Memory, Data, & Addressing I

CSE 351 Summer 2021

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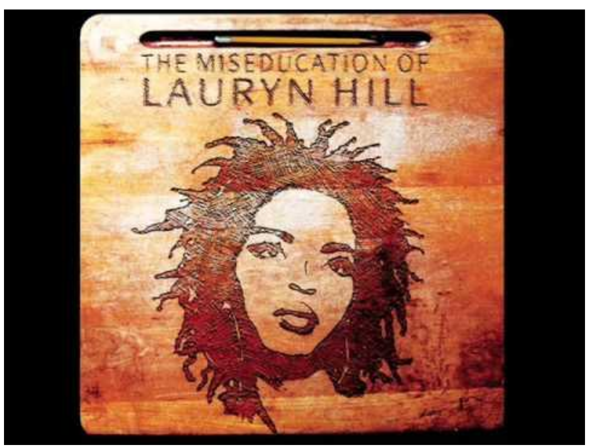

Questions in Lecture

- Ohyay is new for us too!
  - Help us make this course phenomenal
- Questions in “Questions” pane, staff will respond in chat, then remove the question
  - ”Questions” got a bit cluttered on Monday
  - Keep an eye on chat! See if someone’s asked your question!

Gentle reminders!

- Pre-Course Survey and hw0 due tonight @ 8pm
- hw1 due Friday (6/25) @ 8pm
- Lab 0 due Monday (6/28) @ 8pm
  - This lab is *exploratory* and looks like a hw; the other labs will look a lot different (involve writing code etc.)
  - Don't worry if everything in Lab 0 doesn't make perfect sense right now! We'll continue to cover everything in more detail
  - Lab 0: get used to modifying and running C code to see the output
    - A powerful tool for understanding the technical concepts in this course!
- Readings should be completed by 10am on day of lecture
- Lecture activities should be completed by 10am of NEXT lecture

2021

How’d the reading go?

Unit Summaries

- No exams this quarter! Yay!
- We're doing something else instead…

Unit Summaries*

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- 3 Tasks per Summary (we’ll have 3 total):
  1. Create a floorplan (4-5 hours)
  2. Reflect on your learning (30min)
  3. Answer a few “exam-style” questions (30min)

- *this is reiterating http://cs.uw.edu/351/unit_summaries, look there for complete details

Task 1: Create a Floorplan

- We're treating units as "floors" in the HoC
- What would the floorplan for this "floor" look like?
  - Schematics, drawings, sketches, whatever format works for you!
- Good CS Folks™ work to understand socio-technical context!
  - Demonstrate technical & socio-technical understanding!
- You'll also submit:
  - A design doc that justifies your decisions
  - How long this all took you
  - *See the website for details*

Task 1: Design

- This is a design task!
  - There isn't a clear, correct answer!
- **Design Requires Iteration and Feedback!**
  - Well-scoring Task 1s probably tried a few things out
- Key Idea: Prototyping
  - *Roughly sketch a few ideas*, then pick one to work on
- Get feedback on prototypes and early iterations!
  - We'll have some in-class time, ask for feedback in OH
  - Small-group work ok, but *your final design should represent your synthesis, words, and design*
  - We can't grade in advance, but we can critique

Task 1: Evaluation Criteria

- **Completeness:** Did you cover everything?
  - Are omissions justified?
- **Cohesion:** Do things fit together sensibly?
  - We'll be gentle, we understand it isn't a perfect fit
- **Clarity**: Can we understand you?
  - Have you worked through meaningful iterations? Does this seem polished for 4-5 hours of work?
- **Creativity:** Does your floorplan feel uniquely yours?
- We're not grading on conventional artistic skill!
  - Be unconventional! We're cool with that!

Task 1: Qualification

- This is different than anything from my undergrad
  - Probably different from most CSE courses as well
- **I want to try this at least once!**
- No examples, but we're here to help!

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- **I want to try this at least once!**
- No examples, but we're here to help!
- If you're not sure where to start, that's ok!
  - Design tasks usually feel this way
- **Most of the work you do after college will be a design task!**
  - No examples, no clear answers, requiring creativity and justification
  - Hopefully, this is good preparation 😊

Unit Summary: Call to Action

- Start thinking about how these pieces fit together!
  - Start now! It’ll save you time! 😁
- Reach out if you have concerns/questions!
  - This is an experiment*, I’d like it to be a good one
- Demonstrate your socio-technical understanding!

- *an experiment that’s based in best-practices in education

2021

"It is creative apperception more than anything else that makes the individual feel that life is worth living. Contrasted with this is a relationship to external reality which is one of compliance, the world and its details being recognized but only as something to be fitted in with or demanding adaption.

2021

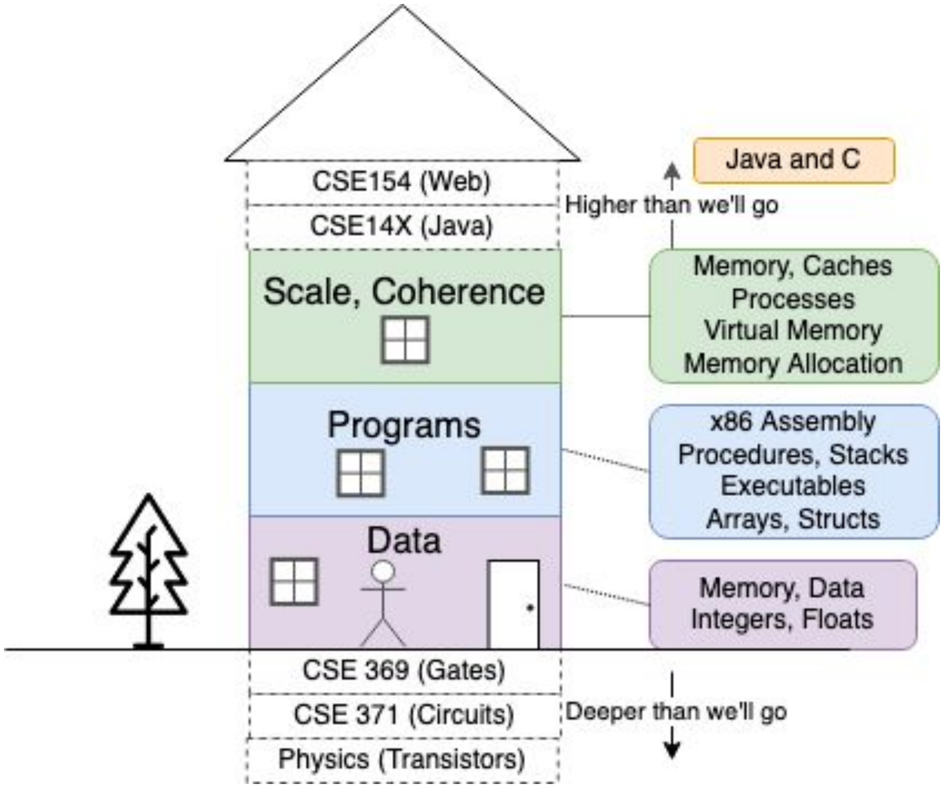
"It is creative apperception more than anything else that makes the individual feel that life is worth living. Contrasted with this is a relationship to external reality which is one of compliance, the world and its details being recognized but only as something to be fitted in with or demanding adaption. Compliance carries with it a sense of futility for the individual and is associated with the idea that nothing matters and life is not worth living. In a tantalizing way, many individuals have experienced just enough of creative living to recognize that for most of their time they are living uncreatively, as if caught up in the creativity of someone else, or of a machine" (p87).

D.W. Winnicott

First Floor: Data

- How do we represent data (strings, numbers) computationally?
- What limits exist? Why?
- What values were encoded into data representations?
- What was prioritized? Why?

