NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE

SkillsFuture Career Transition Program

Cloud Infrastructure Engineering

CPU, Threading & Processing

Nanyang Technological University
Skills Union

Course Content

- Gain knowledge of CPU and GPU
  - Explain why CPUs are important
- Describe the differences between programs, processes, and threads

CPU

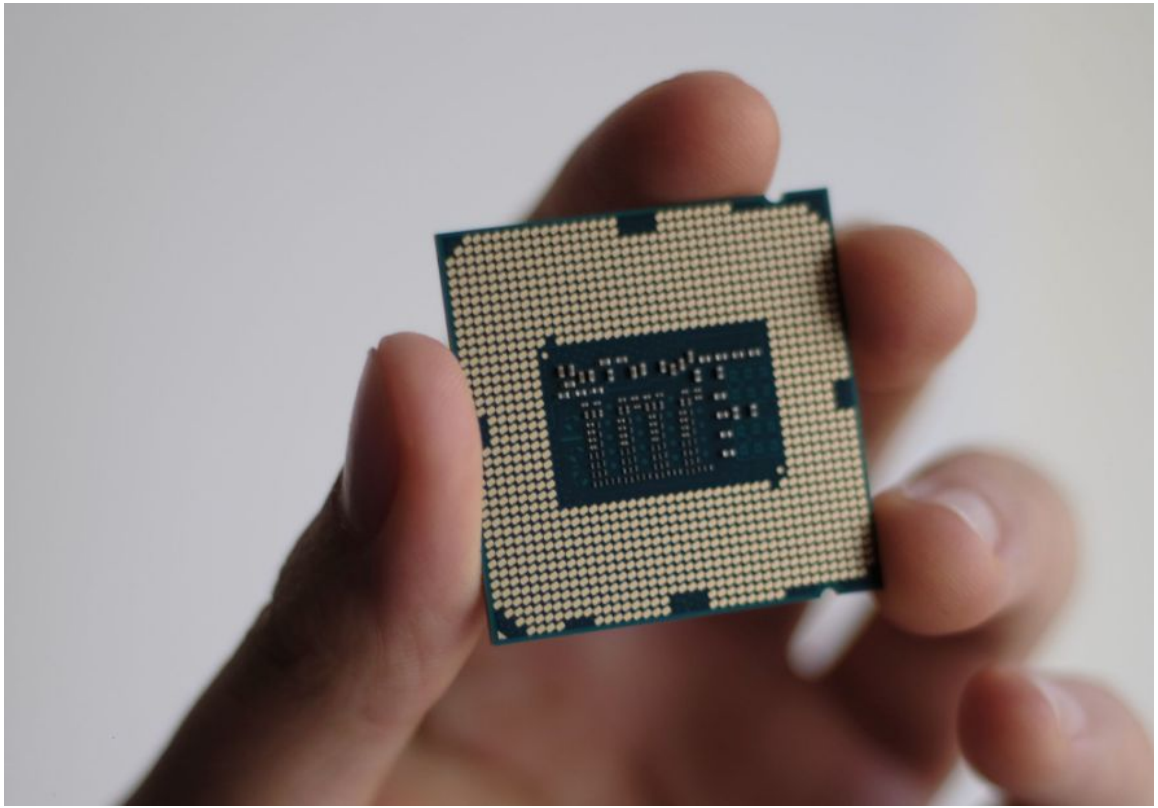
What is CPU?

Central Processing Unit. It is also known as a processor or microprocessor. It's one of the most important pieces of hardware in any digital computing system – if not the most important.

Often referred to as the **brain and heart of all digital systems**, the CPU is responsible for doing all the work.

It performs every single action a computer does and executes programs.

What is CPU?

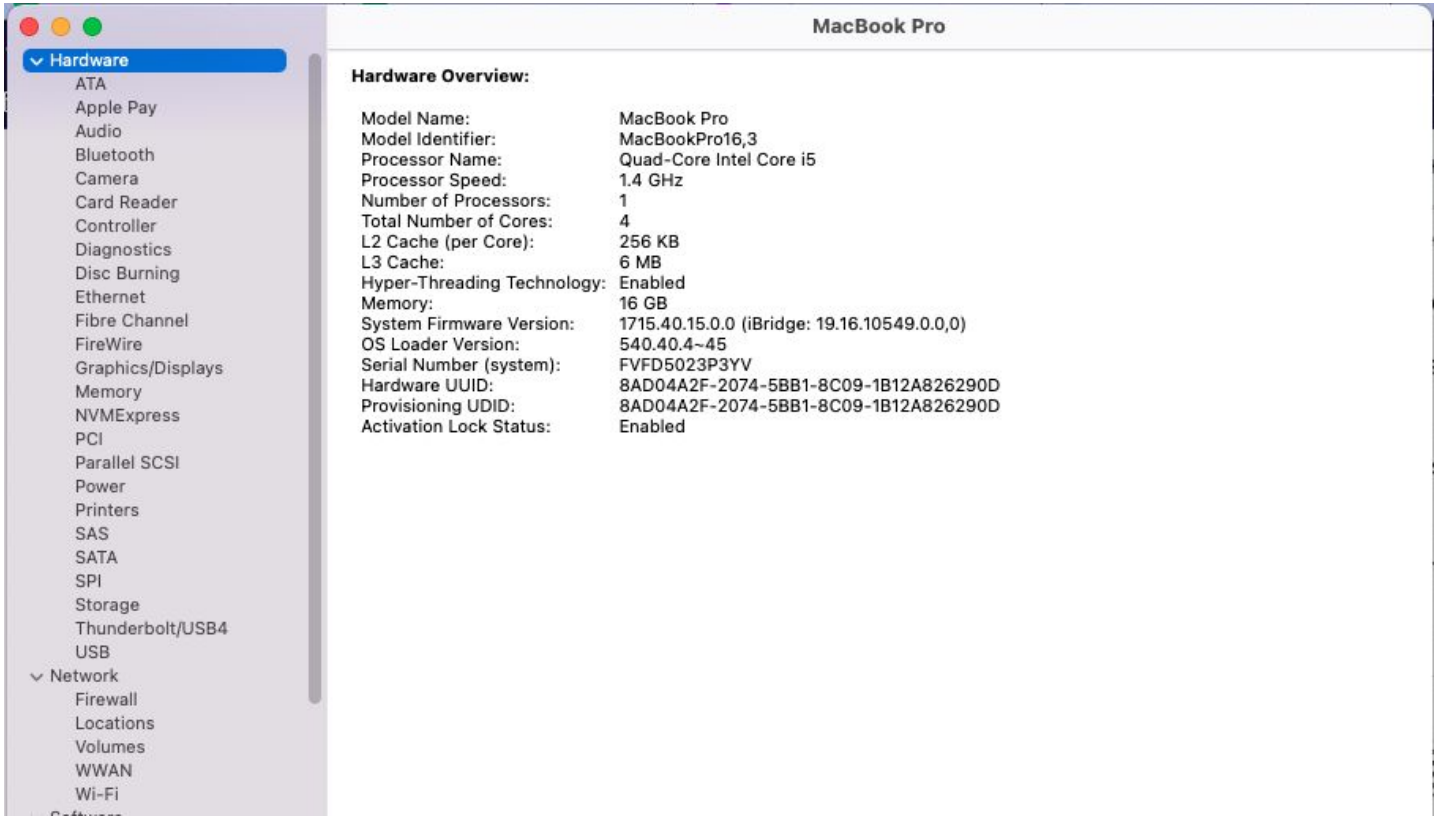


What does a CPU do?

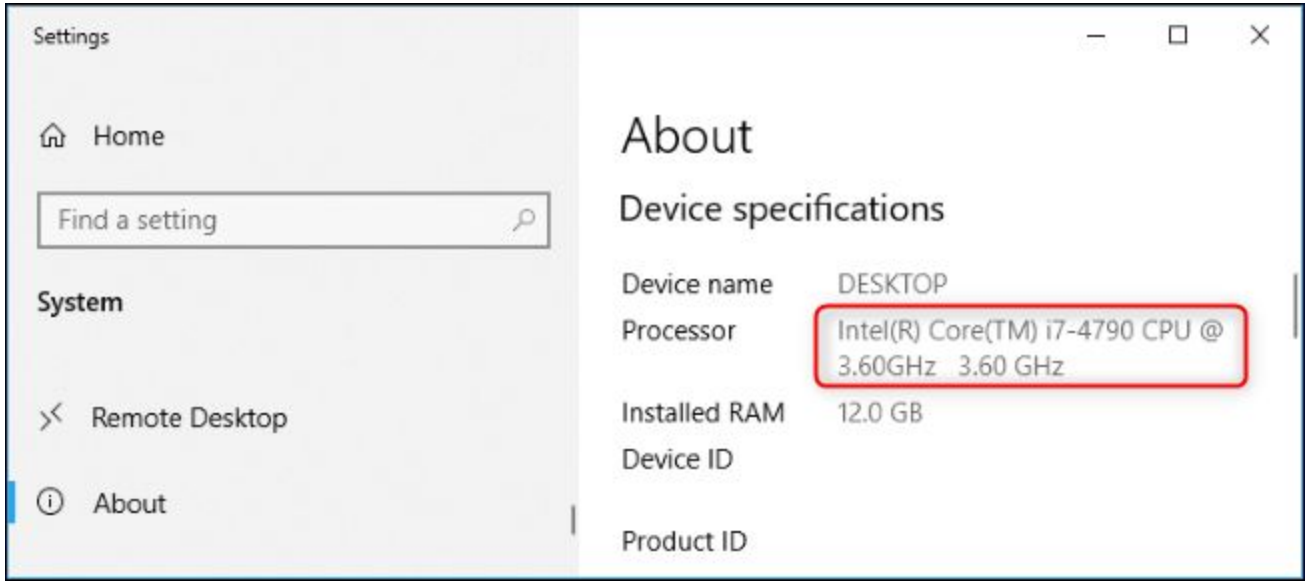
A CPU is responsible for **handling the processing of logical and mathematical operations and executing instructions** that it is given.

It can execute millions of instructions per second – but can carry out only one instruction at a time.

