COS 109
Lecture 2: What is a computer?
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 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 (disk, drive, SSD)
    stores everything even when computer is turned off
  - other devices ("peripherals")
Freshman SCI computer for class of 2023

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

- **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

Price: $1,099.99

Price Match Guarantee
Save $200
2009 freshman offering:

**Apple iBook**
- 1.33Ghz G4 PowerPC processor
- 12.1" viewable display
- ATI Mobility Radeon 9550 with 32MB
- 512MB RAM, 1 DIMMs
- 60GB hard drive, 4200RPM
- 4.9 lbs.
- AirPort Extreme Card included (802.11 b/g)
- Bluetooth included
- DVD/CD-RW Combo drive
- up to 6 hours of battery life
- Built-in Ethernet and Modem
- Built-in sound and speakers
Block diagram of a typical laptop computer

- Processor
- Display/screen
- Keyboard, touchpad, mouse
- Primary memory
- Secondary storage
- Other devices: camera, speakers, microphone, ...
Motherboard (~1998)
Backplane (~1998)
Processor or CPU (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
“I wish to God these calculations had been executed by steam.” (1821)

Charles Babbage
1791–1871
Ada Byron, Countess Lovelace

the world's first programmer?
John von Neumann and the Johnniac (1953)
IBM 7090 (e.g., at Princeton in 1964)
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
  – might even complete more than one instruction in one tick

• modern processors execute several billion instructions/sec
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, Mac OS X, 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-rom, 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
Other views of a disk: Windows, Unix/Linux

bash-3.00$ ls -l tr | tail -8
-rw-r--r-- 1 bwk fac  3283 Sep 19 08:10 survey.html
-rw-r--r-- 1 bwk fac  6034432 Sep 20 10:43 01intro.ppt
-rw-r--r-- 1 bwk fac   6870 Sep 20 10:54 psl.html
-rw-r--r-- 1 bwk fac   2803 Sep 21 08:09 rita.09
-rw-r--r-- 1 bwk fac   7101 Sep 21 09:49 ideas.09
-rw-r--r-- 1 bwk fac  21766 Sep 21 13:55 index.html
-rw-r--r-- 1 bwk fac  143872 Sep 22 15:35 grades09.xls
-rw-r--r-- 1 bwk fac   3161 Sep 22 15:44 surveyresults.html
2.5" laptop disk
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 should know

<table>
<thead>
<tr>
<th>Prefix</th>
<th>Symbol</th>
<th>Value</th>
<th>Multiplier</th>
</tr>
</thead>
<tbody>
<tr>
<td>nano</td>
<td>n</td>
<td>$10^{-9}$</td>
<td>billionth</td>
</tr>
<tr>
<td>micro</td>
<td>µ</td>
<td>$10^{-6}$</td>
<td>millionth</td>
</tr>
<tr>
<td>milli</td>
<td>m</td>
<td>$10^{-3}$</td>
<td>thousandth</td>
</tr>
<tr>
<td>-</td>
<td></td>
<td>$10^0$</td>
<td></td>
</tr>
<tr>
<td>kilo</td>
<td>k</td>
<td>$10^3$</td>
<td>thousand</td>
</tr>
<tr>
<td>mega</td>
<td>M</td>
<td>$10^6$</td>
<td>million</td>
</tr>
<tr>
<td>giga</td>
<td>G</td>
<td>$10^9$</td>
<td>billion</td>
</tr>
<tr>
<td>tera</td>
<td>T</td>
<td>$10^{12}$</td>
<td>trillion</td>
</tr>
<tr>
<td>peta</td>
<td>P</td>
<td>$10^{15}$</td>
<td>quadrillion</td>
</tr>
</tbody>
</table>
THE YEAR 3000 (B.C.)
I'll still keep a bunch of rocks in my basement, just in case...

THERE IS MORE COMPUTING POWER IN THIS LITTLE ABACUS THAN IN ALL THE GIANT ROCKS WE MOVE AROUND TO DO ADDITION.

OOOOOH!