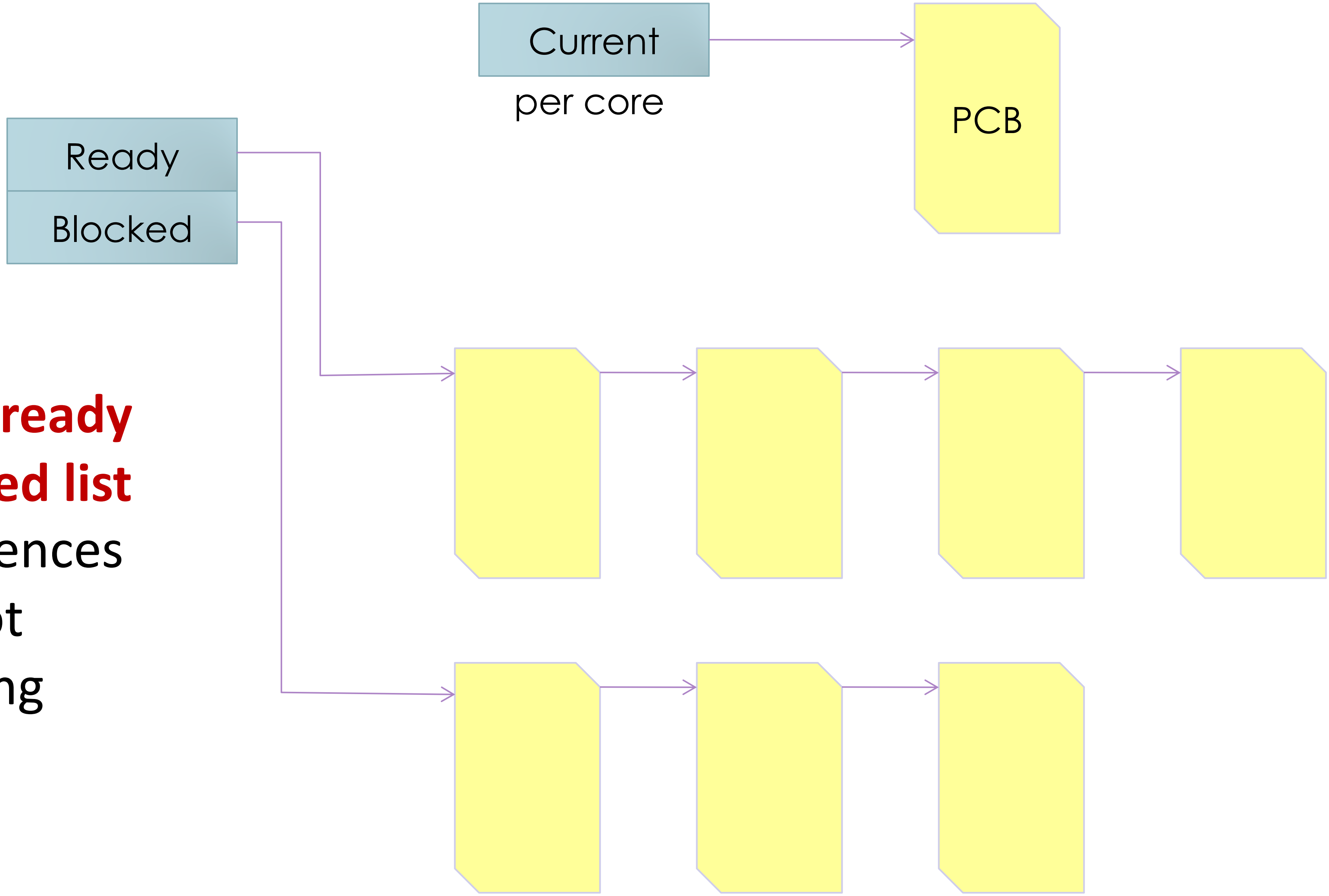
Process Table

- To manage many processes, OS needs someway to **quickly access** process's PCB



- OS keeps pointers to each process's PCB in a table
  - Example - Linux "process table" is organized in a form of hashed table
- When a process is "completely" terminated, OS removes the process from the process table and frees all of the process's resources