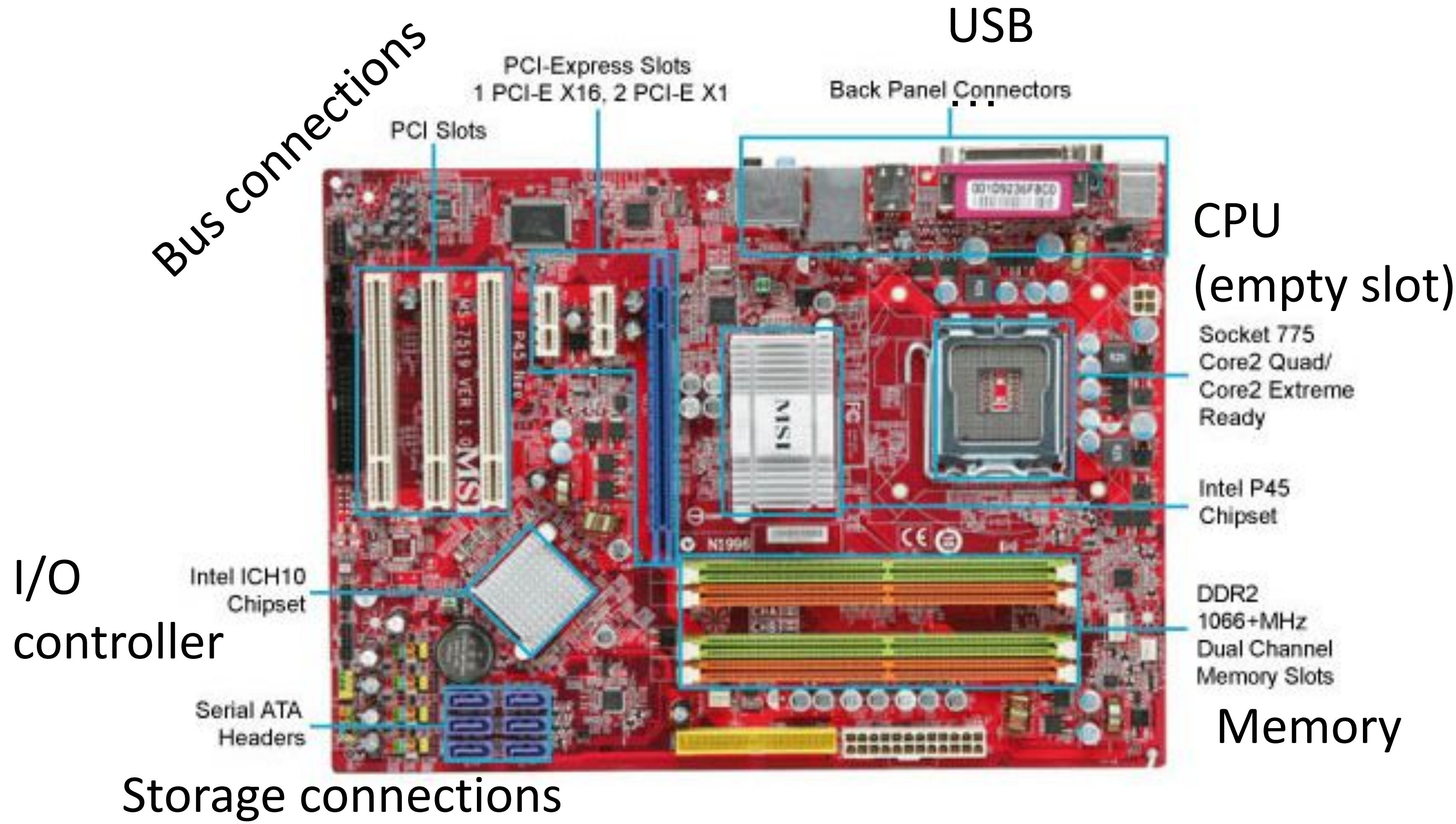
- Today: Memory!



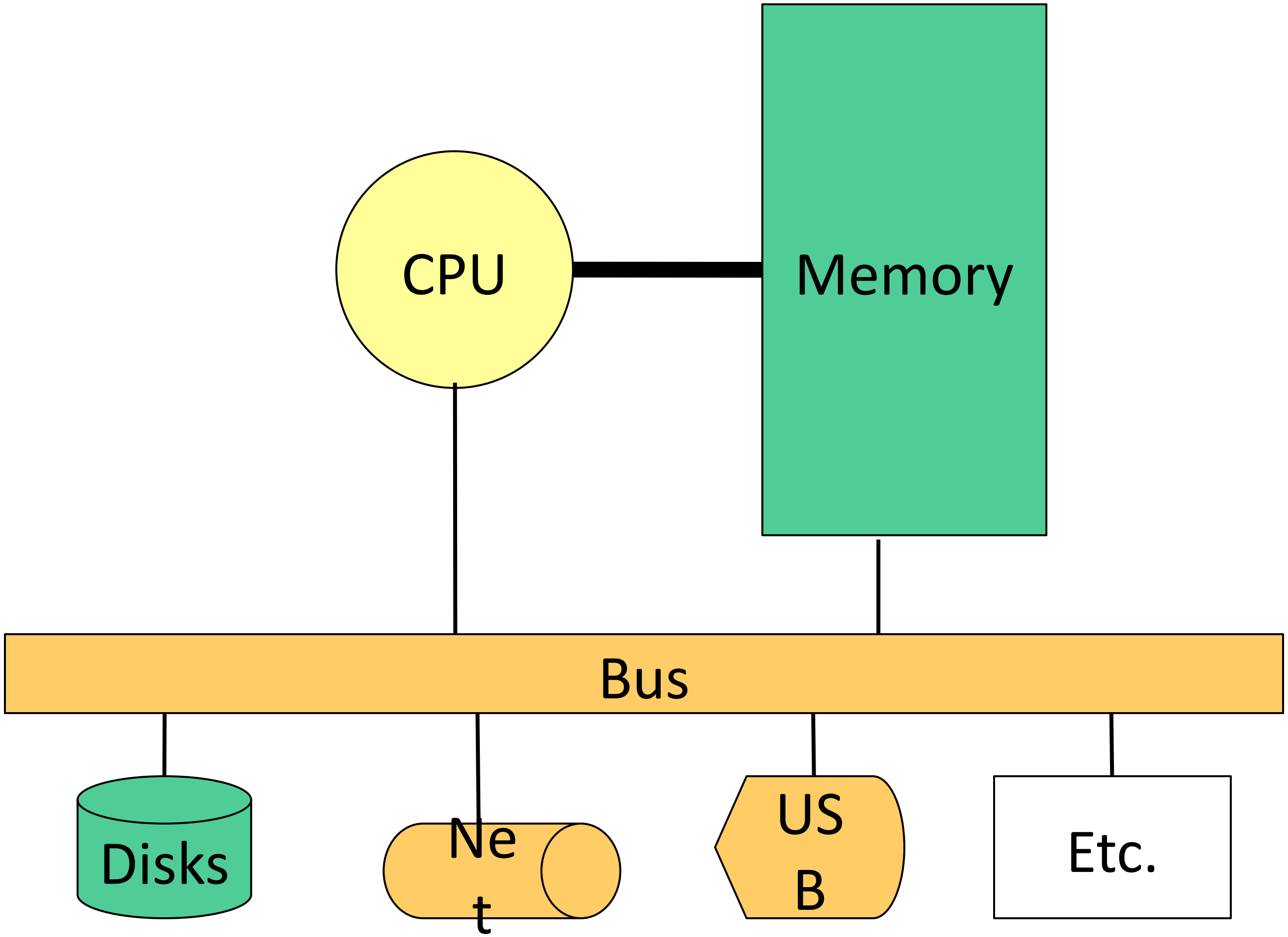
Memory, Data, and Addressing

- Hardware - High Level Overview
- Representing information as bits and bytes
  - Memory is a byte-addressable array
  - “Word” size = address size = register size
- Organizing and addressing data in memory
  - Endianness – ordering bytes in memory
- Manipulating data in memory using C
- Boolean algebra and bit-level manipulations
- *How do we store information for other floors and systems to access?*