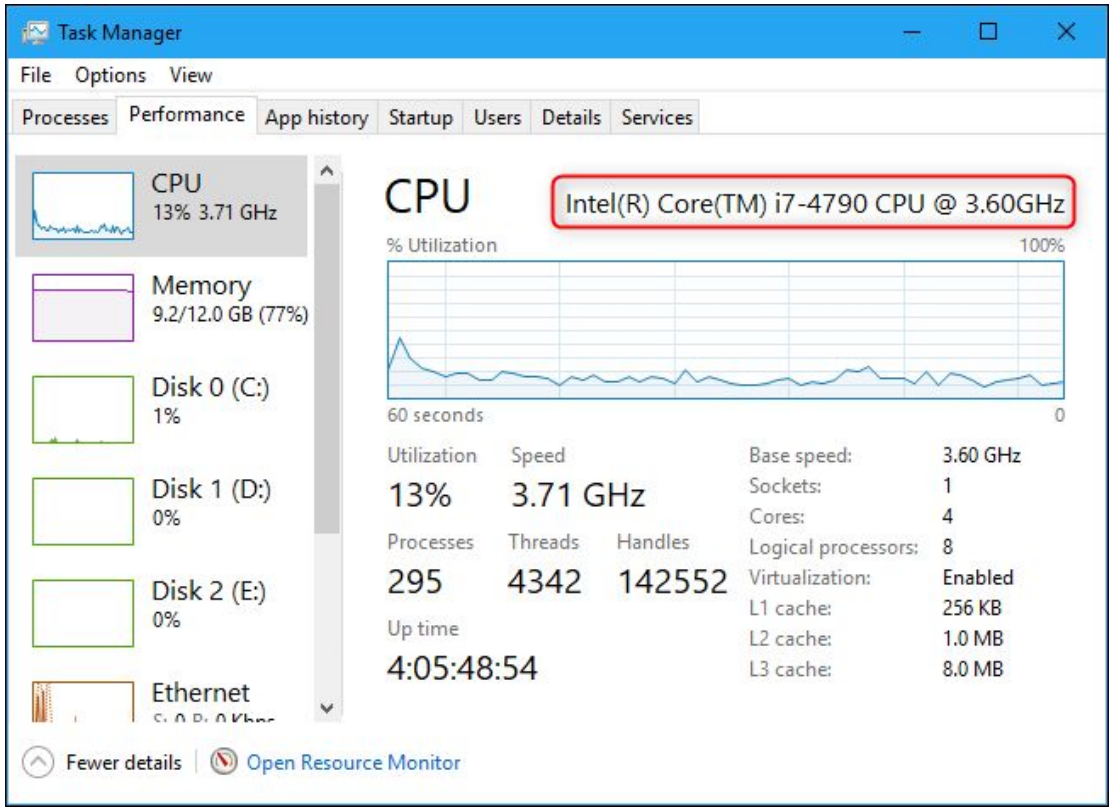
Let's Check Your CPU



Let's Check Your CPU

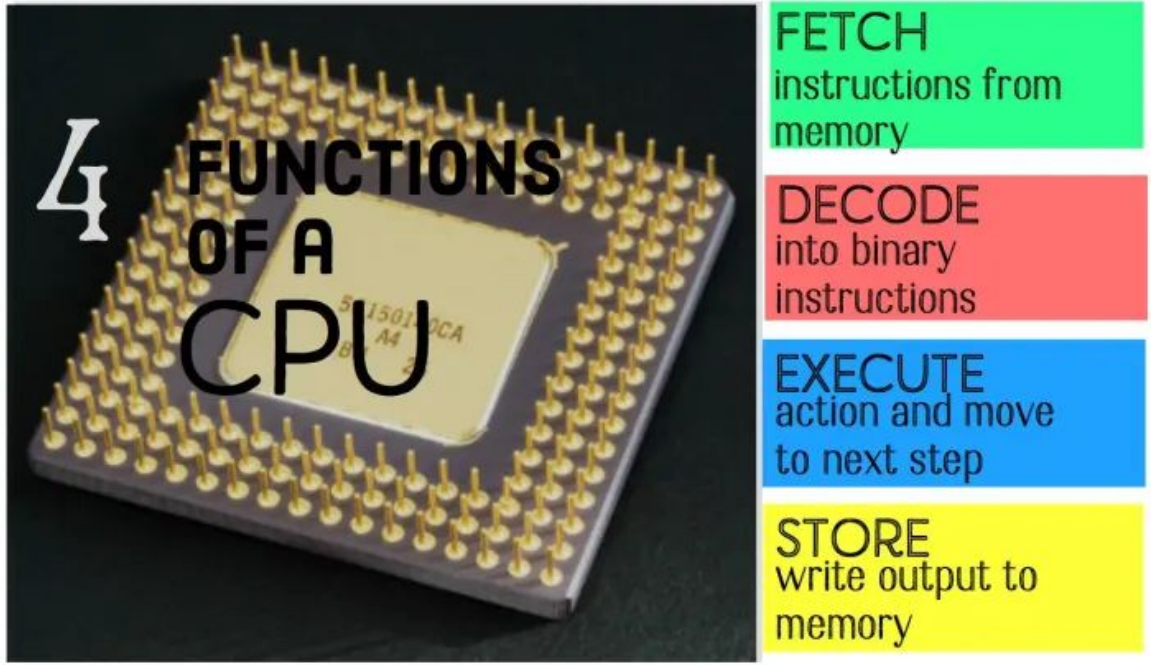


Let's Check Your CPU

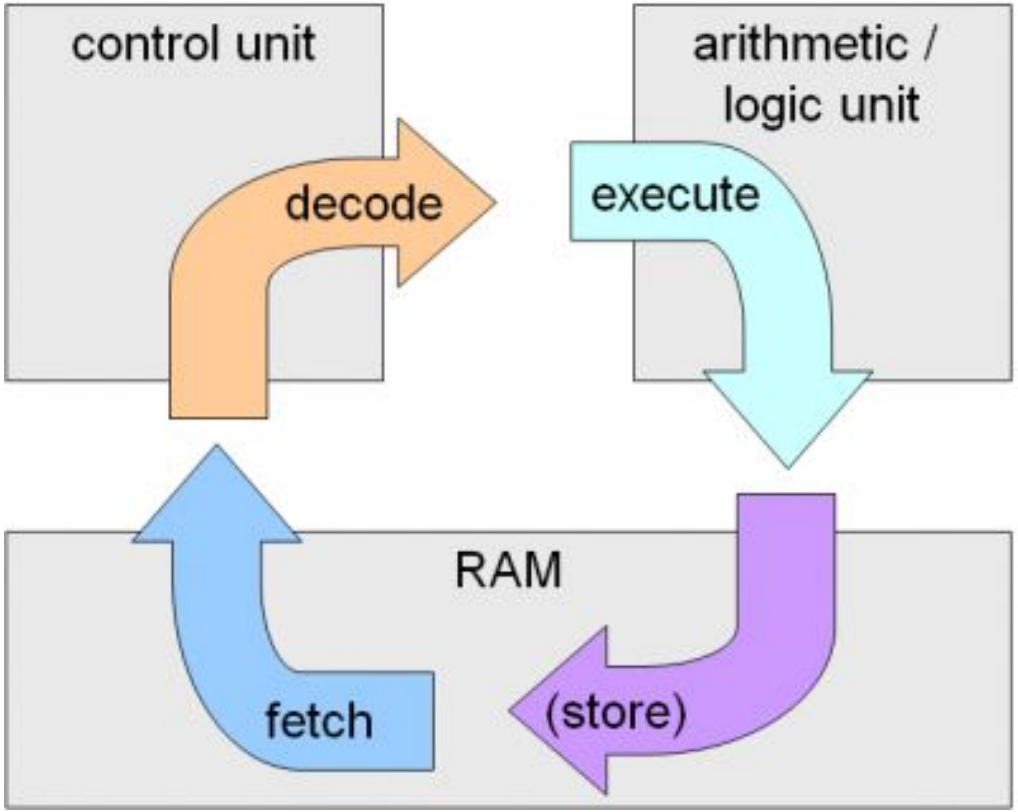


CPU Tasks

Then the CPU is in charge of four tasks:



Fetch-Execute Cycle



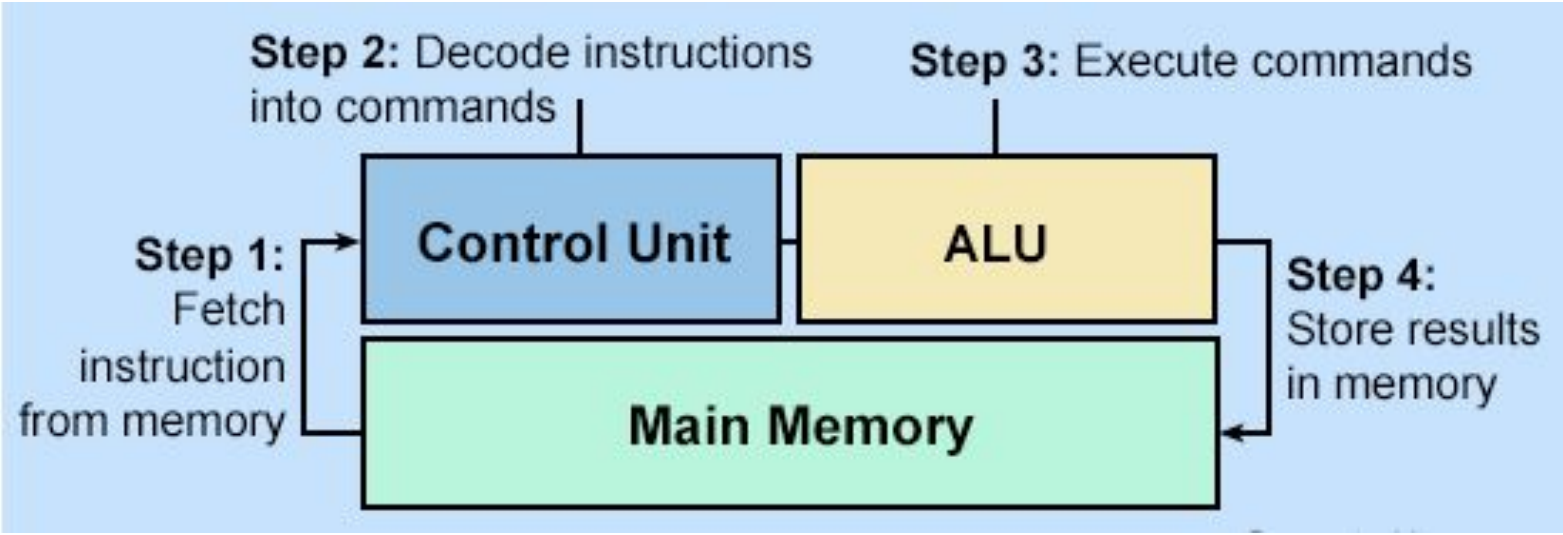
Components of CPU

CU (Control Unit). It regulates the **flow of input and output**. It's the part that fetches and retrieves the instructions from main memory and later decodes them.

ALU (Arithmetic Logic Unit). The part where all the processing happens. Here is where all **mathematical calculations** take place, as well as all the **logical operations** for decision making, such as comparing data.

Registers. An **extremely fast memory location**. The data and instructions that are currently being processed during the fetch-execute cycle are stored there, for quick access by the processor.

