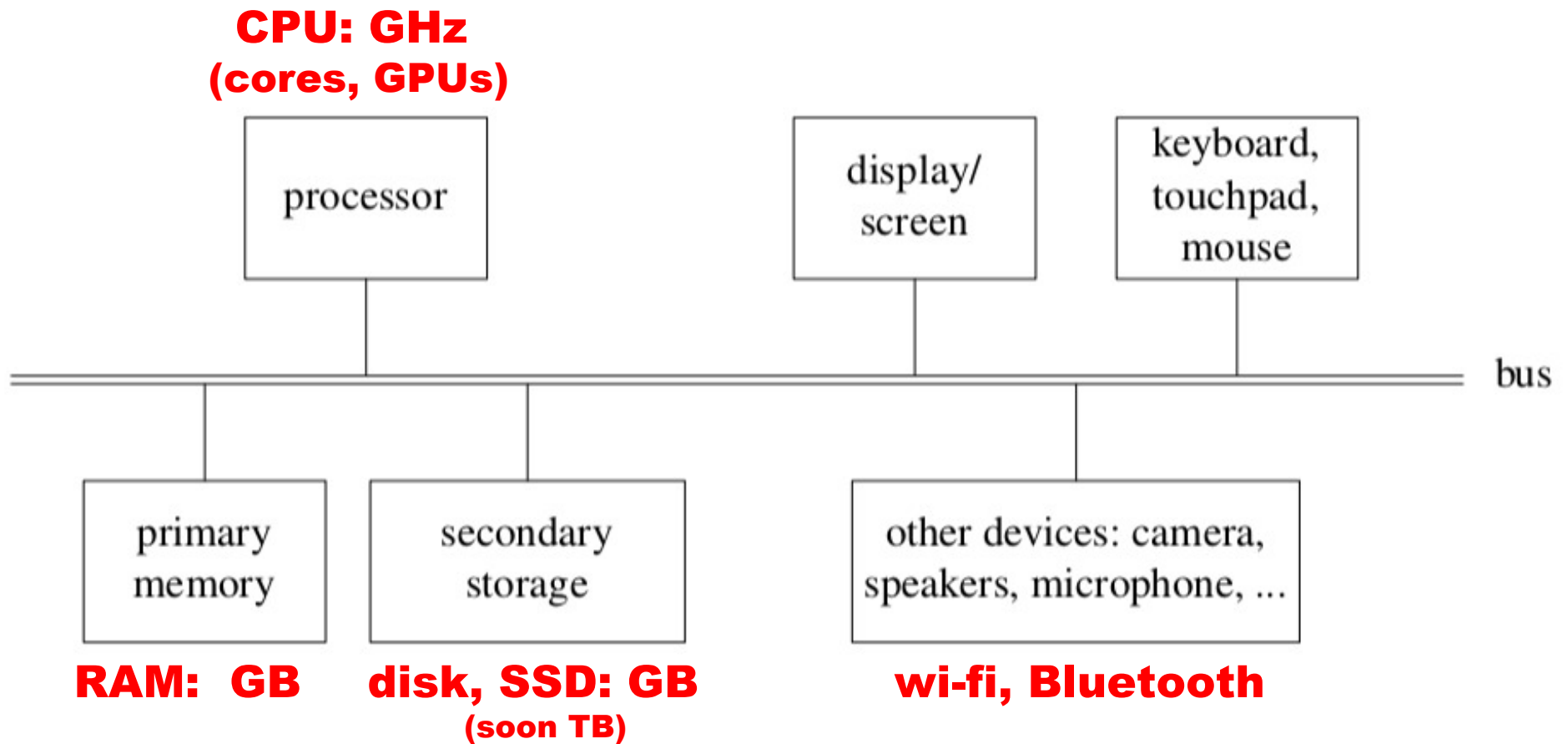# Lecture 2: What's in a computer?

- logical or functional organization: "architecture"
  - what the pieces are, what they do, how they work
  - how they are connected, how they work together
  - what their functional properties are

- physical structure
  - what they look like, how they are made

- major pieces
  - processor ("central processing unit" or CPU)
    - does the work, controls the rest
    - GPU ("graphics processing unit") speeds up some computations
  - primary memory (RAM = random access memory)
    - stores instructions and data while computer is running
  - secondary memory/storage (disk, drive, SSD)
    - stores everything even when computer is turned off
  - other devices ("peripherals"), especially wireless

Block diagram of a typical laptop computer

CPU: GHz
(cores, GPUs)

| processor | | display/ screen | keyboard, touchpad, mouse |

bus

| primary memory | secondary storage | | other devices: camera, speakers, microphone, ... |

RAM: GB   disk, SSD: GB   wi-fi, Bluetooth
(soon TB)

Phones are the same!