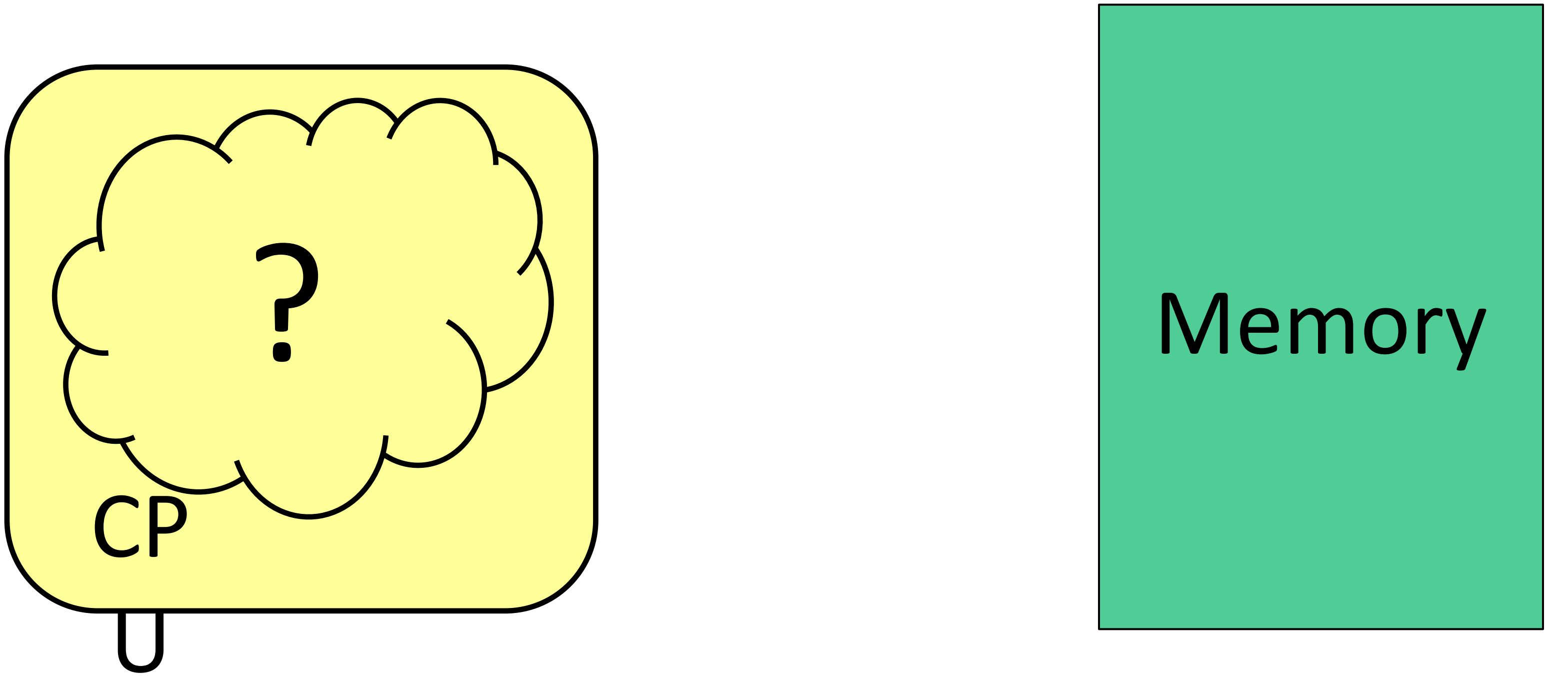
(Modern) Hardware: Physical View



(Modern) Hardware: Logical View



Hardware: 351 View (version 0)



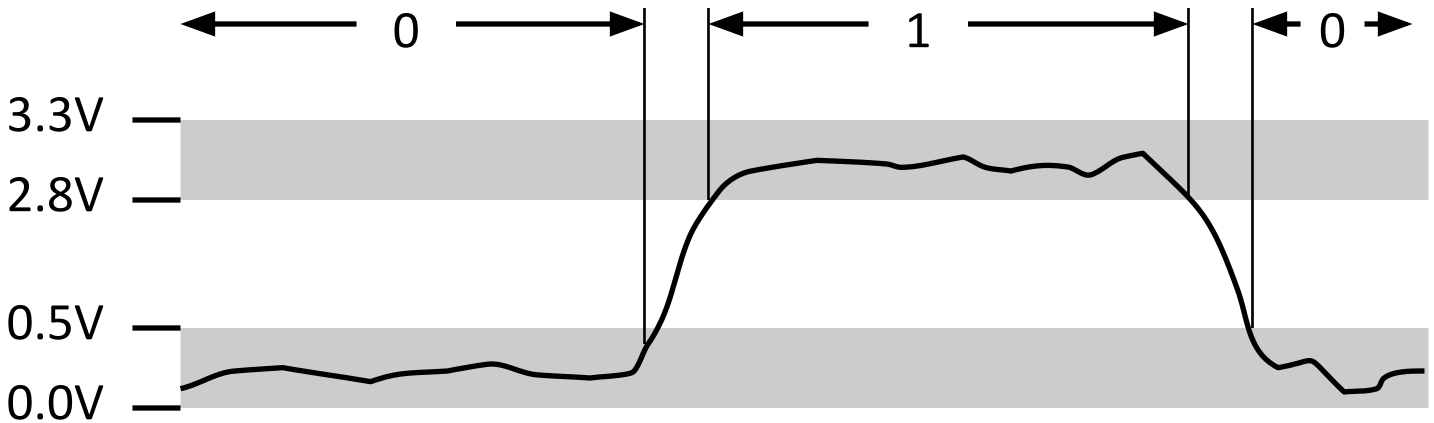
- The CPU **executes** instructions
- Memory **stores** data

How are data and instructions represented?