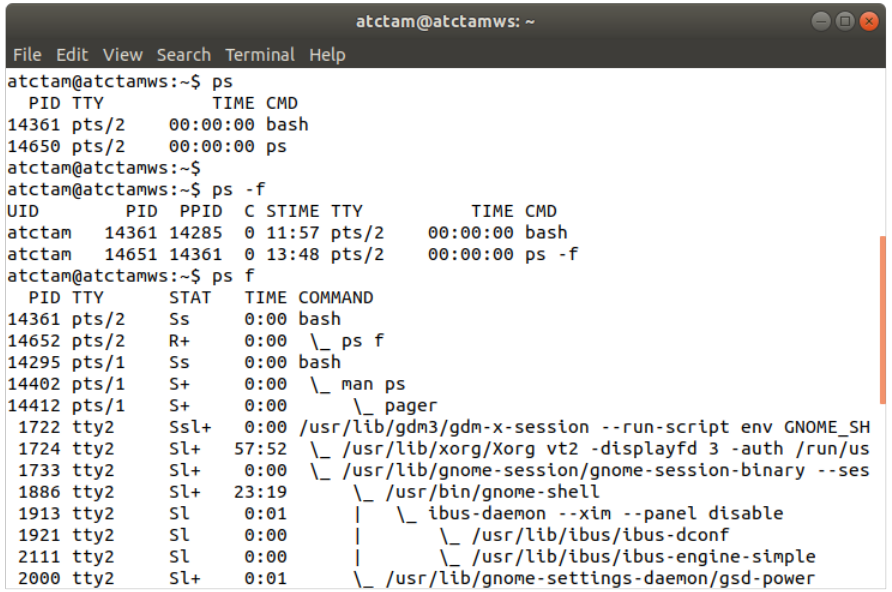
Process List Structures



OS maintains a **ready list** and a **blocked list** that store references to processes not currently running

ps - Show Processes information

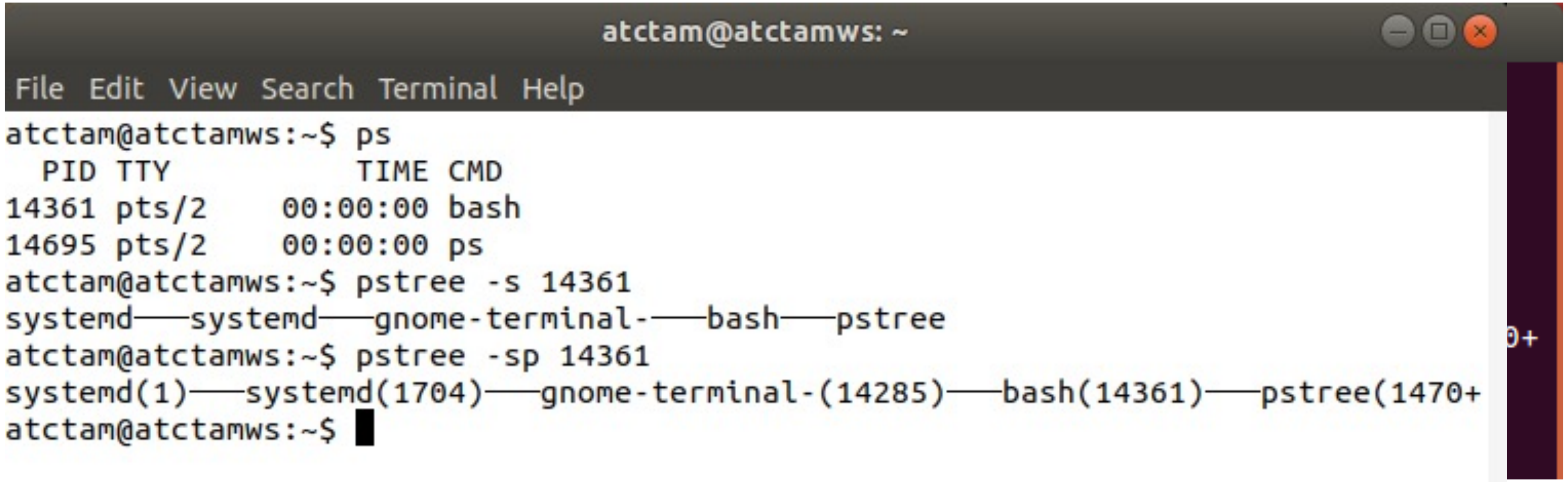
- You can list the processes' details in Linux/Mac OS X by using *ps* command
- Usage: ps [option]
  - When executed without any options, only processes that are associated with the current terminal are shown.
- Use man-page to learn how to use
- Some Useful options (Linux)
  - -e: Select all processes
  - -f: Show in full format
  - w: Wide output
  - f: ASCII-art process hierarchy (forest)