- basic structure is identical

- details vary a lot because of different purposes and tradeoffs

- different peripherals / devices
  - radio
  - GPS
  - accelerometers
  - compass
  - fingerprint sensor
  - multiple cameras

Processor (CPU, or Central Processing Unit)

- can perform a small set of basic operations ("instructions")
  - arithmetic: add, subtract, multiply, divide, …
  - memory access:
    fetch information from memory, store results back into memory
  - decision making: compare numbers, letters, …
    decide what to do next depending on result of previous computations
  - control the rest of the machine
    tell memory to send data to display; tell disk to read data from network; ...

- operates by performing sequences of simple operations _very_ fast

- instructions to be performed are stored in the same memory as the data is
  - instructions are encoded as numbers: e,g., Add = 1, Subtract = 2, ...

- the processor is a general-purpose device: putting different instructions into the memory makes it do a different task
  - this is what happens when you run different programs
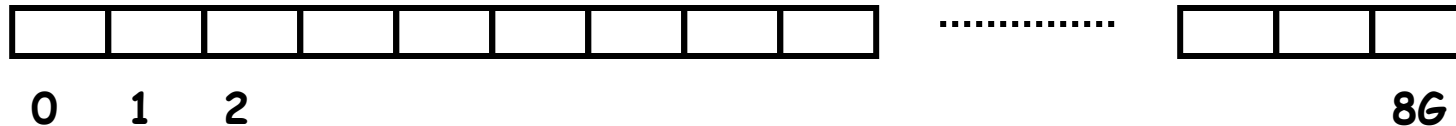
How fast is fast?

- CPU uses an internal "clock" (like a heartbeat) to step through instructions

- 900 MHz, 2.5 GHz, etc., is the number of clock ticks per second
  - 1 Hertz = 1 tick per second; abbreviated 1 Hz
  - mega = million = 10^6
  - giga = billion = 10^9
  - 1 MHz = 1 megaHertz = 1 million ticks per second
  - 1 GHz = 1 gigaHertz = 1 billion ticks per second = 1000 MHz

- one instruction (like adding two numbers) might take one, two or several ticks, depending on design of the CPU
  - or it might complete more than one instruction in one tick

- modern processors execute several billion instructions/sec

GPU: graphics processing unit

- **specialized processor, originally for graphics**
  - many specialized processors working in parallel on simple computations

    drawing things, e.g., for gaming

    video

    many other computations

    speech, image, motion, ...

- **works with, complements the CPU**
  - usually on the same chip as the CPU

Primary Memory (Random Access Memory = "RAM")

- a place to store information while the computer is running
    - the programs that are running
    - their data
    - the operating system (Windows, MacOS, Unix/Linux, ...)
- volatile: forgets everything when power is turned off
- limited (though large) capacity
- logically, a set of numbered boxes ("pigeonholes"?   mailboxes?)
    - each capable of storing one byte = 8 bits of information

        a small number or a single character like A or part of a larger value
    - random access

        CPU can access any location as quickly as any other location

```
┌──┬──┬──┬──┬──┬──┬──┬──┐  .............  ┌──┬──┬──┐
│  │  │  │  │  │  │  │  │                 │  │  │  │
└──┴──┴──┴──┴──┴──┴──┴──┘                 └──┴──┴──┘
 0    1    2                                      8G
```

What's a bit? What's a byte?

- a bit is the smallest unit of information
- represents one 2-way decision or a choice out of two possibilities
  - yes / no, true / false, on / off, up / down, ...
- abstraction of all of these is represented as 0 or 1
  - enough to tell which of TWO possibilities has been chosen
  - a single digit with one of two values
  - hence "binary digit"
  - hence bit
- binary is used in computers because it's easy to make
  fast, reliable, small devices that have only two states
  - high voltage/low voltage, current flowing/not flowing (chips)
  - electrical charge present/not present (Flash)
  - magnetized this way or that (disks)
  - light bounces off/doesn't bounce off (CD, DVD)