- Binary encoding!
  - Instructions *are* just data

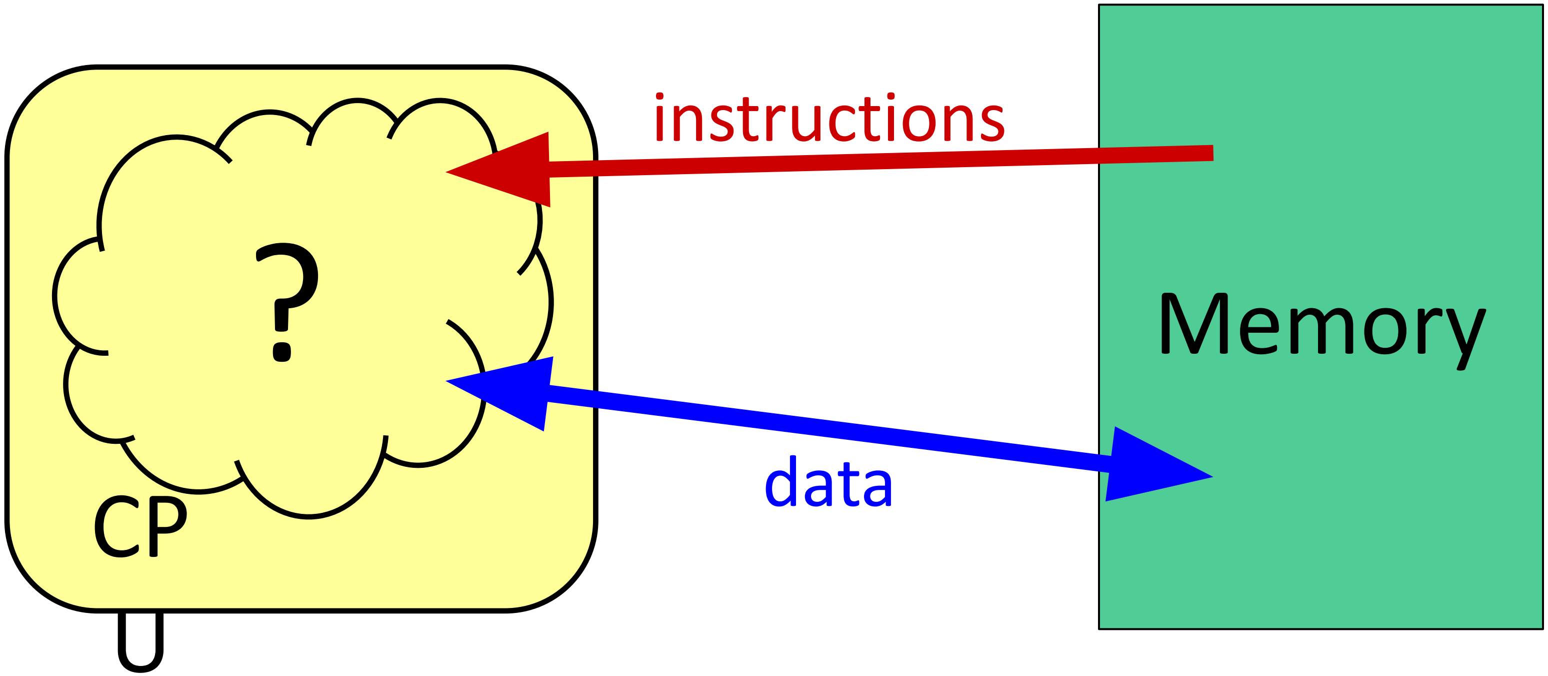
Aside: Why Base 2?

- Electronic implementation
  - Easy to store with bi-stable elements
  - Reliably transmitted on noisy and inaccurate wires



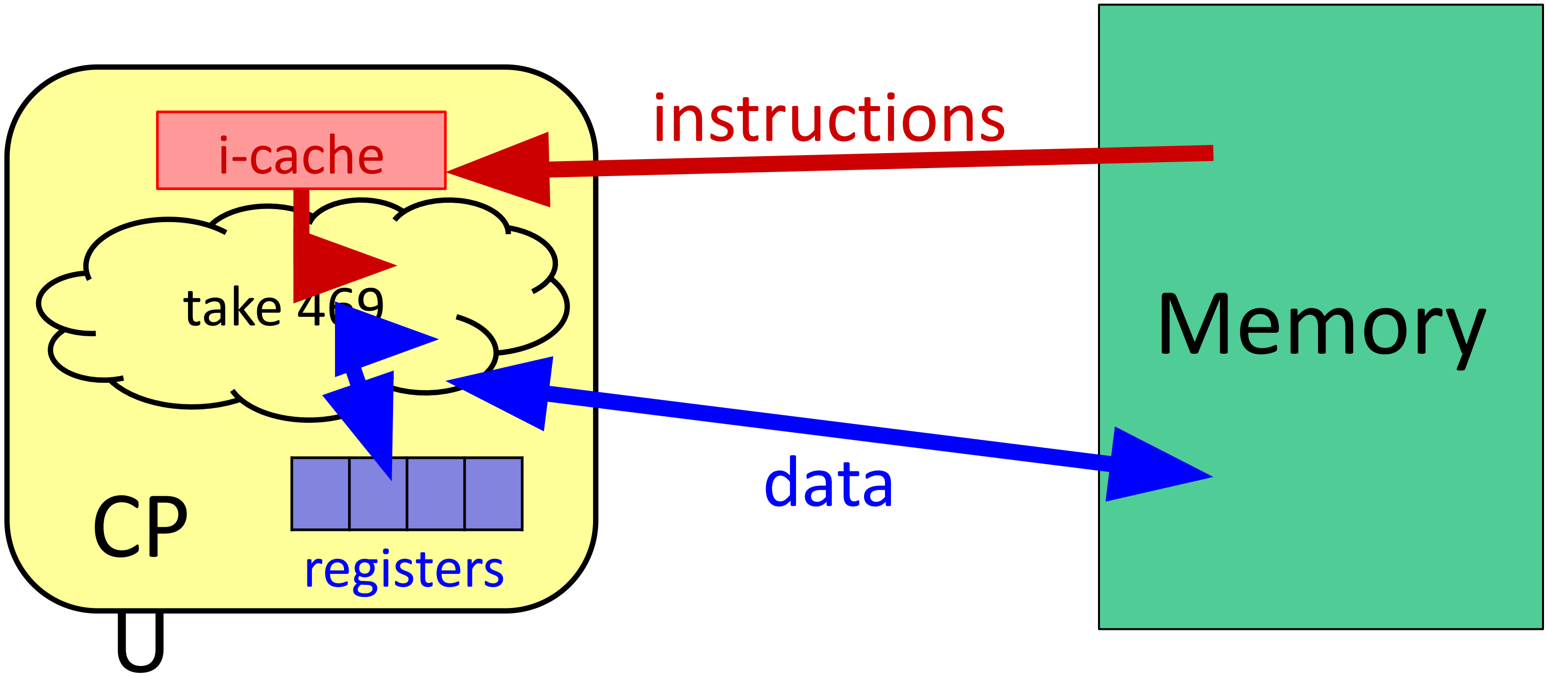
- Other bases possible, but not yet viable:
  - DNA data storage (base 4: A, C, G, T) is hot@UW
  - Quantum computing

Hardware: 351 View (version 0)



- To execute an instruction, the CPU must:
  1) Fetch the instruction
  2) (if applicable) Fetch data needed by the instruction
  3) Perform the specified computation
  4) (if applicable) Write the result back to memory

Hardware: 351 View (version 1)



- More CPU details:
  - Instructions are held temporarily in the instruction cache
  - Other data are held temporarily in registers
- Instruction fetching is hardware-controlled
- Data movement is programmer-controlled (assembly)