Components of CPU



CPU In The Cloud

CPU in the cloud is a little different because, when we provision a Virtual Machine, the CPU capacity we provision is a **share of the physical host's CPU**.

If the physical host has multiple vCPUs to run, it **schedules our vCPU a time slot to receive instructions, execute tasks, and communicate** with other virtual components.

Effectively, each **vCPU is a thread of the physical host's CPU** sharing its CPU cycle.

vCPU

A virtual CPU (vCPU) or virtual processor is a **physical CPU core** that is **assigned to a virtual machine**. It is the amount of processing power that a hypervisor provides to a virtual server.

vCPU

Instance types (1/459)

Filter instance types

1 2 3 4 5 6 7 ... 10

Instance type	vCPUs	Architecture	Memory (GiB)	Storage (GB)	Storage type	Network performance	On-Demand Linux pricing	On-Demand Windows pricing
t1.micro	1	i386, x86_64	0.612	-	-	Very Low	0.02 USD per Hour	0.02 USD per Hour
t2.nano	1	i386, x86_64	0.5	-	-	Low to Moderate	0.0073 USD per Hour	0.0096 USD per Hour
t2.micro	1	i386, x86_64	1	-	-	Low to Moderate	0.0146 USD per Hour	0.0192 USD per Hour
t2.small	1	i386, x86_64	2	-	-	Low to Moderate	0.0292 USD per Hour	0.0384 USD per Hour
t2.medium	2	i386, x86_64	4	-	-	Low to Moderate	0.0584 USD per Hour	0.0764 USD per Hour
t2.large	2	x86_64	8	-	-	Low to Moderate	0.1168 USD per Hour	0.1448 USD per Hour
t2.2xlarge	8	x86_64	32	-	-	Moderate	0.4672 USD per Hour	0.5292 USD per Hour
t2.xlarge	4	x86_64	16	-	-	Moderate	0.2336 USD per Hour	0.2746 USD per Hour
t3.nano	2	x86_64	0.5	-	-	Up to 5 Gigabit	0.0066 USD per Hour	0.0112 USD per Hour
t3.micro	2	x86_64	1	-	-	Up to 5 Gigabit	0.0132 USD per Hour	0.0224 USD per Hour
t3.small	2	x86_64	2	-	-	Up to 5 Gigabit	0.0264 USD per Hour	0.0448 USD per Hour
t3.medium	2	x86_64	4	-	-	Up to 5 Gigabit	0.0528 USD per Hour	0.0712 USD per Hour
t3.large	2	x86_64	8	-	-	Up to 5 Gigabit	0.1056 USD per Hour	0.1332 USD per Hour
t3.2xlarge	8	x86_64	32	-	-	Up to 5 Gigabit	0.4224 USD per Hour	0.5696 USD per Hour
t3.xlarge	4	x86_64	16	-	-	Up to 5 Gigabit	0.2112 USD per Hour	0.2848 USD per Hour

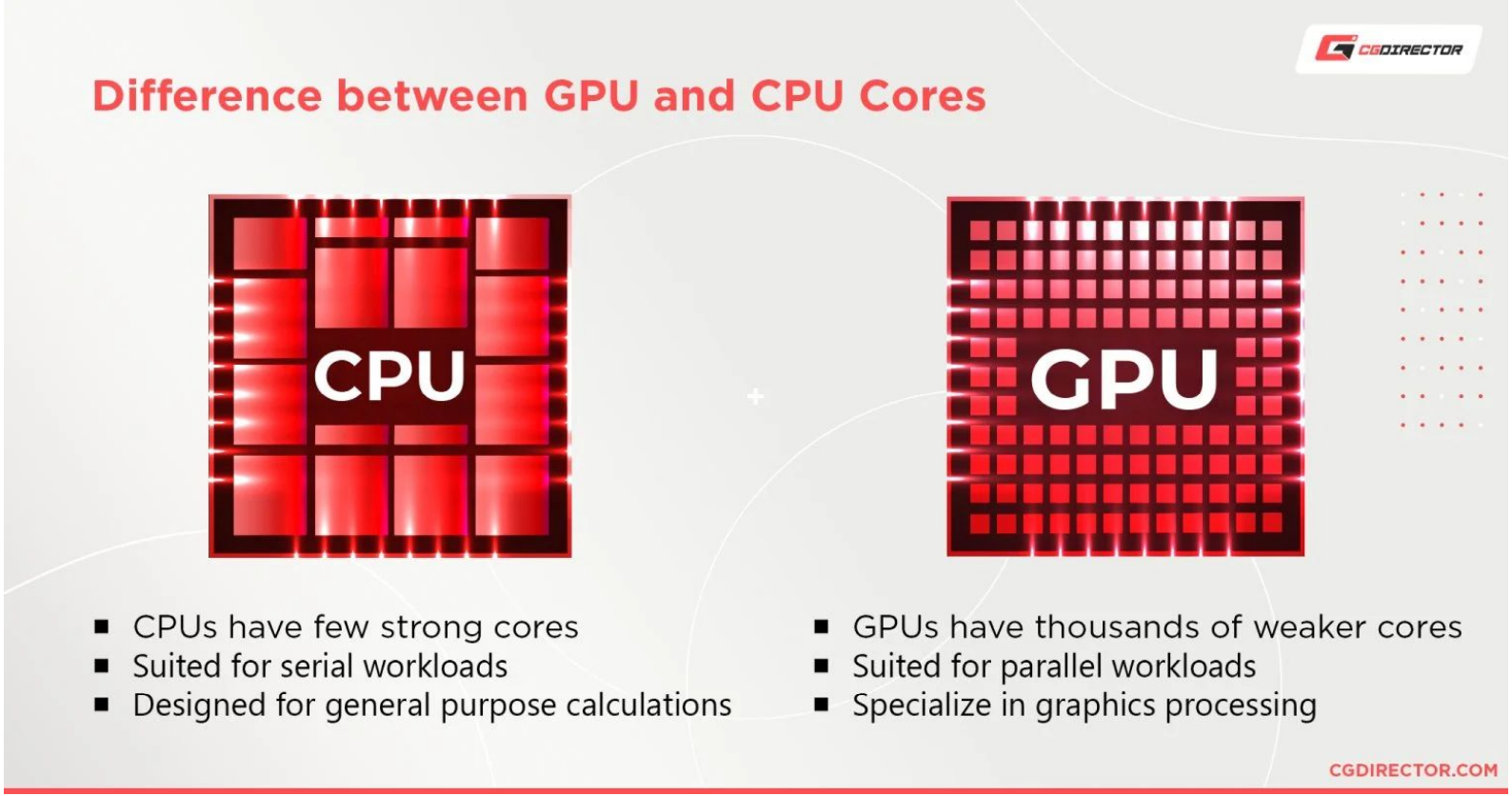
What Are GPUs?

A Graphical Processing Unit (GPU) is designed for **high-performance computing** (HPC) and **graphics applications**.

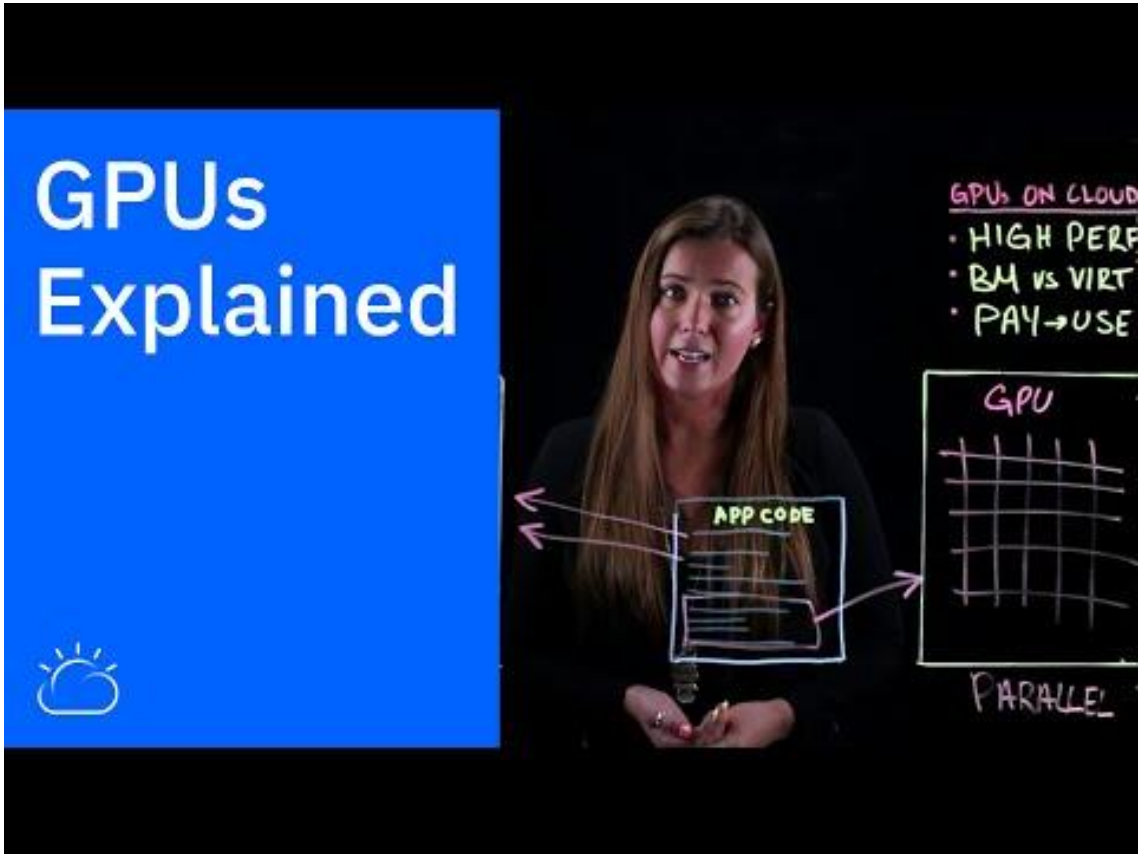
Use cases:

- Deep Learning
- Machine Learning
- Internet of Things
- High Performance Computing

GPUs vs CPUs


CGDIRECTOR
Difference between GPU and CPU Cores
CPU
GPU
CPUs have few strong cores
Suited for serial workloads
Designed for general purpose calculations
GPUs have thousands of weaker cores
Suited for parallel workloads
Specialize in graphics processing
CGDIRECTOR.COM

What Are GPUs?