pstree - Show the relations between processes

- A Linux system program similar to *ps*
  - Processes are organized in hierarchy
    - As every process has a parent process, their relationship can be viewed by using *pstree*

- Usage: *pstree* [option]
  - Use man-page to learn how to use
  - Example:



Operations on Processes

- Operating systems provide fundamental services to processes including:
  - Creating processes
  - Destroying processes
  - Suspending processes
  - Resuming processes
  - Changing process's priority (for scheduling)
  - Waiting for a process (parent process waits for the child process)
  - Check process's status
  - Interprocess communication (IPC)

    :

How to create a new process?

- A process spawns a new process
  - The process that creates a new process is now called the **parent** process
  - The newly created process is called the **child** process
    - It also can create other processes, thus forming a tree of processes

  - When the parent process is destroyed, modern operating systems typically responds in this way
    - Keeps the child processes and allows them to proceed independently of the terminated parent process

Creating process

- Actions taken
  - Assign a unique process ID
  - Allocate memory for the process
    - Space for PCB must be allocated

- Initialize the process control block
  - Save the process ID, parent ID
  - Set program counter and stack pointer to appropriate values

- Set links so it is in the appropriate queue
- Create other data structures
  - Memory, files, accounting

- Set the process state to Ready and put it to the Ready queue

How to Create a Process

- Unix
  - fork() system function
    - A system call that **creates** a new process by **duplicating** the calling process
  - exec () family of functions
    - OS replaces the current program image with a new program image

- Windows API
  - CreateProcess() function
    - Creates a new process and its primary thread and loads program for execution
    - http://msdn.microsoft.com/en-us/library/ms682512(VS.85).aspx
  - CreateProcess() similar to fork() + exec ()

- Question: Why such a design of separate fork() and exec()?

Process Termination

- Process executes last statement and asks the operating system to delete itself
  - exit() or return from main()
- A process may terminate **involuntarily**
  - Parent may terminate execution of children processes (by sending a termination **signal**)
  - A number of **error and fault** conditions can lead to termination of process
- Return termination status from child to parent
  - Parent can obtain this info by calling wait(), waitid() or waitpid()
  - Process' resources are **de-allocated** by OS **afterward**

Zombie Process (UNIX)

- A process is in terminated state
  - When a process exits, OS still **keeps** the PCB of the process, so that the **parent can get** the information later
    - exit status
    - resource usage
  - **Before** the parent process collects the information by calling wait() or waitpid(), the deceased process is kept in the Terminated state, and we called it as the "zombie" process