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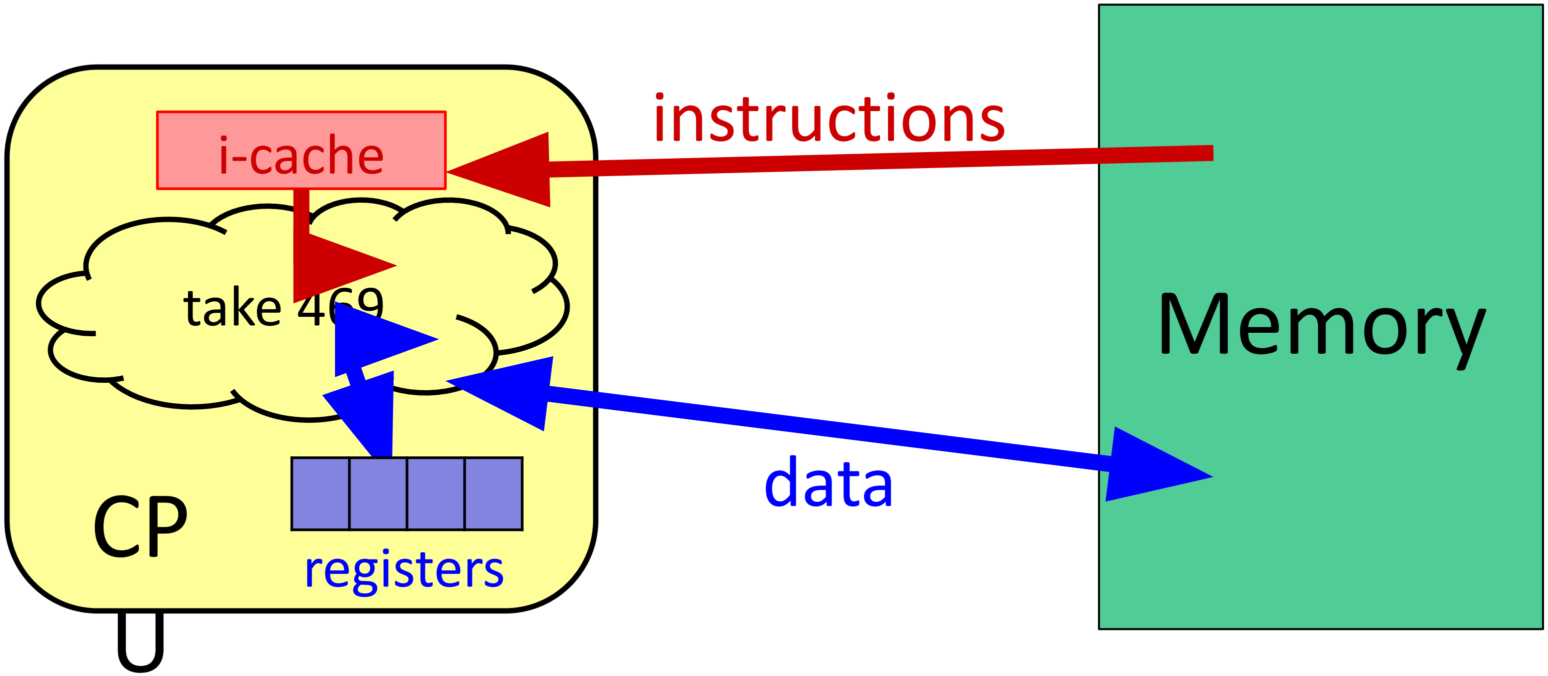

- Let's start with memory!

How does a program find its data in memory?

Review Questions

- By looking at the bits stored in memory, I can tell what a particular 4 bytes is being used to represent.

🤖 True 🏠False 🥶 Help!

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Review Questions

- By looking at the bits stored in memory, I can tell what a particular 4 bytes is being used to represent.

  🤖 True 🏠 False 🥶 Help!

- We can fetch a piece of data from memory if we have its address.

  🤖 True 🏠 False 🥶 Help!

- Which of the following *bytes* have a most-significant bit (MSB) of 1?

  🤖 0x63 🏠 0x90 💡 0xCA ✨ 0xF 🥶 Help!

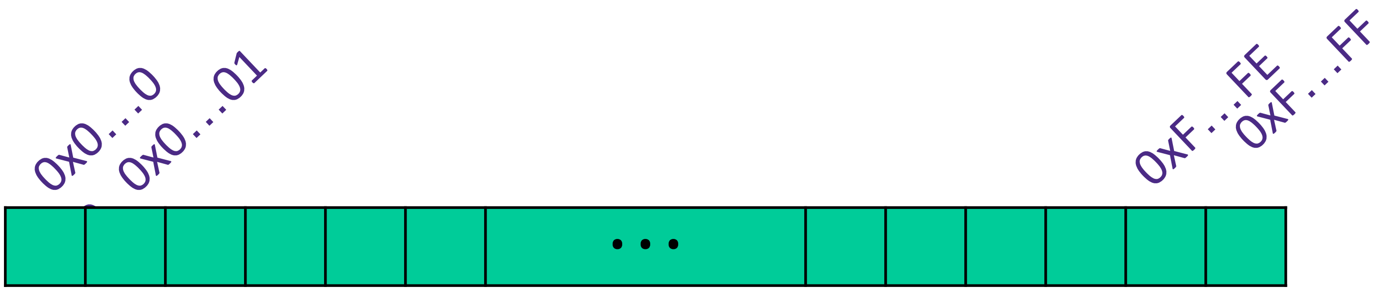
Binary Encoding Additional Details

- Because storage is finite in reality, everything is stored as "fixed" length
  - Data is moved and manipulated in fixed-length chunks
  - Multiple fixed lengths (*e.g.* 1 byte, 4 bytes, 8 bytes)
  - Leading zeros now *must* be included up to "fill out" the fixed length
- Example: the "eight-bit" representation of the number 4 is 0b00000100

Least Significant Bit (LSB)

Most Significant Bit (MSB)

Addresses refer to Bytes of Memory!



- Conceptually, memory is a single, large array of bytes, each with a unique *address* (index)
  - Each address is just a number represented in *fixed-length* binary
- Programs refer to bytes in memory by their *addresses*
  - Domain of possible addresses = *address space*
  - We can store addresses as data to "remember" where other data is in memory
- But not all values fit in a single byte… (*e.g.* 351)
  - Many operations use multi-byte values

Machine "Words"

- Instructions encoded into machine code (binary)
  - Historically (still true in some assembly languages), all instructions were exactly the size of a word
- We chose to match word size to address size
  - word size = address size = register size
  - word size = w bits → 2^w addresses
- Current x86 systems use **64-bit (8-byte) words**
  - Potential address space: 2^{64} addresses
    2^{64} bytes ≈ **1.8 x 10^{19} bytes**
    = 18 billion billion bytes = 18 EB (exabytes)
  - Actual physical address space: **48 bits**

Data Representations

- Sizes of data types (in bytes)

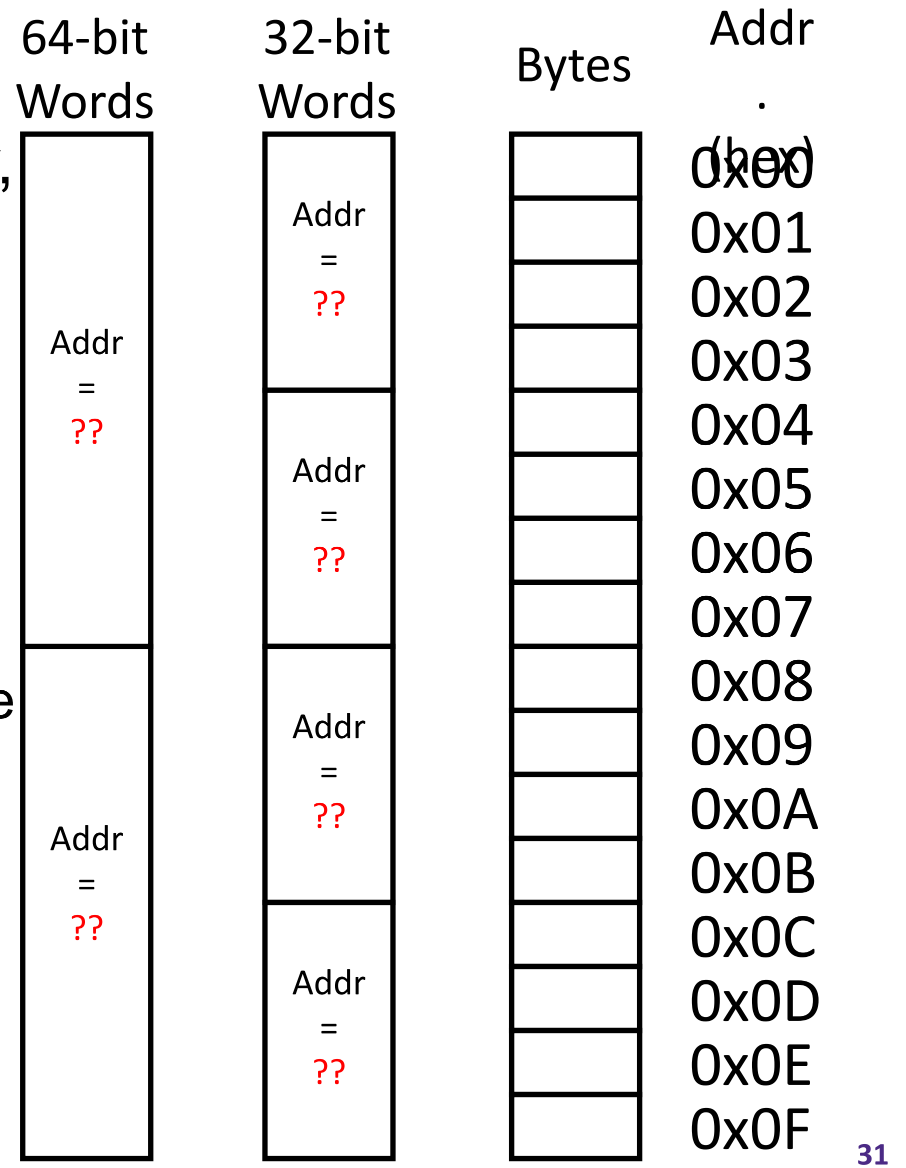
Java Data Type	C Data Type	32-bit (old)	x86-64
`boolean`	`bool`	1	1
`byte`	`char`	1	1
`char`	**none, why?**	2	2
`short`	`short int`	2	2
`int`	`int`	4	4
`float`	`float`	4	4
	`long int`	4	8
`double`	`double`	8	8
`long`	`long long`	8	8
	`long double`	8	16
(reference)	**pointer ***	**4**	**8**

