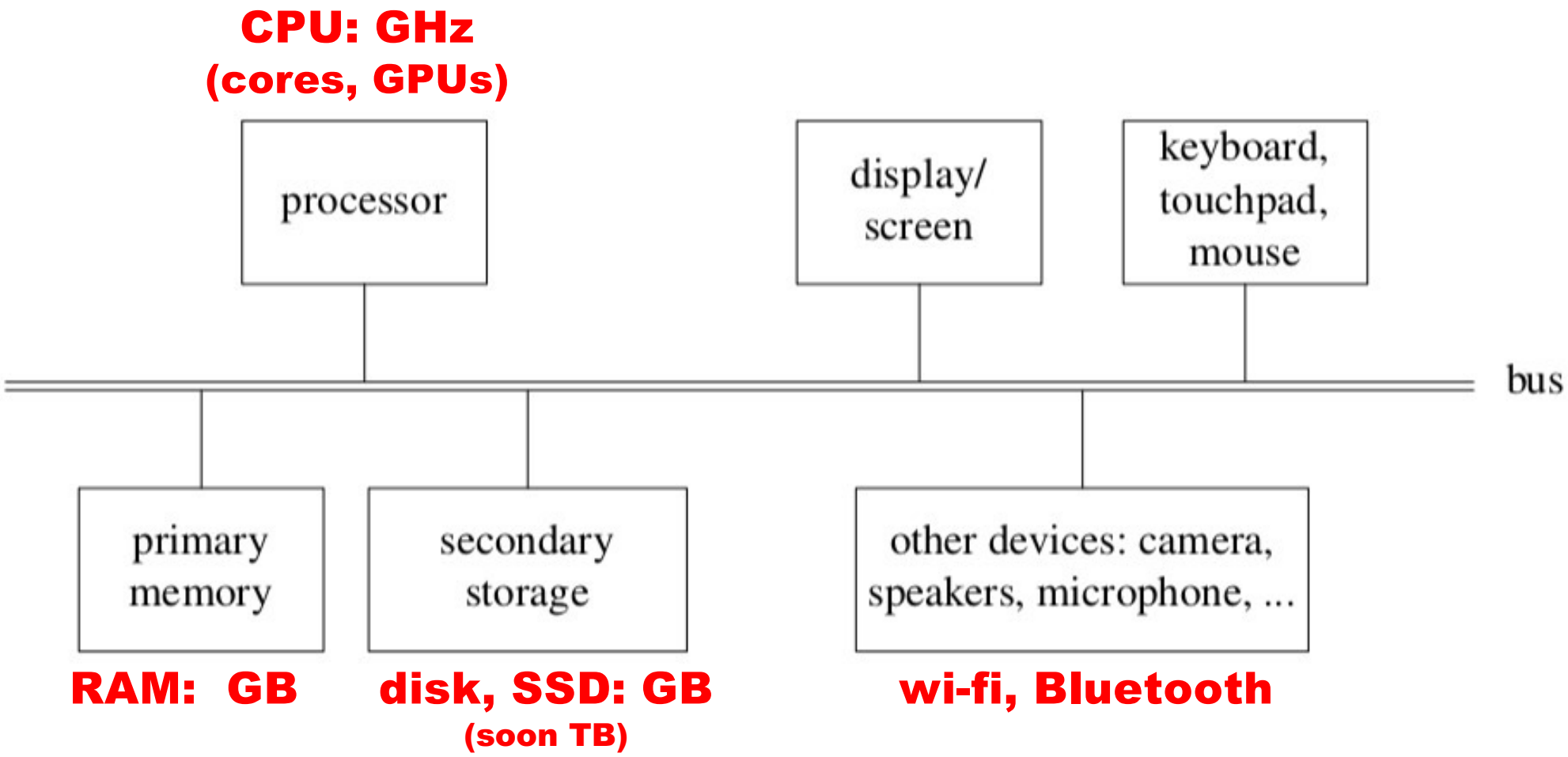
Lecture 2: What's in a computer?

- **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



Phones are the same!

- **basic architecture is identical**
- **details vary a lot because of different purposes and tradeoffs**
- **different peripherals / devices**
  - more 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 billions of instructions/sec**
  - not terribly well defined

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, ...