Programs

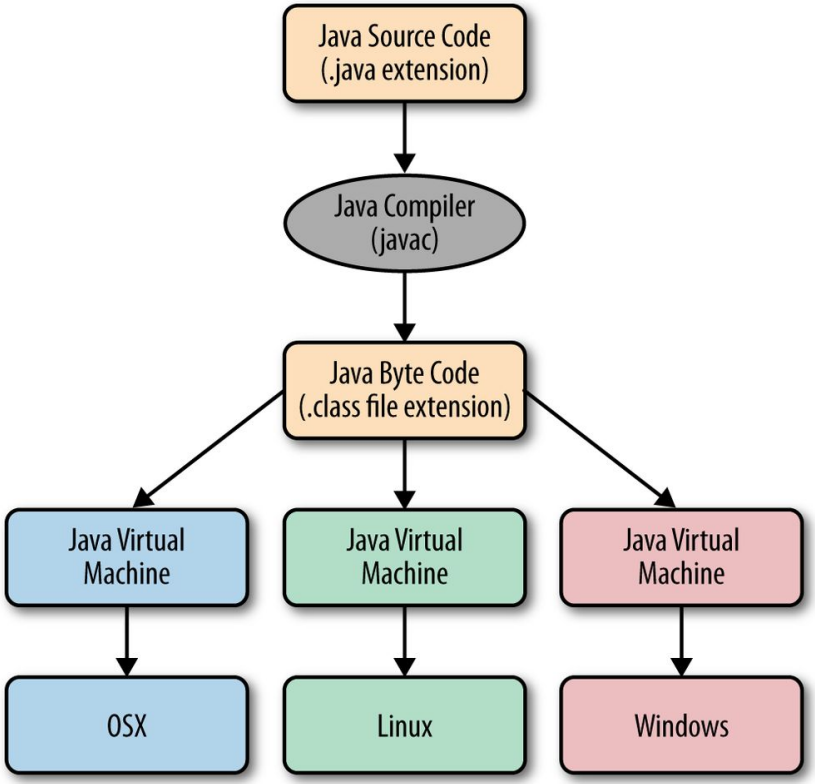
Programs

A program is a **sequence of instructions that a computer can execute or interpret**.

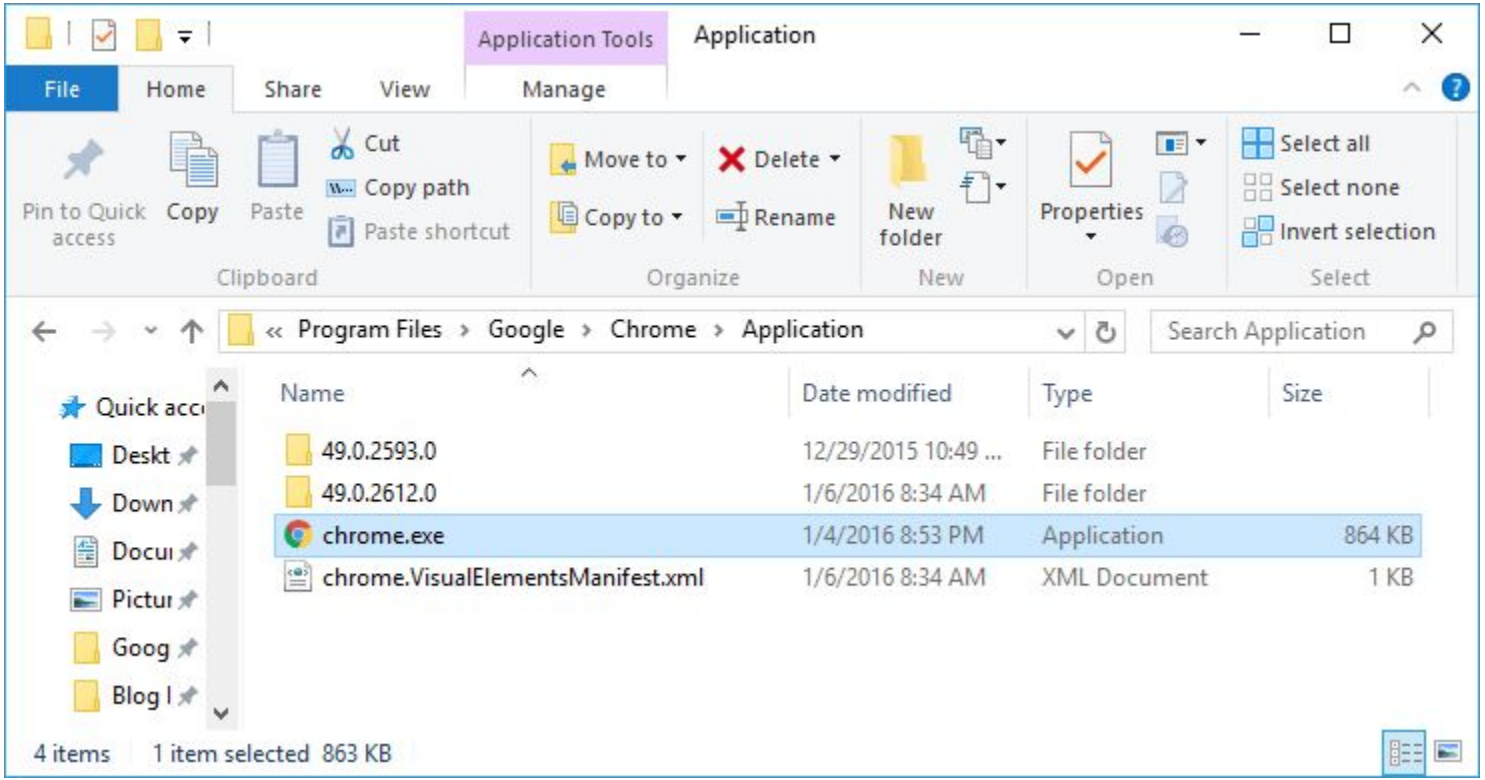
A computer program in its human-readable form is called the **source code**. Usually, the source code needs to be translated to machine instructions using its language compiler. The resulting file is called an **executable**.

Alternatively, source code may execute within the language's interpreter. Java compiles into an intermediate form which is then executed by a Java interpreter.

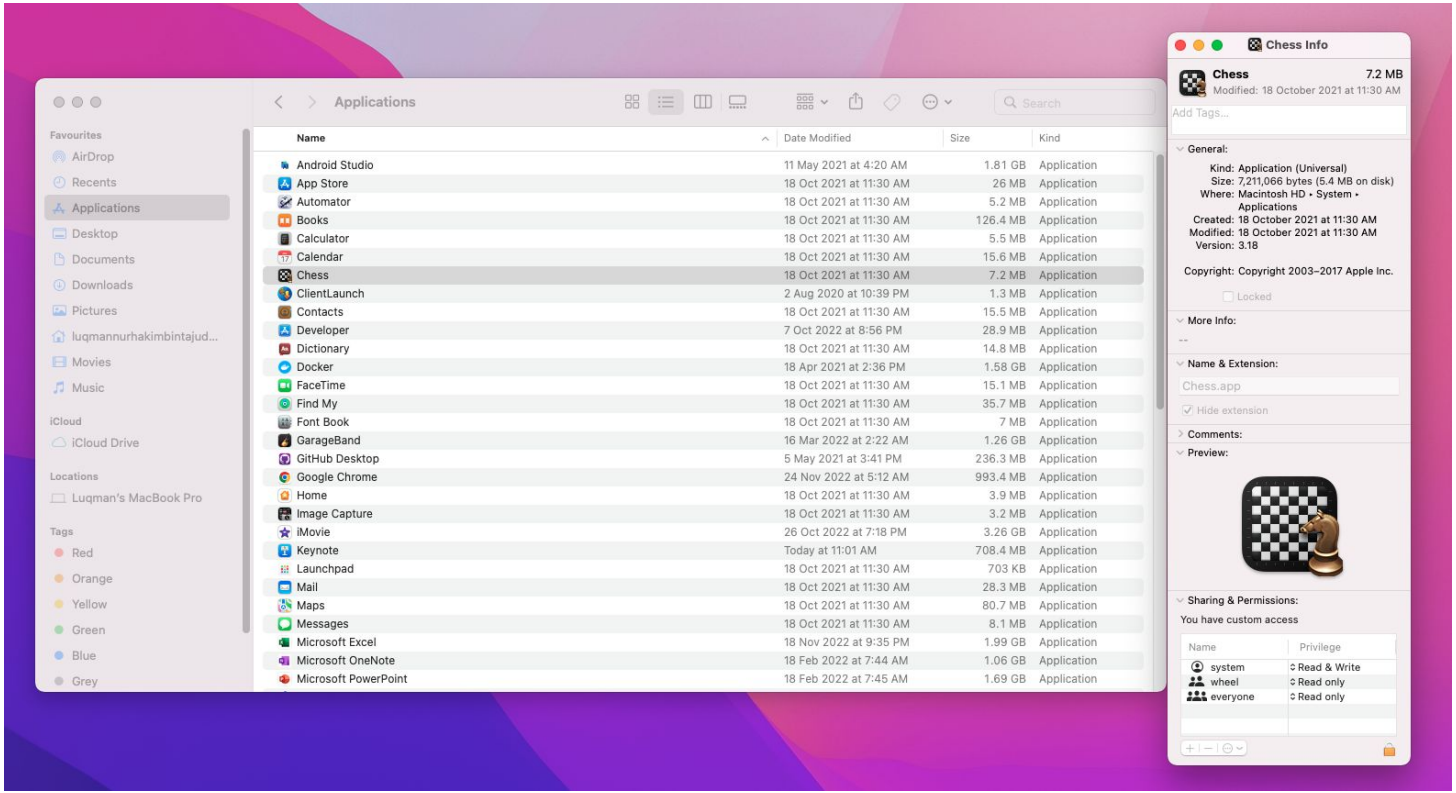
Programs


Java Source Code
(.java extension)
Java Compiler
(javac)
Java Byte Code
(.class file extension)
Java Virtual
Machine
Java Virtual
Machine
Java Virtual
Machine
OSX
Linux
Windows

Programs


Application Tools
Application
File
Home
Share
View
Manage
Pin to Quick access
Copy
Paste
Cut
Copy path
Paste shortcut
Clipboard
Move to
Copy to
Delete
Rename
Organize
New folder
New
Properties
Open
Select all
Select none
Invert selection
Select
« Program Files › Google › Chrome › Application
Search Application
Quick acc
Deskt
Down
Docu
Pictu
Goog
Blog I
Name
Date modified
Type
Size
49.0.2593.0
12/29/2015 10:49 ...
File folder
49.0.2612.0
1/6/2016 8:34 AM
File folder
chrome.exe
1/4/2016 8:53 PM
Application
864 KB
chrome.VisualElementsManifest.xml
1/6/2016 8:34 AM
XML Document
1 KB
4 items
1 item selected 863 KB