address size = word size

To use "`bool`" in C, you must `#include <stdbool.h>`

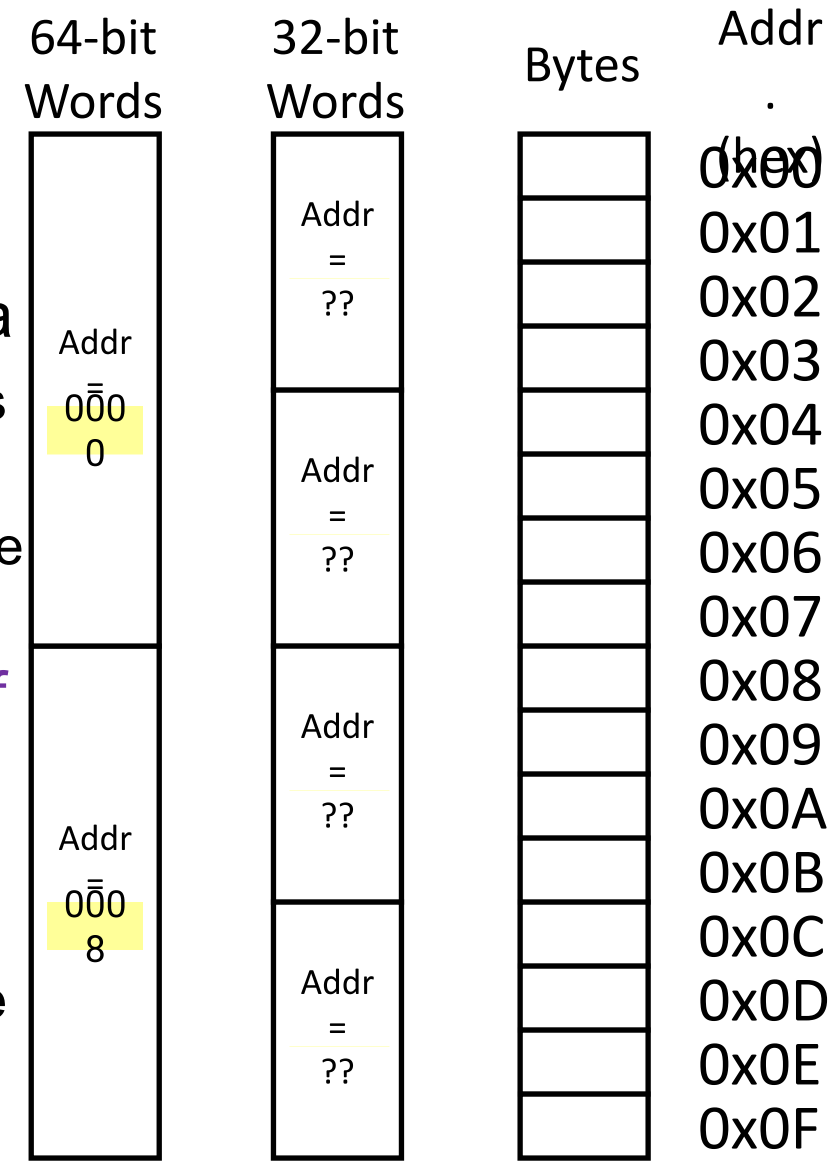
Word-Oriented View of Memory

- Addresses still specify locations of bytes in memory, but we can choose to *view* memory as a series of word-sized chunks of data instead
  - Addresses of successive words differ by word size
  - Which byte's address should we use for each word?



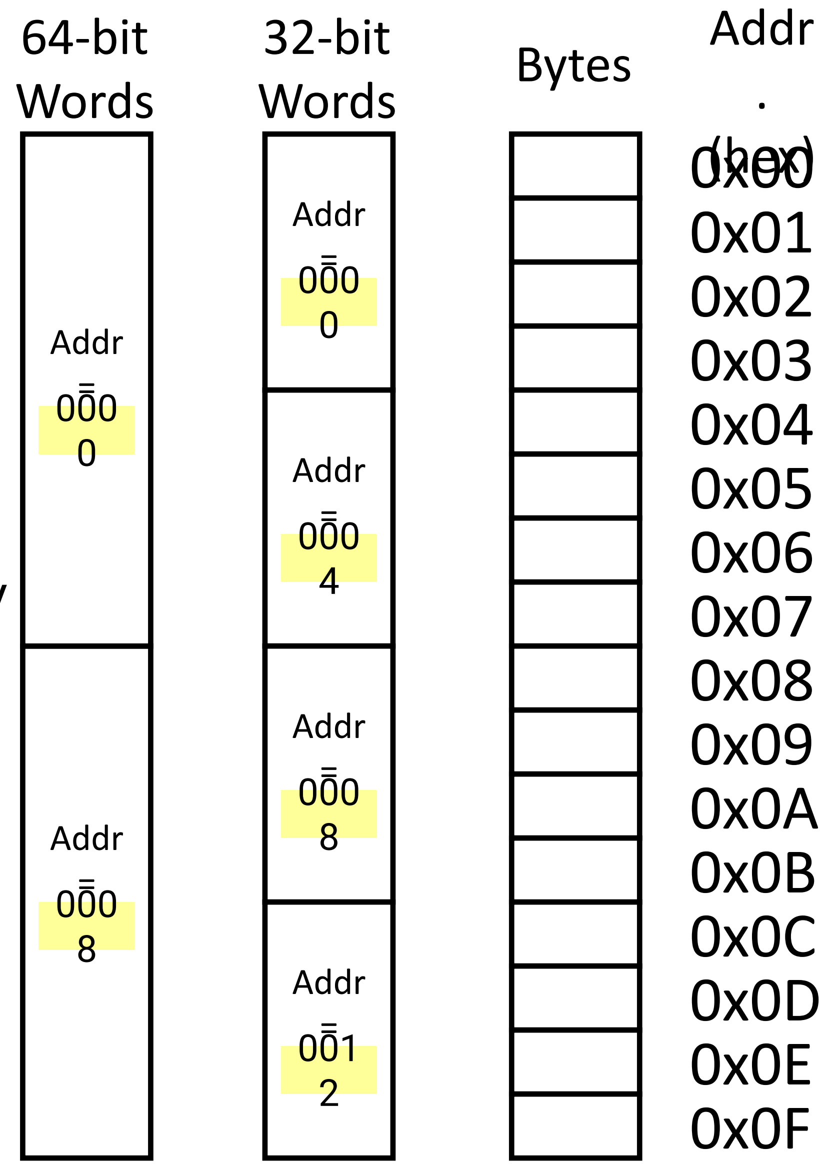
Addresses of multi-byte data

- Addresses -> <u>bytes</u> in memory, but we can choose to *view* memory as a series of <u>word-sized chunks</u> of data
  - Addresses of successive words differ by word size
  - Which byte's address should we use for each word?
- The address of *any* chunk of memory is given by the address of the first byte
  - To specify a chunk of memory, need *both* its **address** and **size**