- all information in a computer is stored and processed as bits

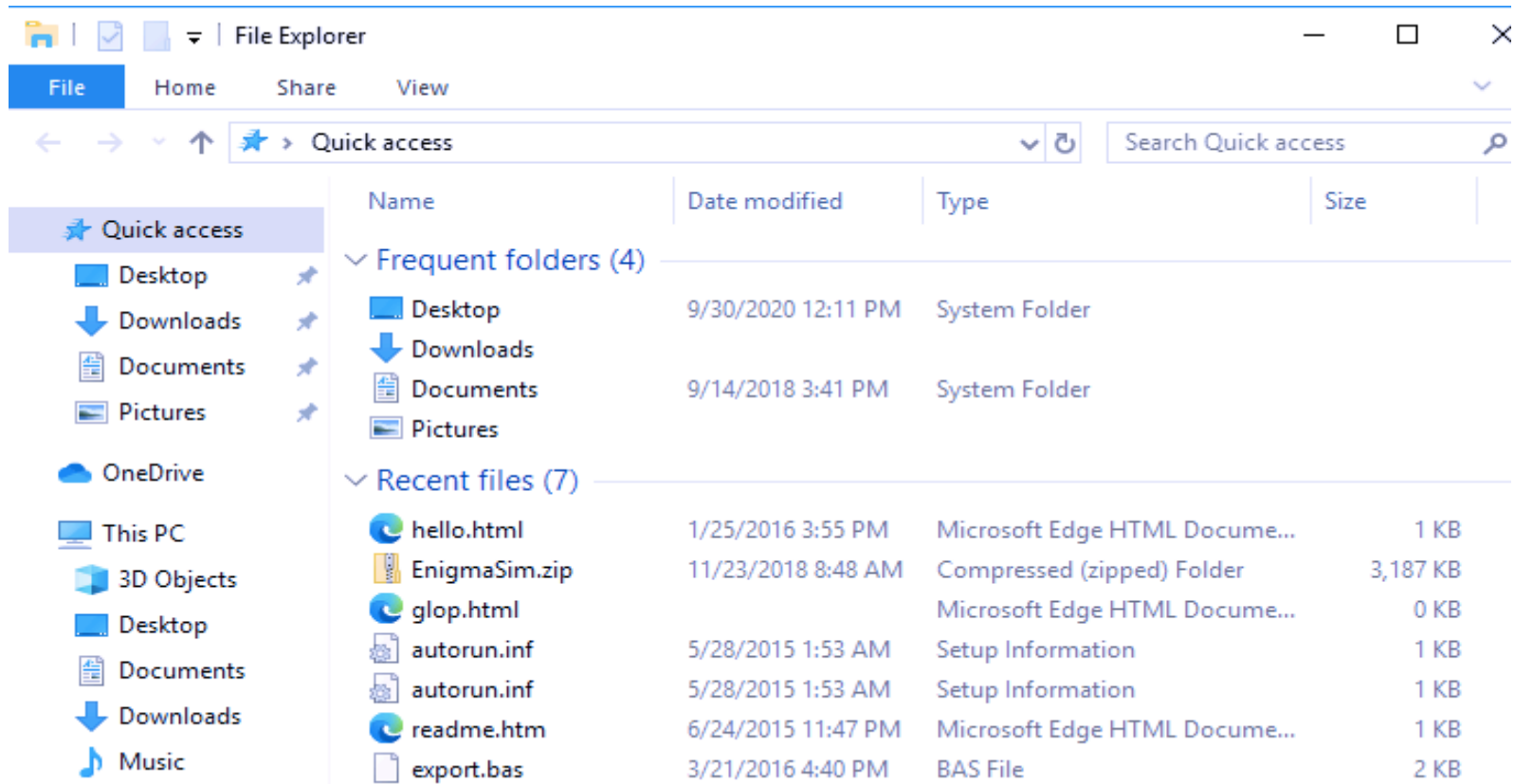- a byte is 8 bits that are treated as a unit