Programs


Applications
Search
Favourites
AirDrop
Recents
Applications
Desktop
Documents
Downloads
Pictures
luqmannurhakimbintajud...
Movies
Music
iCloud
iCloud Drive
Locations
Luqman's MacBook Pro
Tags
Red
Orange
Yellow
Green
Blue
Grey
Name
Date Modified
Size
Kind
Android Studio 11 May 2021 at 4:20 AM 1.81 GB Application
App Store 18 Oct 2021 at 11:30 AM 26 MB Application
Automator 18 Oct 2021 at 11:30 AM 5.2 MB Application
Books 18 Oct 2021 at 11:30 AM 126.4 MB Application
Calculator 18 Oct 2021 at 11:30 AM 5.5 MB Application
Calendar 18 Oct 2021 at 11:30 AM 15.6 MB Application
Chess 18 Oct 2021 at 11:30 AM 7.2 MB Application
ClientLaunch 2 Aug 2020 at 10:39 PM 1.3 MB Application
Contacts 18 Oct 2021 at 11:30 AM 15.5 MB Application
Developer 7 Oct 2022 at 8:56 PM 28.9 MB Application
Dictionary 18 Oct 2021 at 11:30 AM 14.8 MB Application
Docker 18 Apr 2021 at 2:36 PM 1.58 GB Application
FaceTime 18 Oct 2021 at 11:30 AM 15.1 MB Application
Find My 18 Oct 2021 at 11:30 AM 35.7 MB Application
Font Book 18 Oct 2021 at 11:30 AM 7 MB Application
GarageBand 16 Mar 2022 at 2:22 AM 1.26 GB Application
GitHub Desktop 5 May 2021 at 3:41 PM 236.3 MB Application
Google Chrome 24 Nov 2022 at 5:12 AM 993.4 MB Application
Home 18 Oct 2021 at 11:30 AM 3.9 MB Application
Image Capture 18 Oct 2021 at 11:30 AM 3.2 MB Application
iMovie 26 Oct 2022 at 7:18 PM 3.26 GB Application
Keynote Today at 11:01 AM 708.4 MB Application
Launchpad 18 Oct 2021 at 11:30 AM 703 KB Application
Mail 18 Oct 2021 at 11:30 AM 28.3 MB Application
Maps 18 Oct 2021 at 11:30 AM 80.7 MB Application
Messages 18 Oct 2021 at 11:30 AM 8.1 MB Application
Microsoft Excel 18 Nov 2022 at 9:35 PM 1.99 GB Application
Microsoft OneNote 18 Feb 2022 at 7:44 AM 1.06 GB Application
Microsoft PowerPoint 18 Feb 2022 at 7:45 AM 1.69 GB Application
Chess Info
Chess 7.2 MB
Modified: 18 October 2021 at 11:30 AM
Add Tags...
General:
Kind: Application (Universal)
Size: 7,211,066 bytes (5.4 MB on disk)
Where: Macintosh HD ▸ System ▸ Applications
Created: 18 October 2021 at 11:30 AM
Modified: 18 October 2021 at 11:30 AM
Version: 3.18
Copyright: Copyright 2003–2017 Apple Inc.
Locked
More Info:
--
Name & Extension:
Chess.app
Hide extension
Comments:
Preview:
Sharing & Permissions:
You have custom access
Name
Privilege
system Read & Write
wheel Read only
everyone Read only

Processes

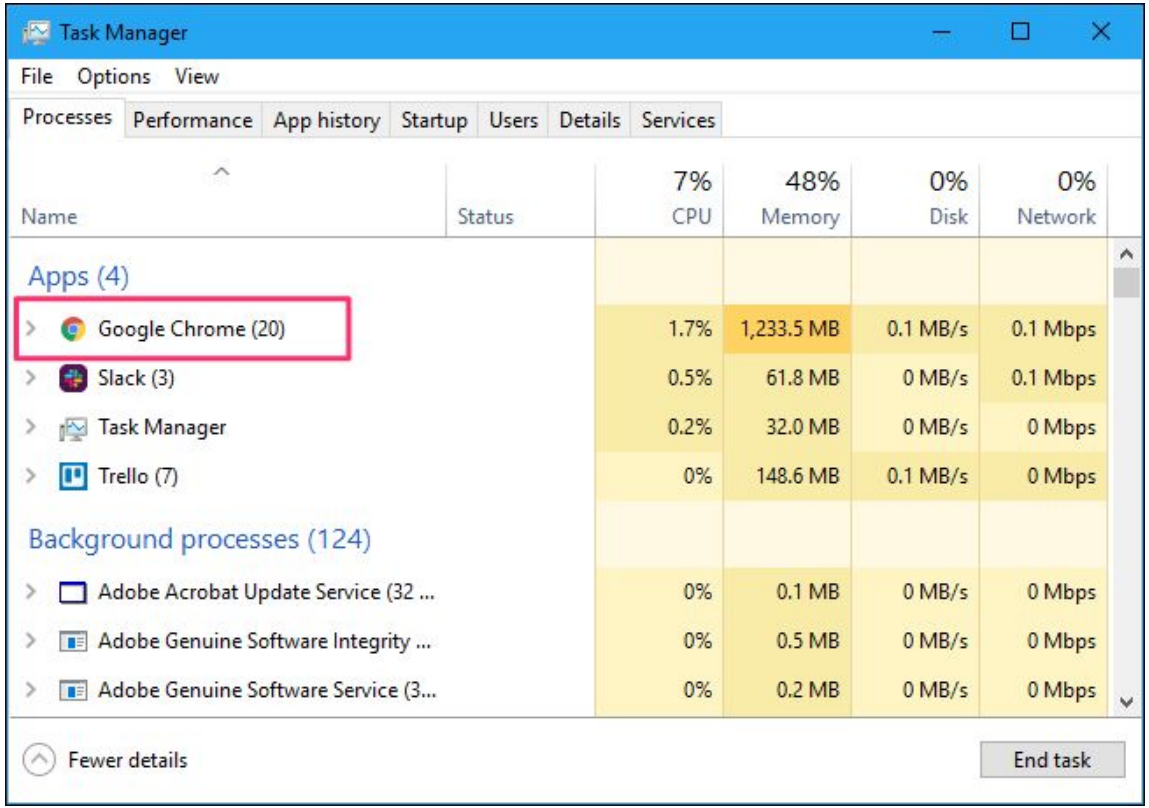
What is a Process?

A process is an **instance of a program that is being executed**.

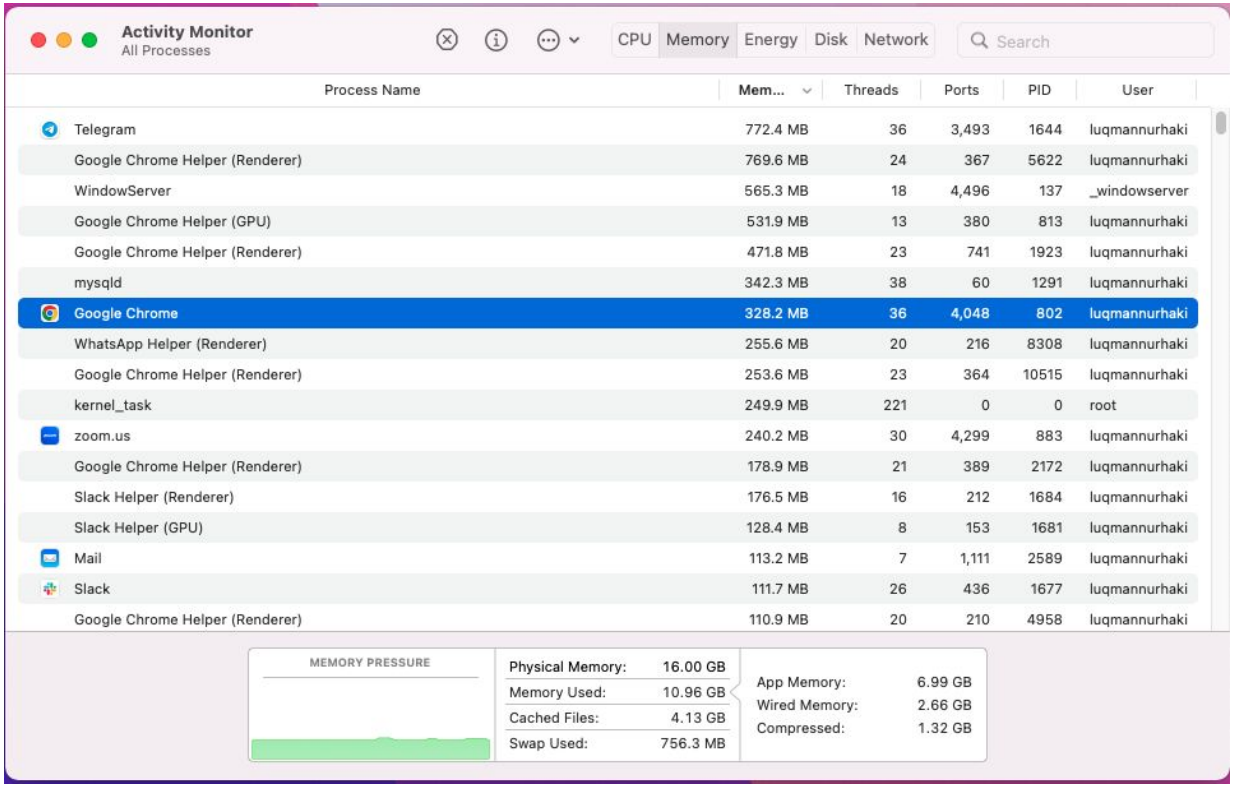
A process can create other processes to perform multiple tasks at a time; the created processes are known as clone or child processes, and the main process is known as the parent process.

Each process contains its **own memory space** and does not share it with the other processes. It is known as the active entity. A typical process remains in the below form in memory.

Process in Windows



Process in MacOS



Process Lifecycle

A process can remain in any of the following states:

NEW: A new process is being created.

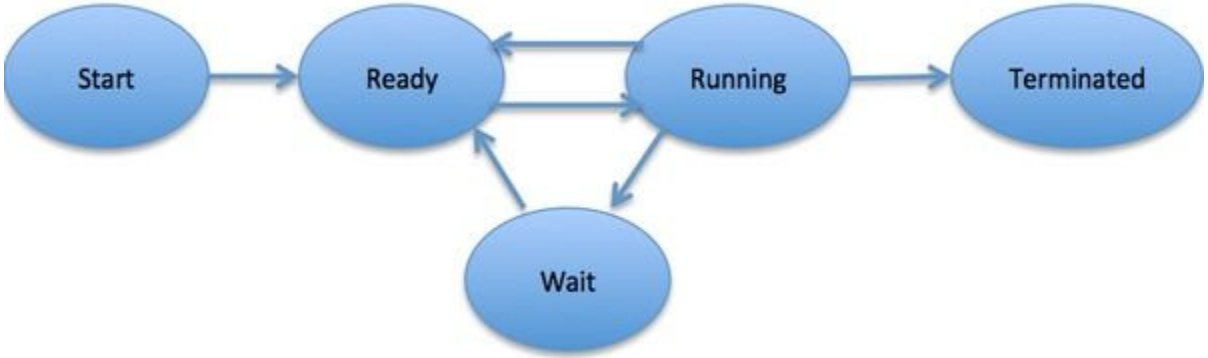
READY: A process is ready and waiting to be allocated to a processor.