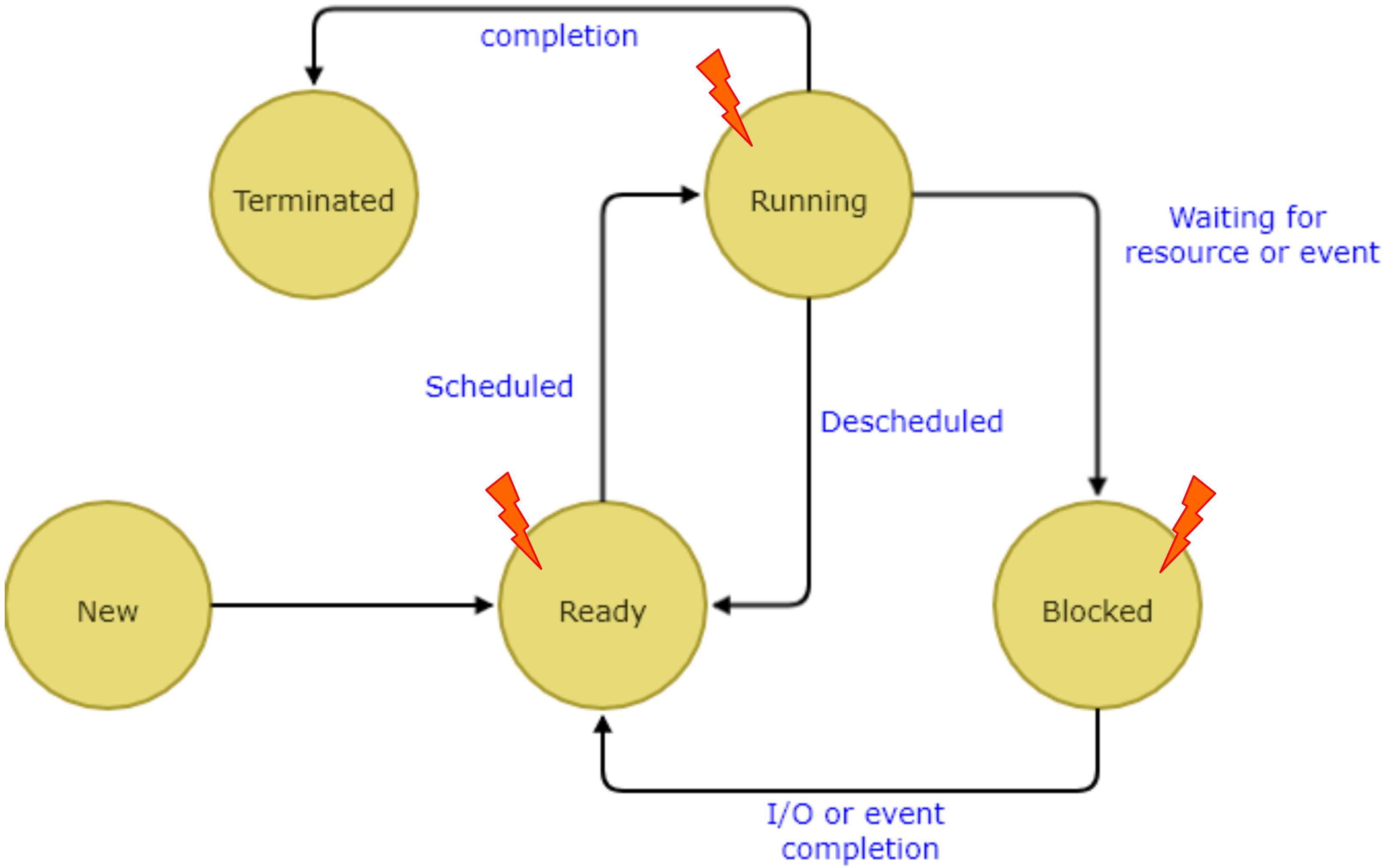
Suspending a Process

- Temporarily deactivate the process, such that it is not being considered for processor scheduling
- Why doing so:
  - Upon user request
  - Request by the parent process
  - OS may decide to suspend a **blocked** process so as to free up the memory for another ready process