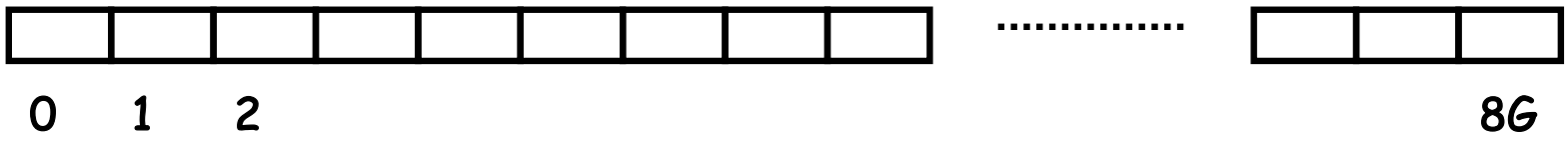
- **works with, complements the CPU**
  - usually on the same chip as the CPU

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

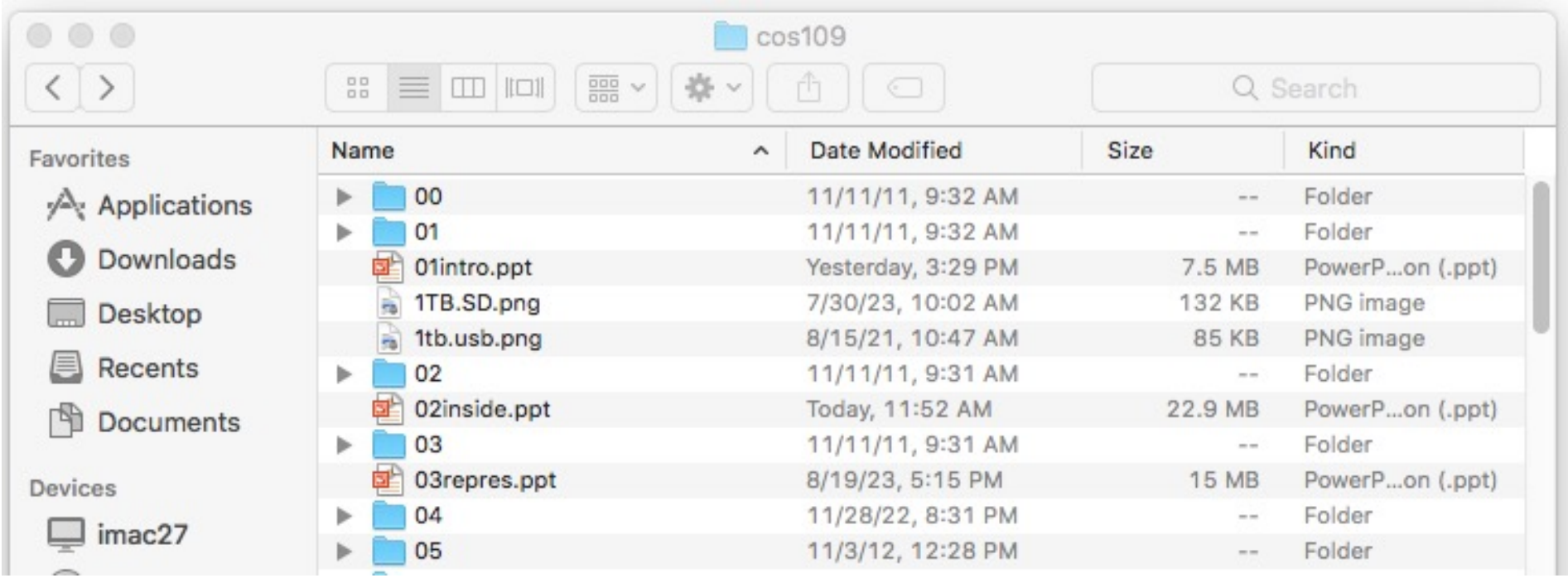


What's a bit? What's a byte?

