# 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
  - 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

# Hardware: tangible devices and gadgets

- **how computers represent and process information**
  - universal digital representation of information:
    everything is represented as numbers
  - bits, bytes, binary numbers

- **a computer is a universal digital processor**
  - it stores data and instructions in the same memory
  - the instructions are numbers
  - it's a general purpose machine:
    change the numbers and it does something different
  - your phone is a computer

- **hardware has been getting smaller, cheaper, faster exponentially for 60+ years**

# 2023 freshman computer

Apple - MacBook Air 13.3" Laptop with Touch ID - Intel Core i5 - 8GB Memory - 256GB Solid State Drive (Latest Model) - Space Gray

Model: MVFJ2LL/A SKU: 6356923

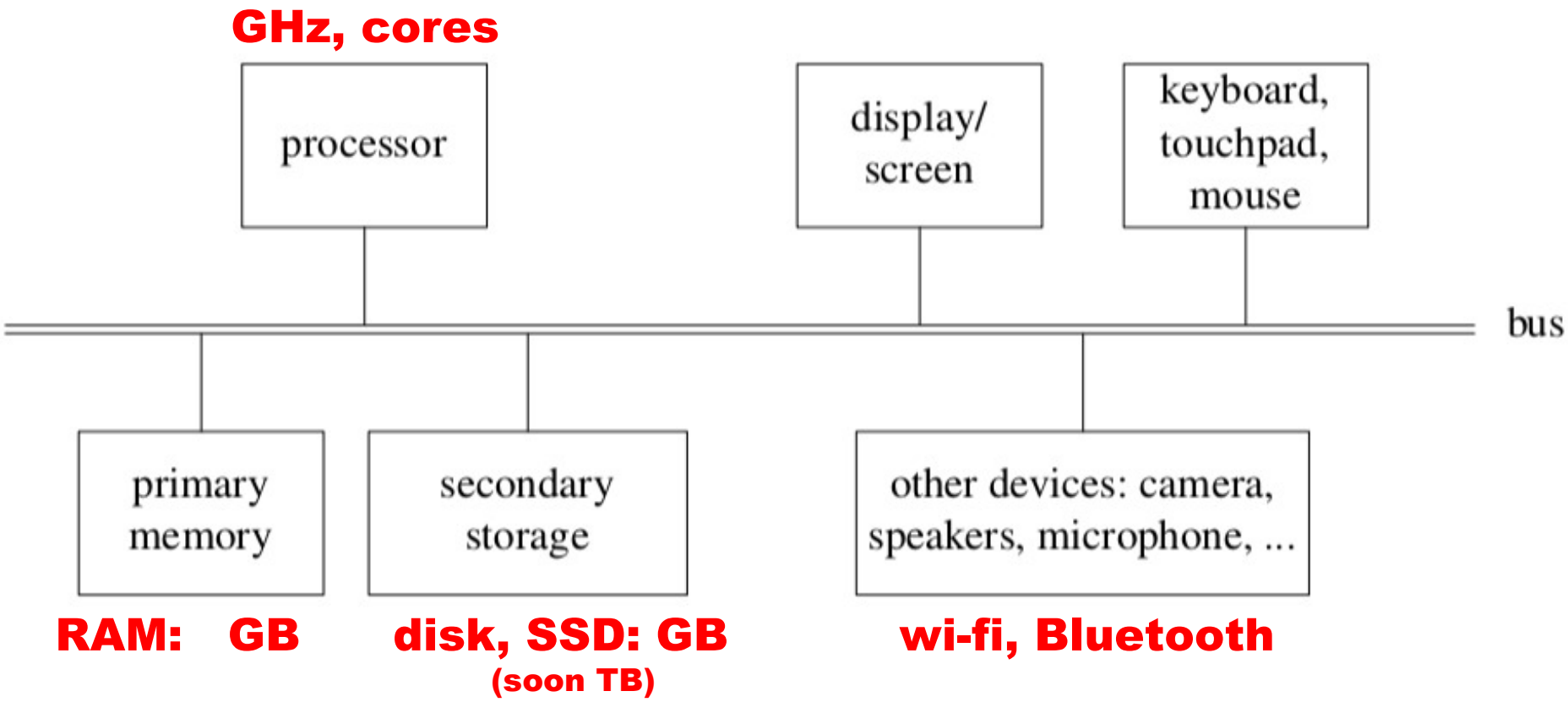
Price Match Guarantee

$1,099.99 c

Save $200

| | | |
|---|---|---|
| **Solid State Drive Capacity** | → | 256 gigabytes |
| **System Memory (RAM)** ⓘ | → | 8 gigabytes |
| **Graphics** | | Intel Iris Plus Graphics 640 |
| **Processor Speed (Base)** ⓘ | → | 2.3 gigahertz |
| **Processor Model** ⓘ | → | Intel 7th Generation Core i5 |
| **Processor Model Number** | | Not Available |
| **Operating System** ⓘ | → | Mac OS |
| **Battery Life** ⓘ | | 10 hours |
| **Battery Type** | | Lithium-polymer |

# Block diagram of a typical laptop computer



# 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
  - giga = billion
  - 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 games
    - video
    - many other computations
      - speech, image, motion, ...