RUNNING: The program is being executed.

WAITING: Waiting for some event to happen or occur.

TERMINATED: Execution finished.

Process Lifecycle



How Do Processes Work?

When we execute a program, the processor begins to process it. It takes the following steps:

1. The **program is loaded into the computer's memory** in binary code after translation.
2. A **program requires memory and other resources**, such as registers, program counter, and a stack, to run it.

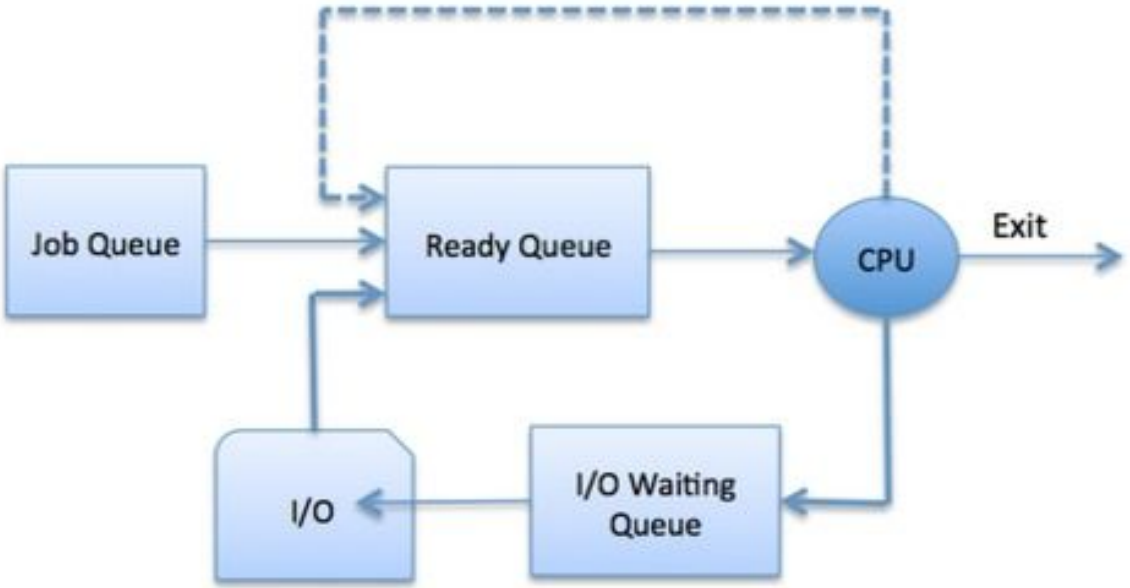
    A register can have an instruction, a storage address, or other data that is required by the process.

    The program counter maintains the track of the program sequence.

    The stack has information on the active subroutines of a computer program.

3. A program may have different instances of it, and each instance of the running program is known as the individual process.

How Do Processes Work?



https://www.tutorialspoint.com/operating_system/os_process_scheduling.htm

Features Of A Process

- Each time a process is created, there is a need to **make separate system calls for each process to the OS**. The fork() function creates the process.
- Each process **exists within its own address or memory space**.
- Each process is **independent and treated as an isolated process** by the OS.
- Processes need IPC (Inter-process Communication) in order to communicate with each other.
- A proper synchronization between processes is not required.

Break Time

Threads

What Is A Thread?

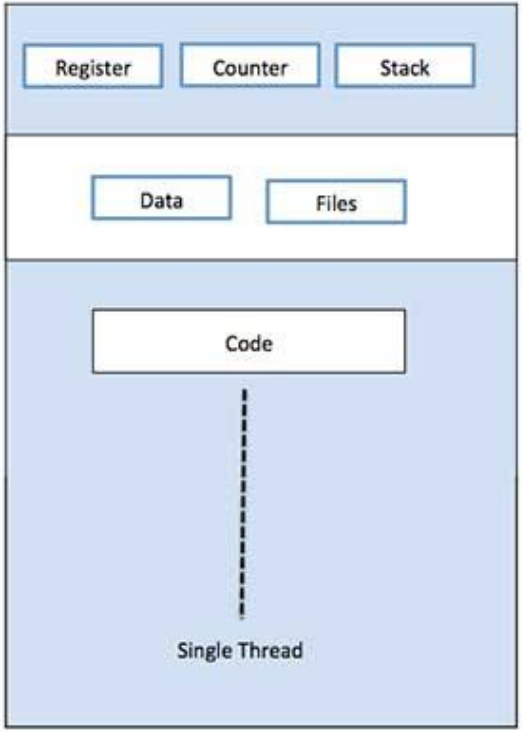
A thread is the **subset of a process** and is also known as the l**ightweight process**.

A process **can have more than one thread**, and these threads are **managed independently** by the scheduler.

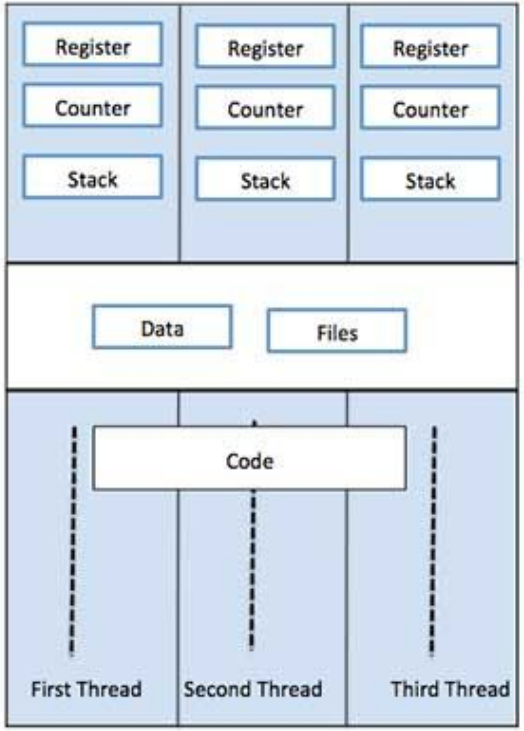
All the threads within one process are **interrelated to each other**. Threads have some common information, such as data segments, code segments, files, etc., that is shared to their peer threads.

However, take note that each thread contains its own registers, stack, and counter.

Thread



Single Process P with single thread



Single Process P with three threads

How Does A Thread Work?

1. When a process starts, the OS **assigns the memory and resources** to it. Each thread within a process shares the memory and resources of that process only.
2. Threads are mainly **used to improve the processing of an application**. In reality, only a single thread is executed at a time, but due to fast context switching between threads gives an illusion that threads are running in parallel.
3. If a single thread executes in a process, it is known as a single-threaded process and if multiple threads execute simultaneously, then it is known as multithreading.

Features Of A Thread

- Threads **share** data, memory, resources, files, etc., with their peer threads within a process.
- One system call is capable of creating more than one thread.
- Each thread has **its own stack and register**.
- Threads can **directly communicate** with each other as they share the same address space.
- Threads need to be synchronized in order to avoid unexpected scenarios.

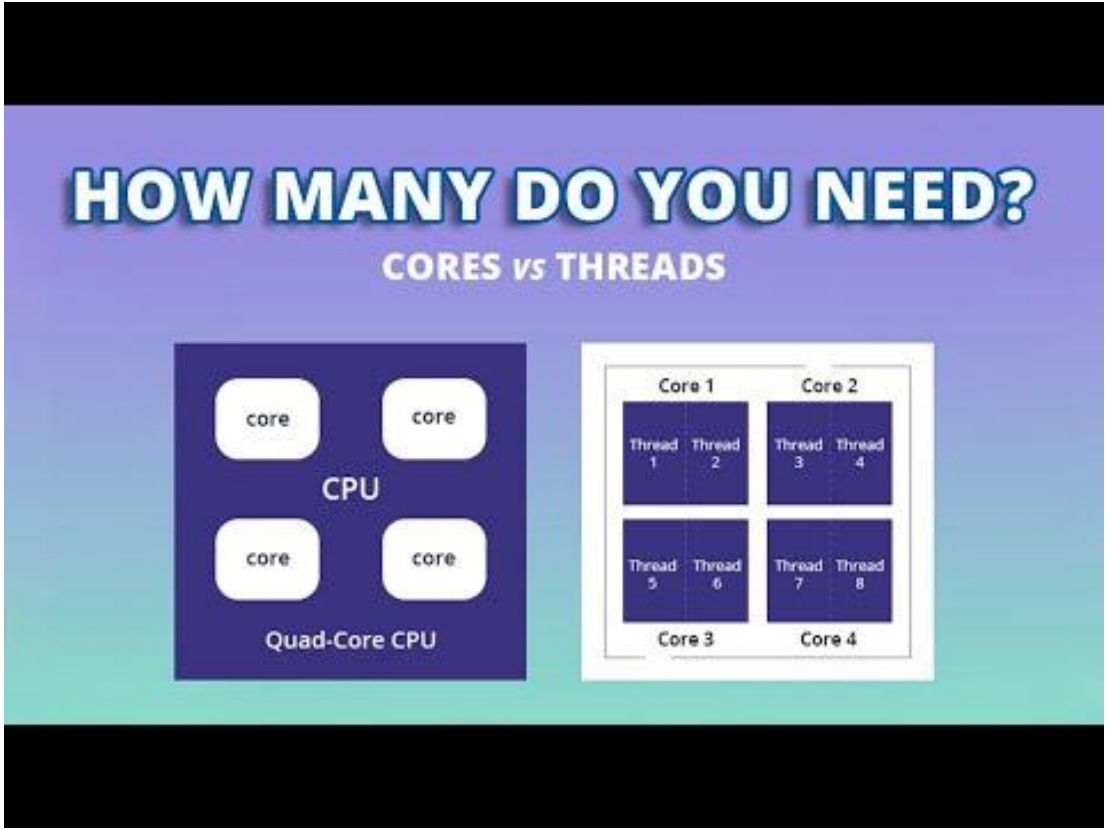
Differences Between Thread & Process

S.N.	Process	Thread
1	Process is **heavy weight** or resource intensive.	Thread is **lightweight**, taking lesser resources than a process.
2	Process switching **needs interaction** with operating system.	Thread switching **does not need to interact** with operating system.
3	In multiple processing environments, each process executes the same code but has its own memory and file resources.	All threads can **share same set of open files, child processes**.
4	In most cases, while one process is blocked, **other processes can continue being executed**..	While one thread is blocked and waiting, a second thread in the same task **can run**.
5	Multiple processes without using threads **use more resources**.	Multiple threaded processes use **fewer resources.**
6	In multiple processes each process operates **independently** of the others.	One thread can **read, write or change another** thread's data.