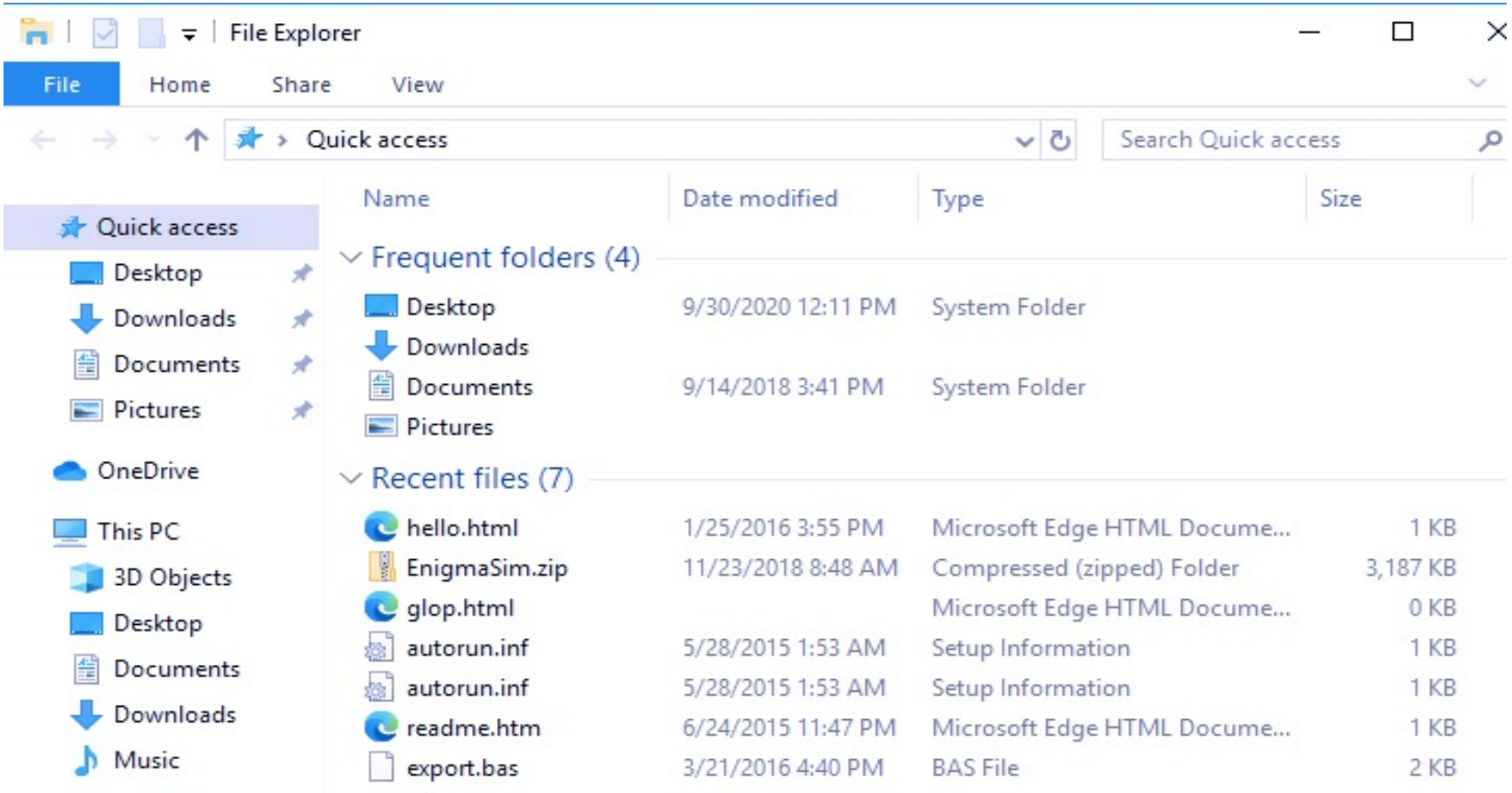
- **a bit is the smallest unit of information**
- **represents one 2-way decision or a choice out of two possibilities**
  - yes / no, true / false, on / off, up / down, ...
- **abstraction of all of these is represented as 0 or 1**
  - enough to tell which of TWO possibilities has been chosen
  - a 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




```
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