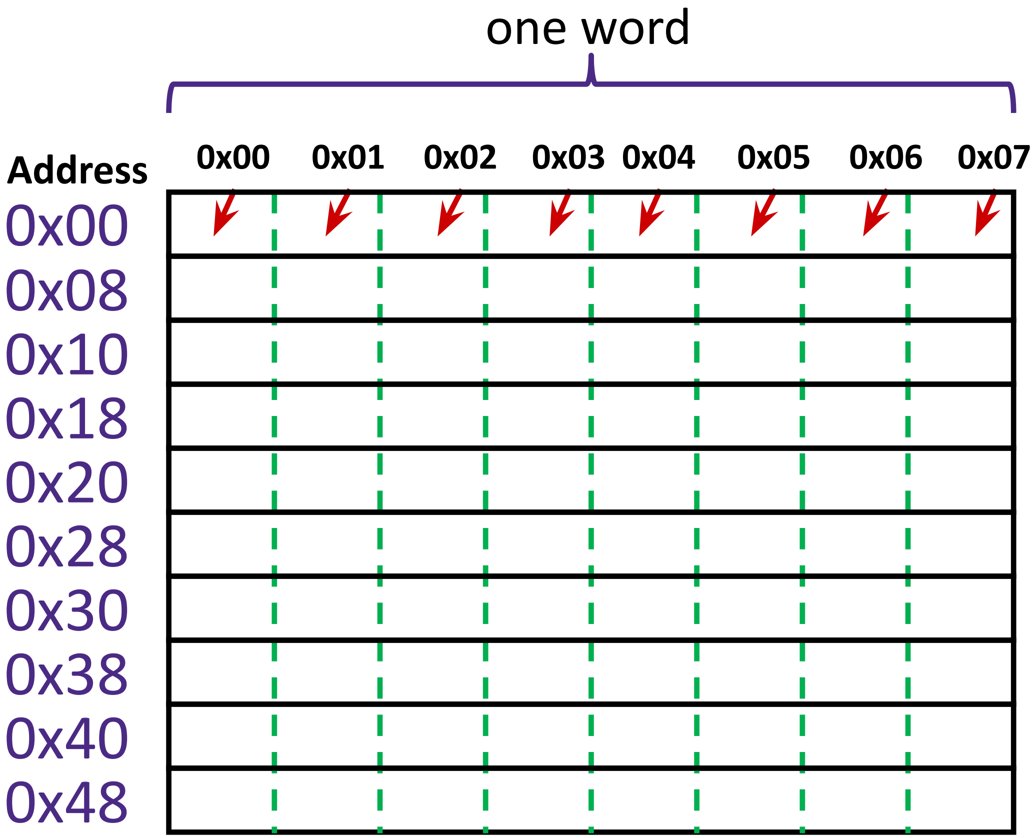
Alignment

- The address of a chunk of memory is considered aligned if its address is a multiple of its size
  - View memory as a series of consecutive chunks of this particular size and see if your chunk doesn't cross a boundary



A Picture of Memory (64-bit view)

- A "64-bit (8-byte) word-aligned" view of memory:
  - In this type of picture, each row is composed of 8 bytes
  - Each cell is a byte
  - An aligned, 64-bit chunk of data will fit on one row



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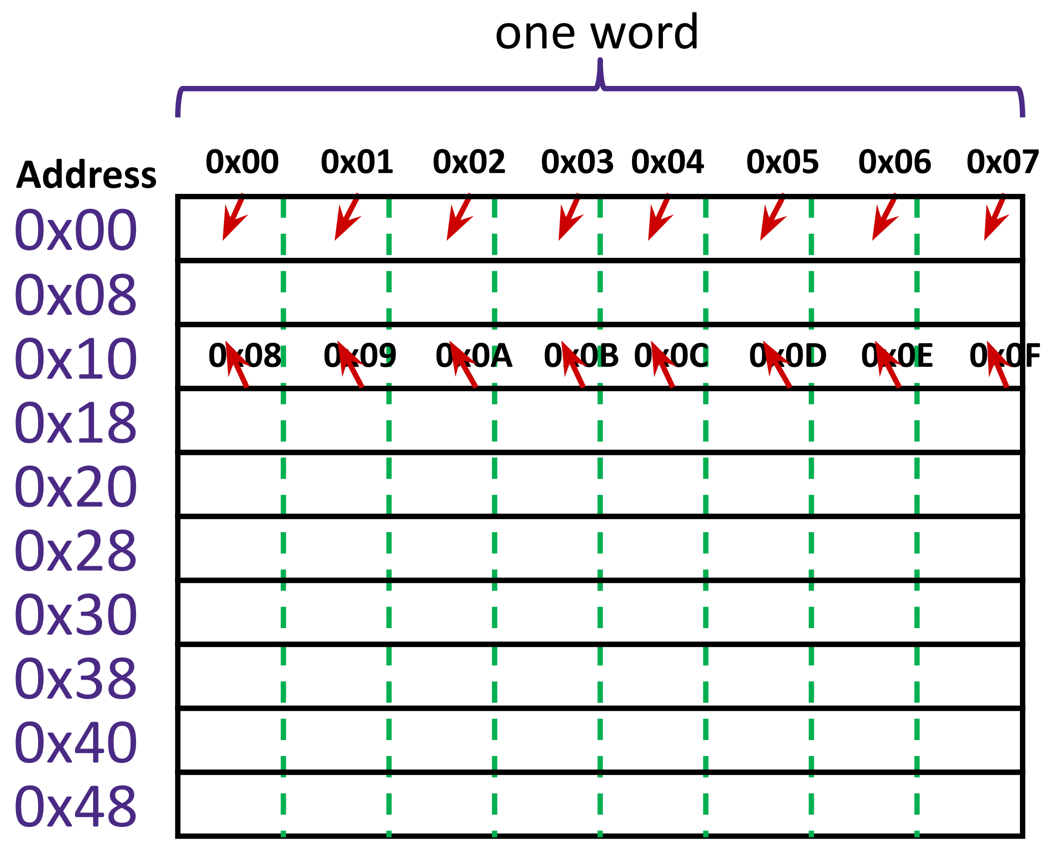
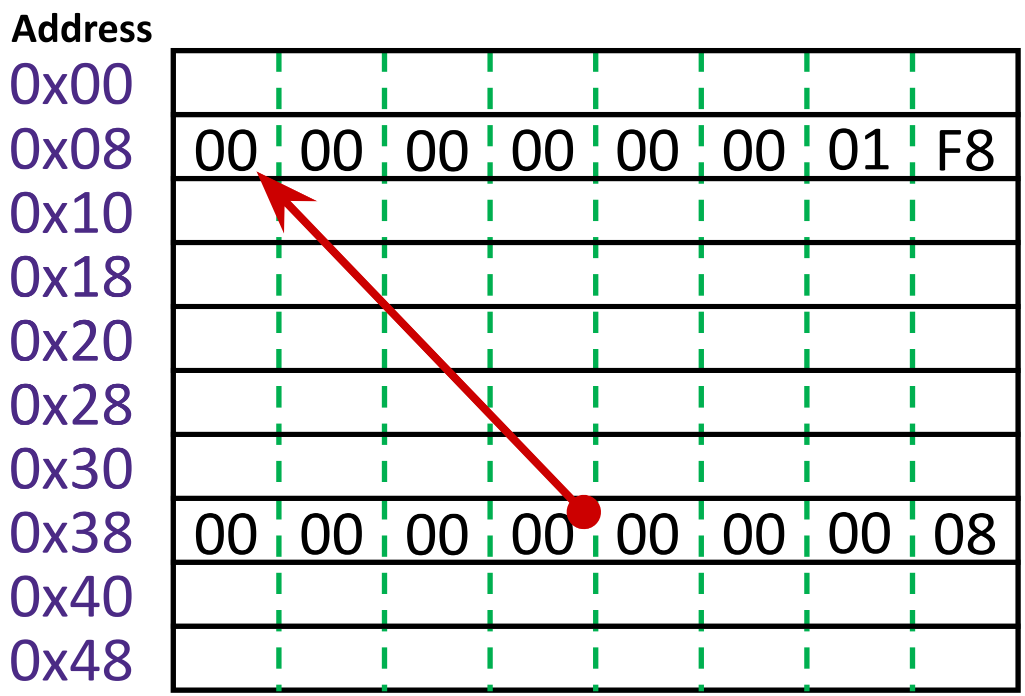