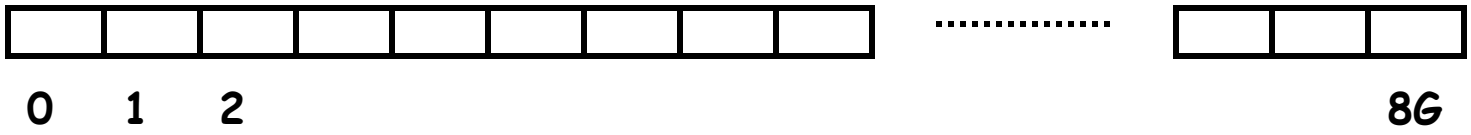
- works with, complements the CPU
  - often on the same chip as the CPU

# 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

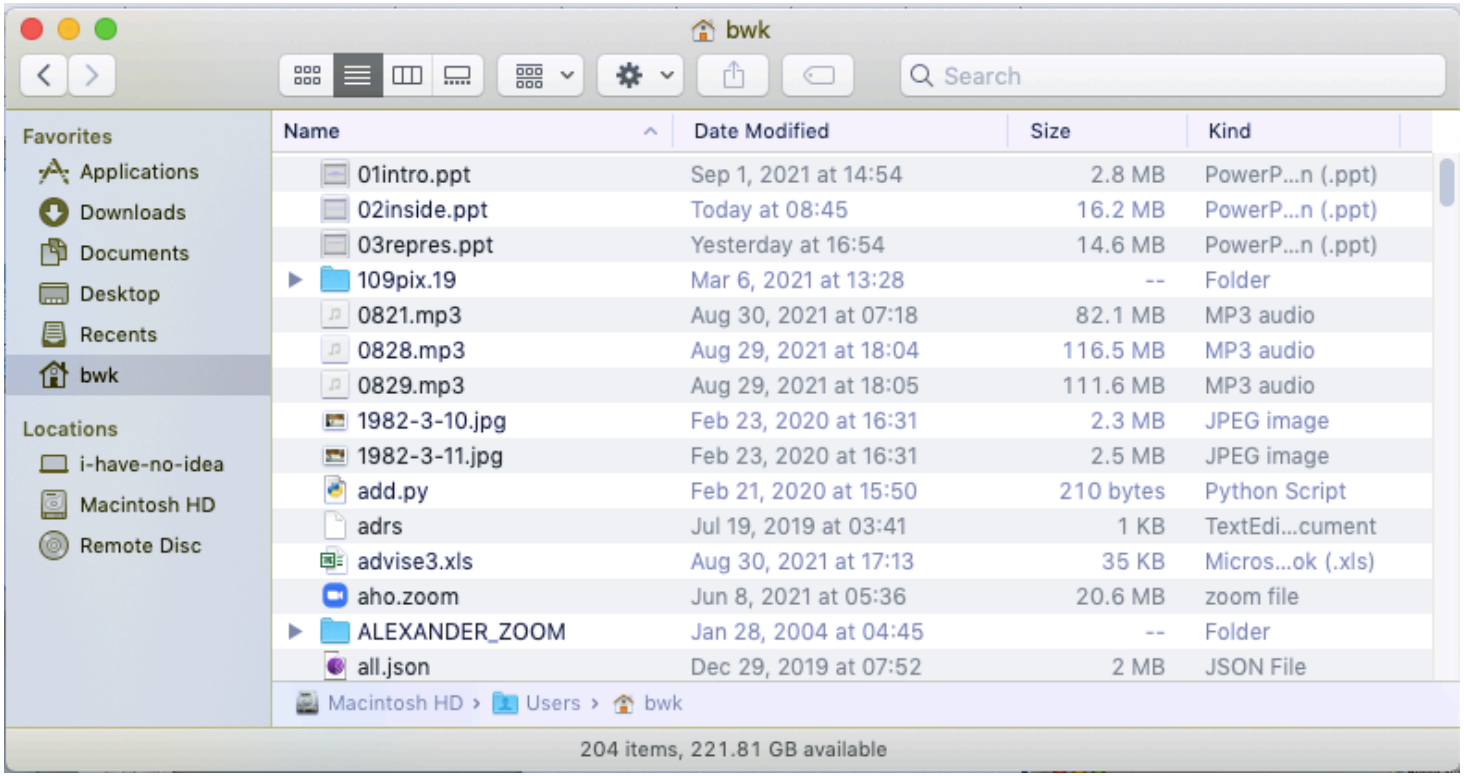


# What's a bit?  What's a byte?

- 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
- was based on magnetic surfaces, rotating machinery
  - today, more often 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



# 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, …)

# Some 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 |