Disks

- a place to store information when the power is turned off
- used to be based on magnetic surfaces, rotating machinery
  - today, usually solid-state Flash memory (SSD)
- logical / functional structure: folders (directories) and files
  - your information: papers, mail, music, web page, …
  - programs and their data: Firefox, Word, iTunes, …
  - operating system(s): Windows, MacOS, Unix, Linux, ...
  - bookkeeping info: where things are physically located
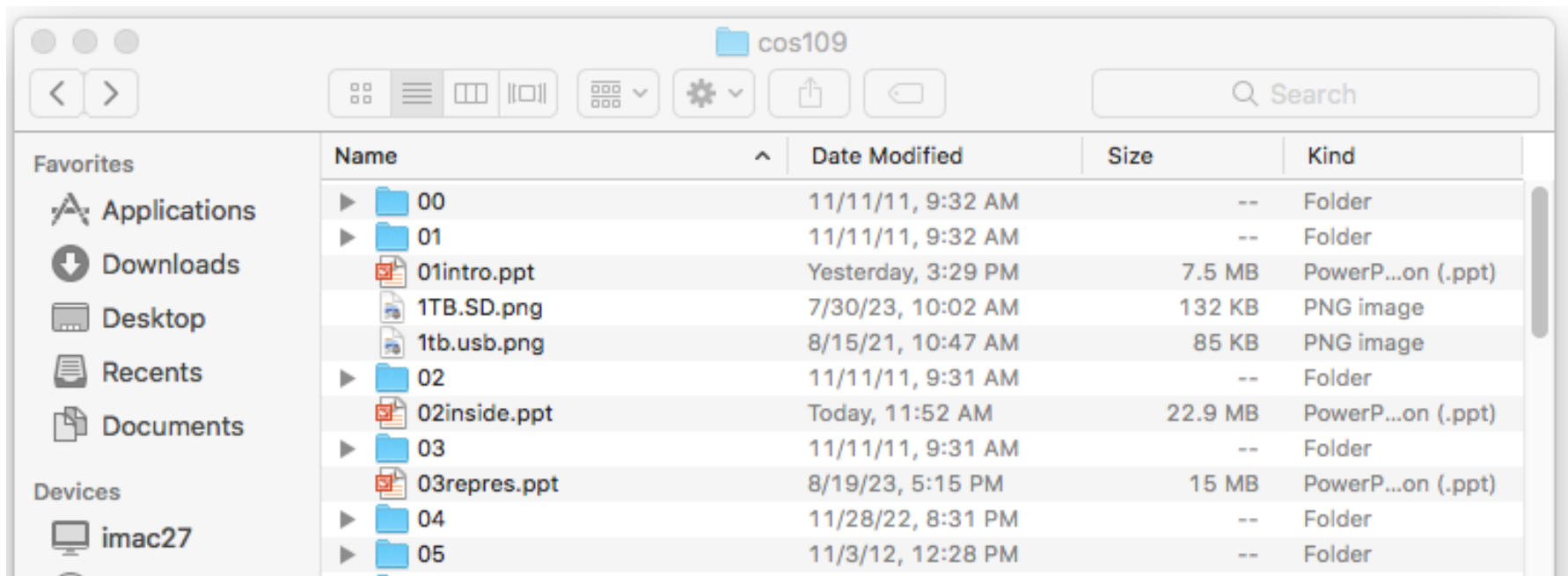
Other views of a disk: Windows, Unix/Linux

File Explorer — Quick access

Name	Date modified	Type	Size
∨ Frequent folders (4)			
Desktop	9/30/2020 12:11 PM	System Folder	
Downloads			
Documents	9/14/2018 3:41 PM	System Folder	
Pictures			
∨ Recent files (7)			
hello.html	1/25/2016 3:55 PM	Microsoft Edge HTML Docume...	1 KB
EnigmaSim.zip	11/23/2018 8:48 AM	Compressed (zipped) Folder	3,187 KB
glop.html		Microsoft Edge HTML Docume...	0 KB
autorun.inf	5/28/2015 1:53 AM	Setup Information	1 KB
autorun.inf	5/28/2015 1:53 AM	Setup Information	1 KB
readme.htm	6/24/2015 11:47 PM	Microsoft Edge HTML Docume...	1 KB
export.bas	3/21/2016 4:40 PM	BAS File	2 KB

```
[soak ~= ls -ltr | tail -8
-rw-r--r--.  1 bwk fac    325578 Sep  6 10:39 wam.out
-rw-r--r--.  1 bwk fac    171239 Sep  6 10:47 x.png
-rw-r--r--.  1 bwk fac     14063 Sep  6 17:47 calendar
-rw-r--r--.  1 bwk fac    817405 Sep  6 19:05 x.pdf
-rwxr-xr-x.  1 bwk fac     29685 Sep  6 19:16 bz
drwxr-xr-x.  2 bwk fac      2149 Sep  7 08:03 t
drwx------. 39 bwk fac      8157 Sep  7 08:33 cos109
drwx------.  2 bwk fac      2034 Sep  7 08:37 mail
```

Wrapup on components

- the logical or functional components of computer hardware

- how they fit together, what the numbers measure

- some Greek/Latin/... prefixes:
  - (...,) nano, micro, milli,   kilo, mega, giga, tera, (peta, ...)

- what the basic physical pieces look like

- one logical organization can have different physical forms
- logical organization hasn't changed much in 60+ years
- physical form has changed rapidly for the entire time
  - many tradeoffs among physical forms (size, weight, power, …)

Numeric prefixes you must know

nano	10^{-9}	billionth
micro	10^{-6}	millionth
milli	10^{-3}	thousandth
-	10^{0}	
kilo	10^{3}	thousand
mega	10^{6}	million
giga	10^{9}	billion
tera	10^{12}	trillion
peta	10^{15}	quadrillion
exa	10^{18}	quintillion