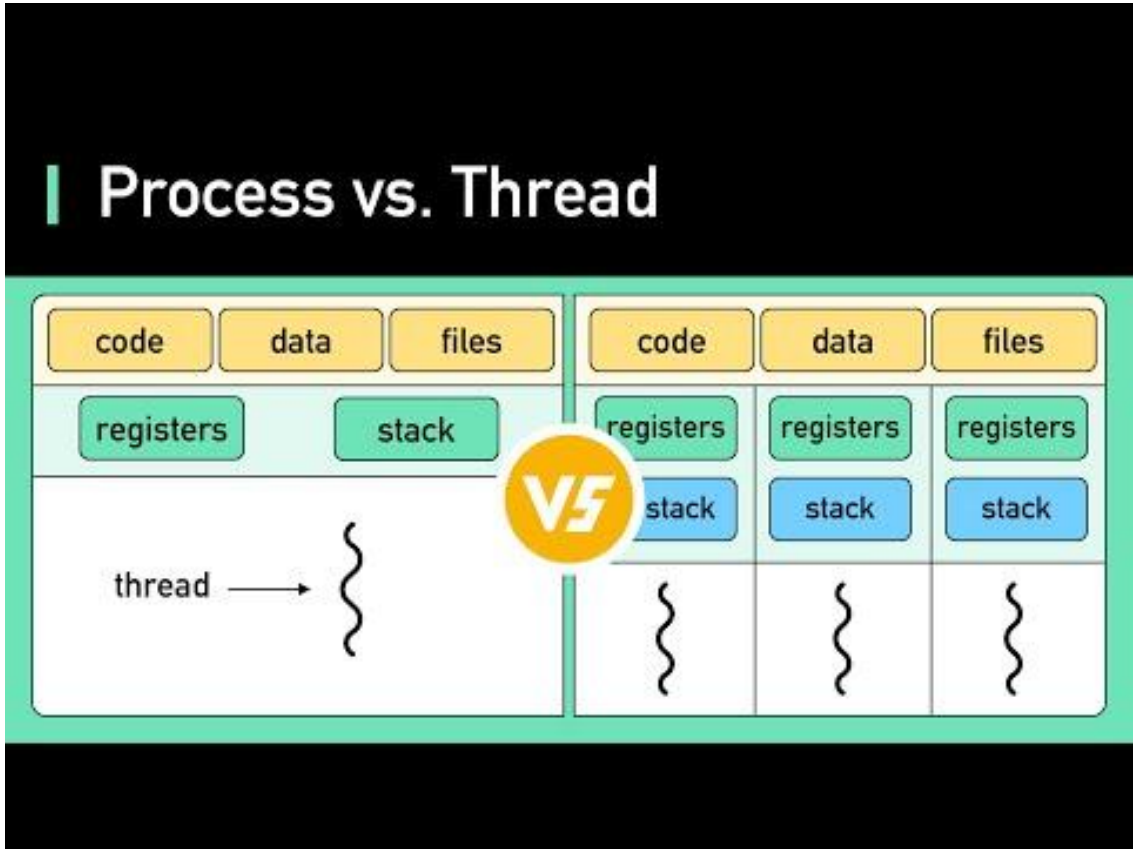
Breakout Room

- Simple Explanation about Process and Thread.
- 5 Differences between Process and Thread.

Let's Review


HOW MANY DO YOU NEED?
CORES vs THREADS
core
core
CPU
core
core
Quad-Core CPU
Core 1
Core 2
Thread 1
Thread 2
Thread 3
Thread 4
Thread 5
Thread 6
Thread 7
Thread 8
Core 3
Core 4

Differences Between Thread & Process



Advantages Of A Thread

- Threads minimize the context switching time.
- Use of threads provides concurrency within a process.
- Efficient communication.
- It is more economical to create and context switch threads.
- Threads allow utilization of multiprocessor architectures to a greater scale and efficiency.

Multiprocessing and Multithreading

Multiprocessing

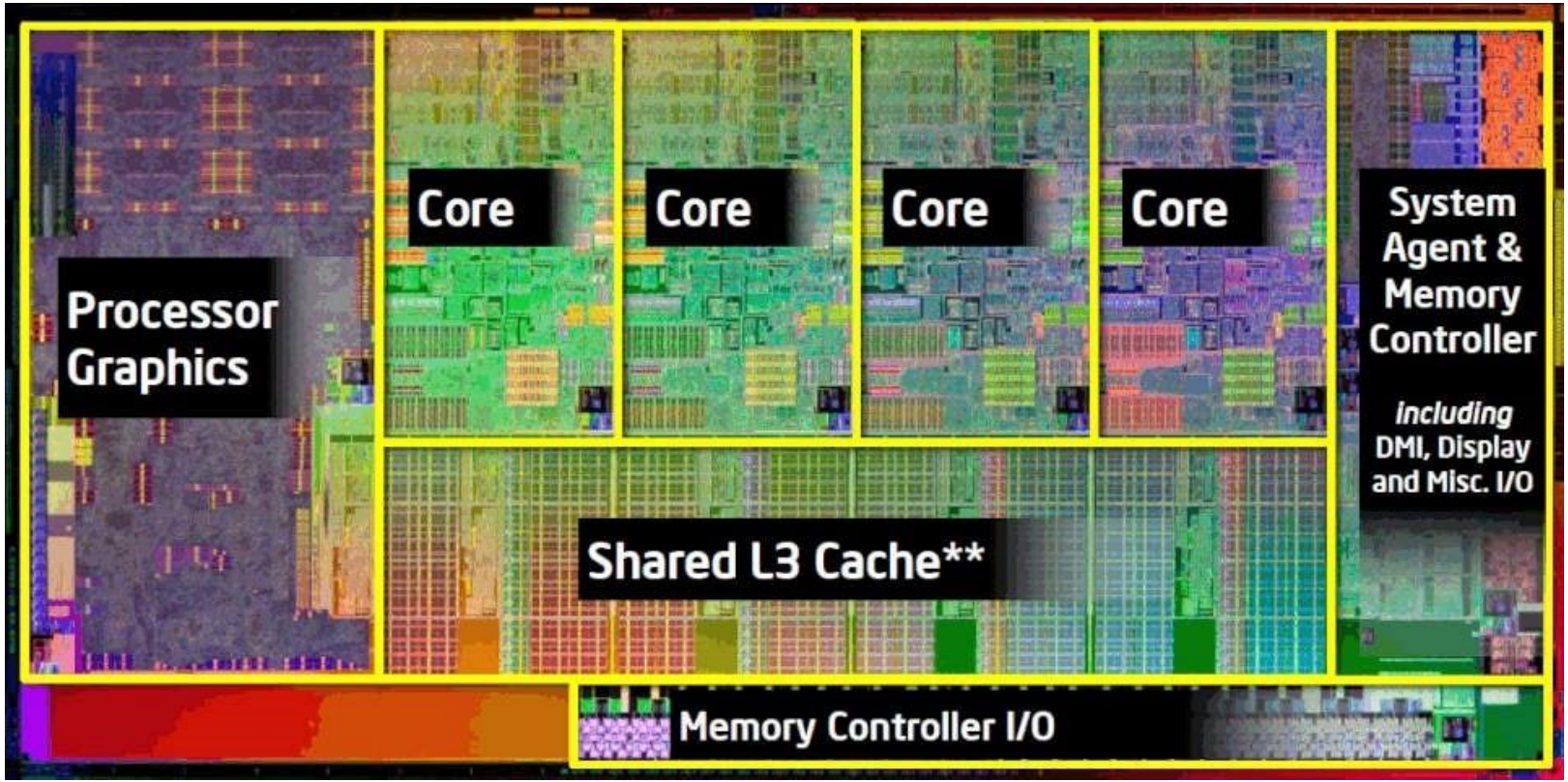
In the past, a CPU has only **one core**. In other words, it can run only a **single process at one time**.

Today, the CPU often has **multiple cores**, e.g., **two cores (dual-core) and four cores (quad-core)**.

The number of cores = the number of processes that the CPU can execute simultaneously.

Multiprocessing uses a **multi-core CPU** within a single computer, which **executes multiple processes** in **parallel**.