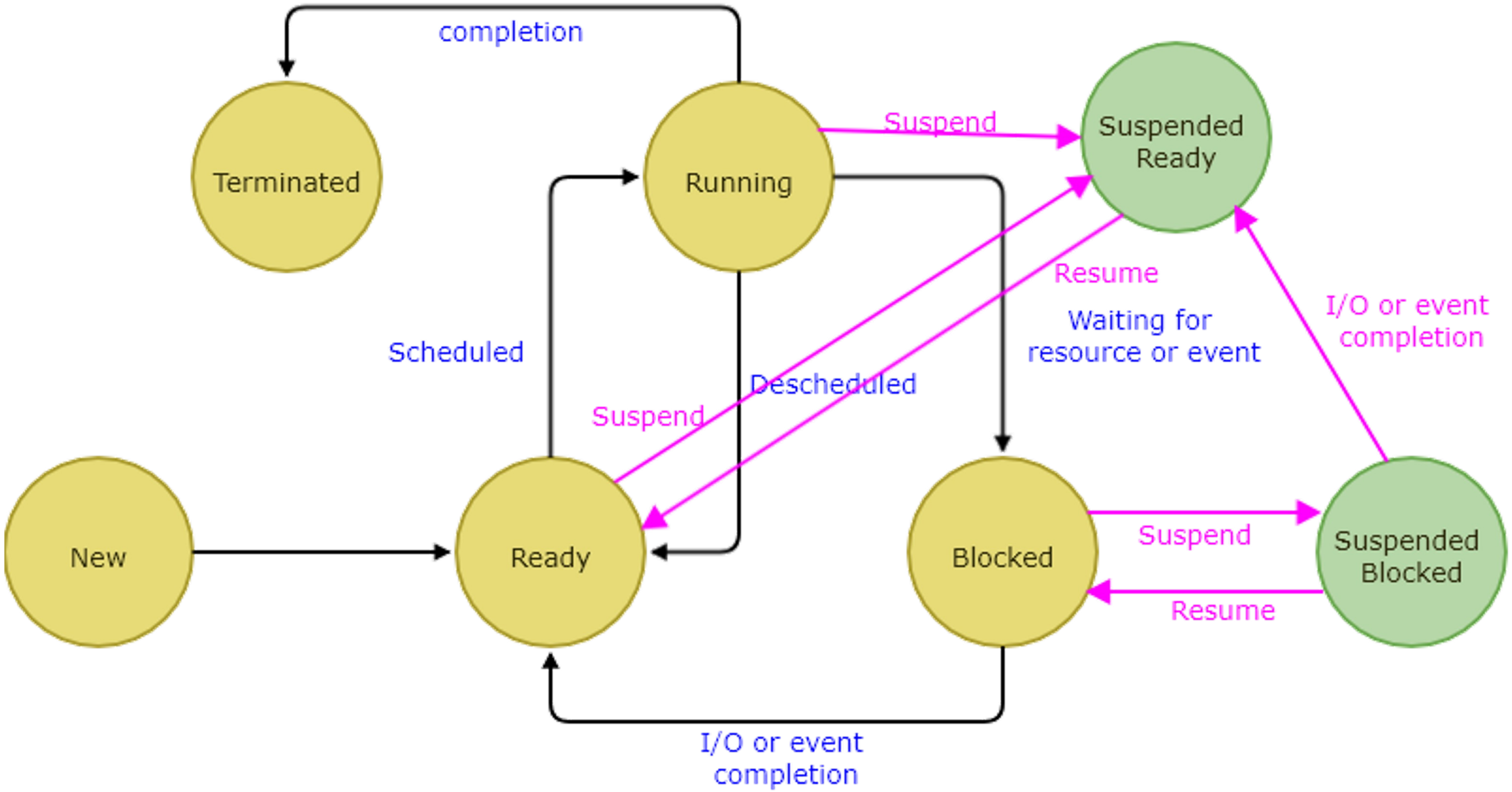
- A suspended process **must be** resumed by another process

- Difference between suspension and blocked
  - blocking is triggered by internal activity of the process, while suspend is coming from **external**