Multiprocessing



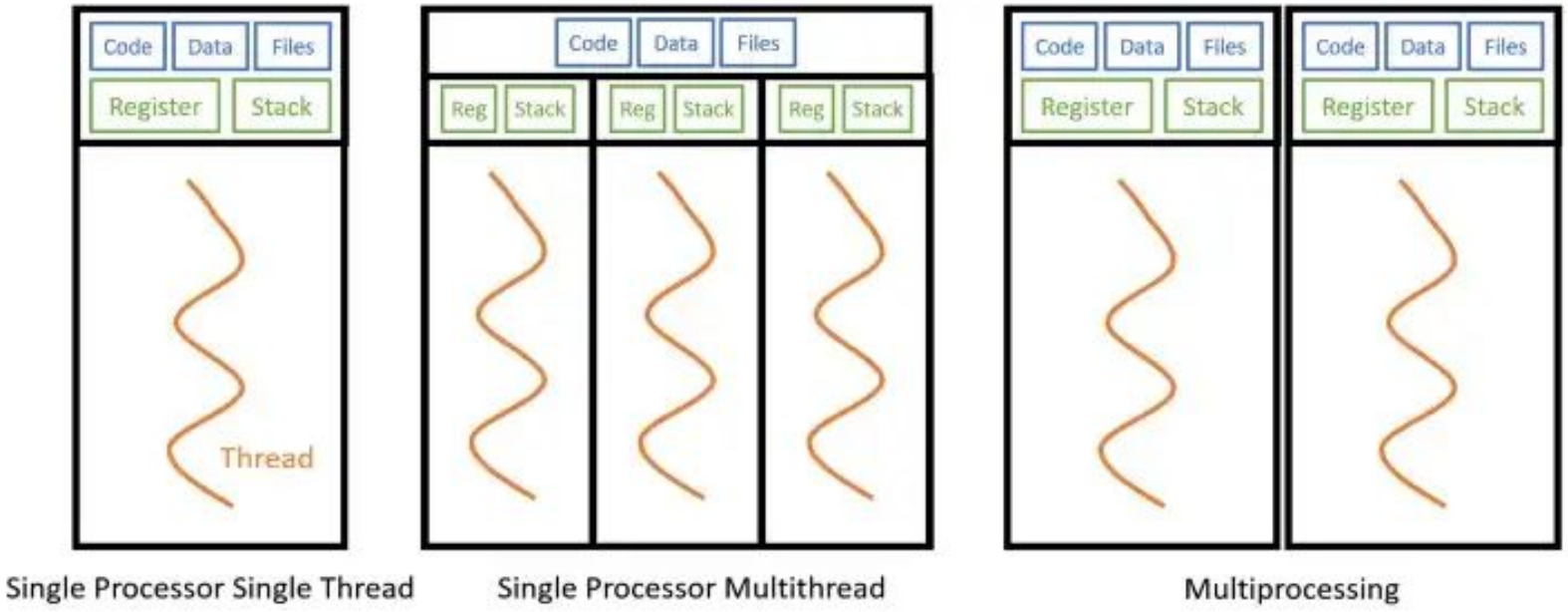
Multiprocessing

	AMD Ryzen 5 5500U	Intel Core i5-1135G7 @ 2.40GHz	+ ADD
Price	Search Online	$309 [1]	
Socket Type	FP6	BGA1526	
CPU Class	Laptop	Laptop	
Clockspeed	2.1 GHz	2.4 GHz	
Turbo Speed	Up to 4.0 GHz	Up to 4.2 GHz	
# of Physical Cores	6 (Threads: 12)	4 (Threads: 8)	
Cache	L1: 768KB, L2: 6.0MB, L3: 8MB	L1: 320KB, L2: 5.0MB, L3: 8MB	
Max TDP	15W	15W	
Yearly Running Cost	$2.74	$2.74	
Other	with Radeon Graphics	Intel Iris Xe Graphics	
First Seen on Chart	Q1 2021	Q3 2020	
# of Samples	1386	3150	
Single Thread Rating (% diff. to max in group)	2455 *(-9.7%)*	2719 *(0.0%)*	
CPU Mark (% diff. to max in group)	**13159** *(0.0%)*	**10026** *(-23.8%)*	

Multithreading

Multithreading refers to **multiple threads of execution** within an operating system. In simple terms, **two or more threads of a same process are executing simultaneously**.

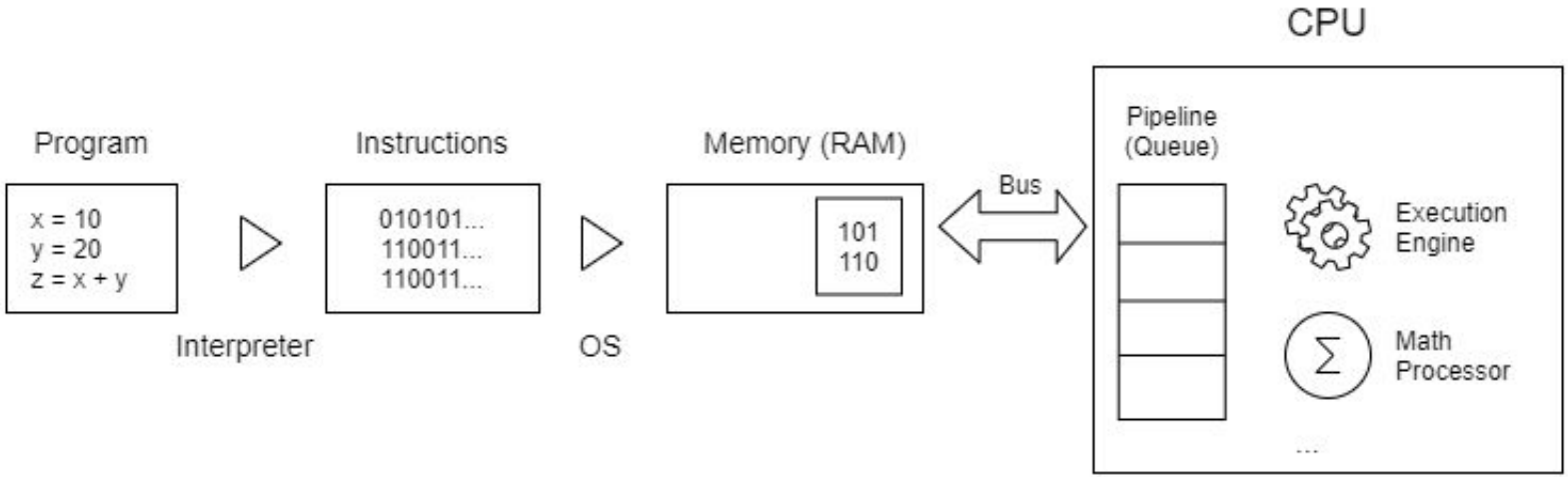
Differences



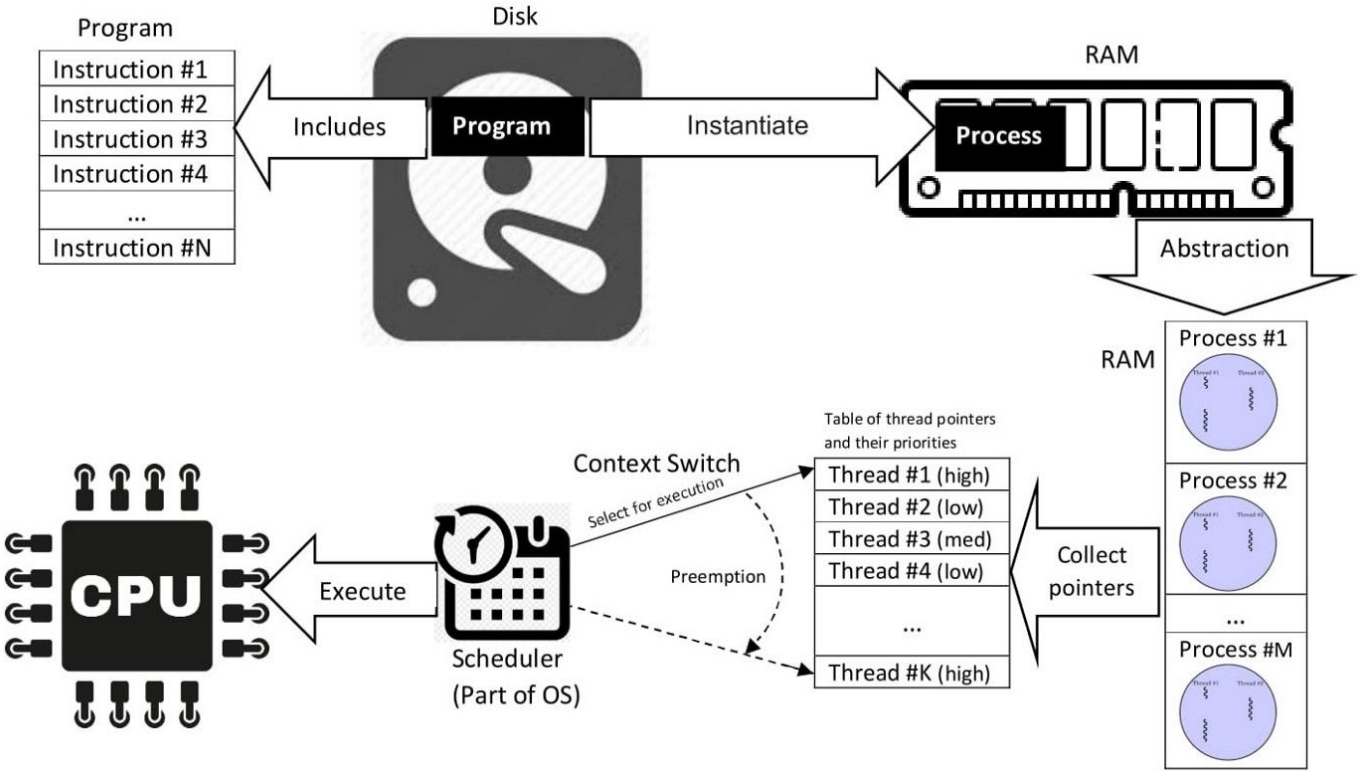
Single Processor Single Thread Single Processor Multithread Multiprocessing

https://towardsdatascience.com/multithreading-and-multiprocessing-in-10-minutes-20d9b3c6a867

Multiprocessing



Multiprocessing



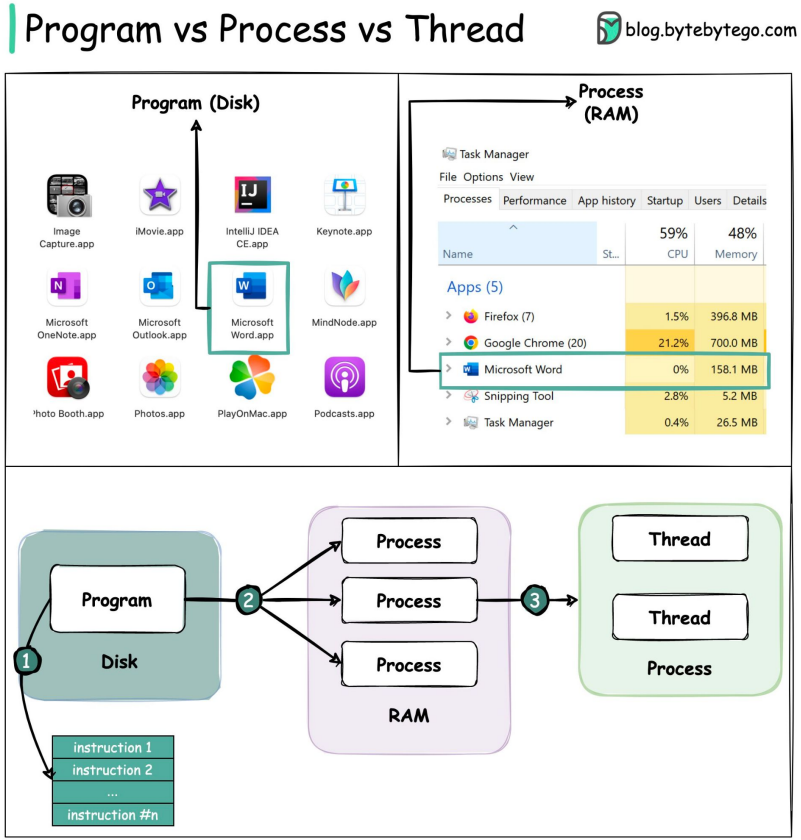
Recap & Summary

A ***Program*** is an **executable file** containing a set of instructions and stored passively on a disk.

A ***Process*** is the execution of those instructions after being loaded from the disk into memory. It is the instance of a computer program, a program in execution. One program can have multiple processes. For example, the Google Chrome browser creates an entirely separate process for every single tab or extra extension you are using.

A ***Thread*** is the smallest unit of execution within a process. One process can have multiple threads.

Recap & Summary



Useful Links

https://www.tutorialspoint.com/operating_system/index.htm

https://towardsdatascience.com/multithreading-and-multiprocessing-in-10-minutes-20d9b3c6a867

https://blog.bytebytego.com

What’s next?