Suspending a Process



Suspending a Process

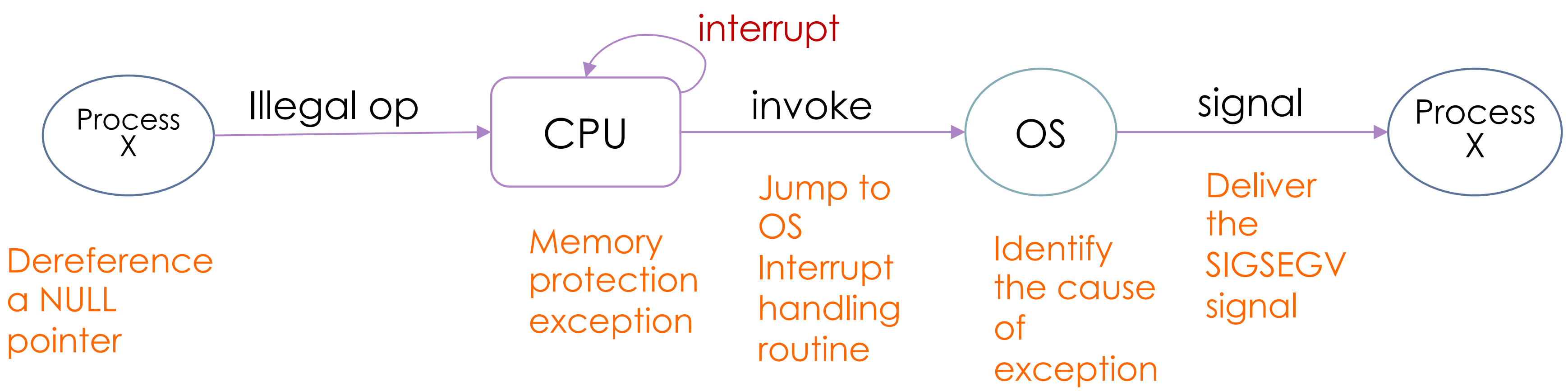


Signals

- Signals are used in UNIX systems to **notify** a process that a **particular event** has occurred
  - Sometimes being referred as "***Software Interrupt***"
- Basically implemented as system calls (kill(), signal(), sigaction(), raise(), pause(), sigsuspend(), etc.)
- Each signal is represented by a value/symbolic name
  - SIGINT: value = 2, generated when Ctrl-C is pressed
  - SIGCHLD: value = 17, generated when child process finishes execution or is terminated

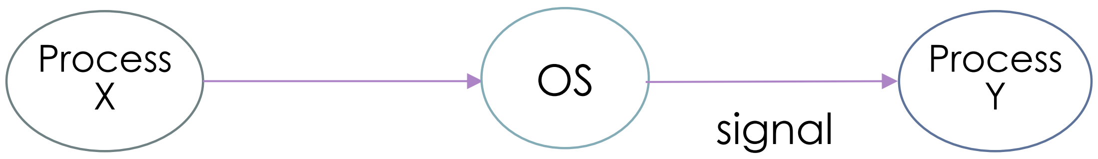
Signals (2)

- A signal is generated by one software entity (in the occurrence of an event) to a target software entity
  - **Synchronous signal** – is triggered by the **current instruction** of the current running process itself and **is delivered** to **that** process by the OS immediately
    - e.g., illegal memory access, division by zero



Signals (3)

- **Asynchronous signals** – are generated by external events / activities, which are **not triggered by the current activity** / action of the target process at the time of receiving the signal
  - i.e., arrive at unpredictable times during execution of the program
  - e.g., by the timer alarm
  - e.g., parent process using kill() system call to kill the child process



Signals (4)

- A process can decide whether it wants to **catch**, **ignore** or **mask** a signal
  - Catching a signal involves specifying a routine (**signal handler**) in advance so that the OS will invoke that handler when the process receives that signal
    - the signal() or sigaction() system calls can be used by the program to specify the signal handler routine to the OS
  - Catching – Using OS's default action to handle the signal
  - Ignore – Inform OS that it does not want to handle that signal
  - Masking a signal is to instruct the OS not to deliver signals of that type until the process clears the signal mask

- SIGKILL and SIGSTOP cannot be caught, blocked or ignored

Signals (5)

- How OS determines what a process will respond to a particular signal
  - A process's PCB contains a pointer to **a vector of signal handlers** (logically order by the signal number)
  - Each entry corresponds to the handler function for that entry (signal)
- A child process inherits the setting from its parent
- However, if use exec…() function to load a new program image, any signals that have the custom-made handlers **will be reset** to default setting

Summary

- To manage and control a running process (application), OS needs some mechanisms to keep track on the current status of the process
  - Various data structures are needed
    - Process control block (PCB)
    - Process table and lists
- OS provides a set of operations for us to work with processes
- Signals were introduced in Unix systems to allow interactions between User Mode processes; the kernel also uses them to notify processes of system events.