Addresses and Pointers

64-bit example
(pointers are 64-bits wide)

big-endian

- An *address* refers to a location in memory
- A *pointer* is a data object that holds an address
  - Address can point to *any* data
- Value 504 stored at address 0x08
  - 504_{10} = 0x1F8 = 0x 00 ... 00 01 F8
- Pointer stored at 0x38 points to address 0x08



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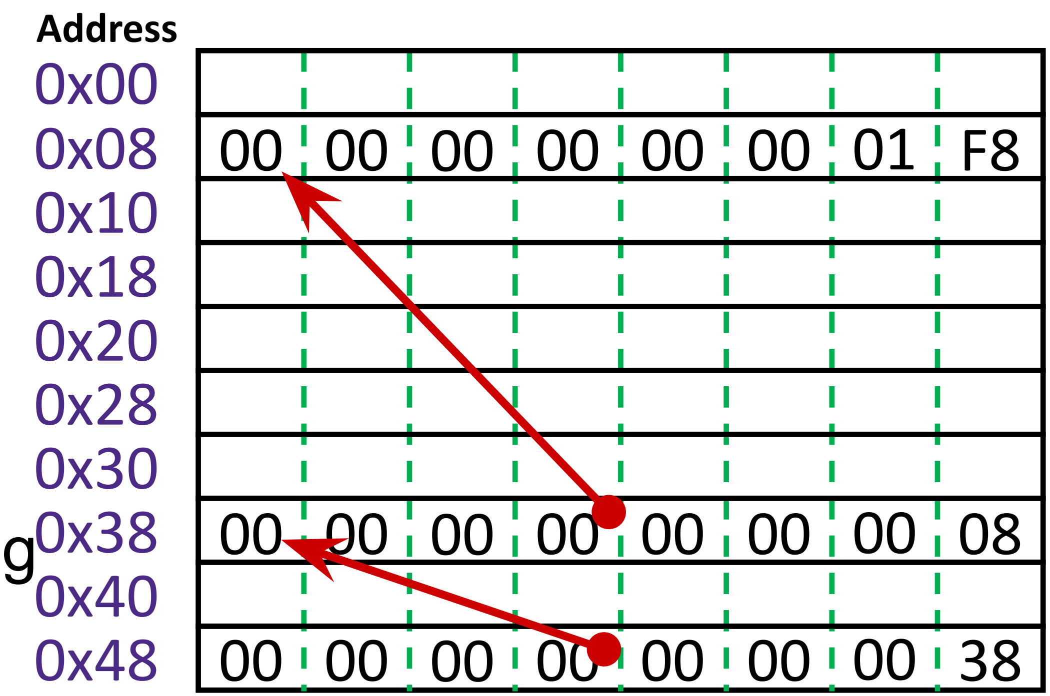
- An *address* refers to a location in memory
- A *pointer* is a data object that holds an address
  - Address can point to *any* data
- Pointer stored at 0x48 points to address 0x38 😵
  - Pointer to a pointer!
- Is the data stored at 0x08 a pointer?
  - Could be, depending on how you use it



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Memory Alignment Revisited

- A primitive object of K bytes must have an address that is a multiple of K to be considered *aligned*

	Type
1	`char`
2	`short`
4	`int, float`
8	`long, double,` pointers

- For good memory system performance, Intel (x86) recommends data be aligned
  - x86-64 hardware will work correctly otherwise
    - *Design choice*: x86-64 instructions are *variable* length

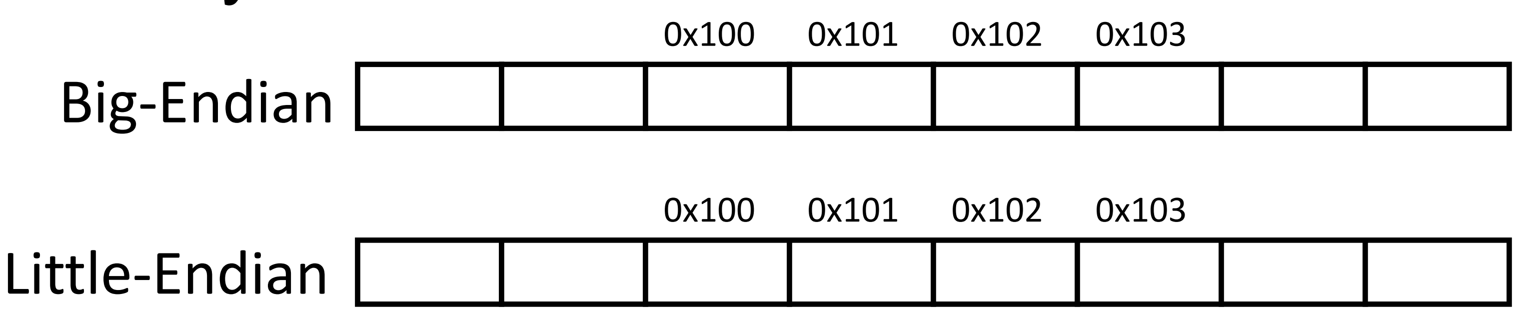
Byte Ordering

- How should bytes within a word be ordered?
  - Goal: consecutive bytes in consecutive addresses
  - **Ex:** store the 4-byte (32-bit) `int: 0x a1 b2 c3 d4`
- Byte ordering convention: *Endianness*
  - The two options are big-endian and little-endian
    - In which address does the least significant *byte* go?
    - Based on *Gulliver's Travels*: tribes cut eggs on different sides (big, little)

Byte Ordering

- Big-endian (SPARC, z/Architecture)
  - Least significant byte has highest address
- Little-endian (x86, x86-64)
  - Least significant byte has lowest address
- Bi-endian (ARM, PowerPC)
  - Endianness can be specified as big or little

- **Ex:** 4-byte data 0xa1b2c3d4 at address 0x100



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- **Ex:** 4-byte data 0xa1b2c3d4 at address 0x100

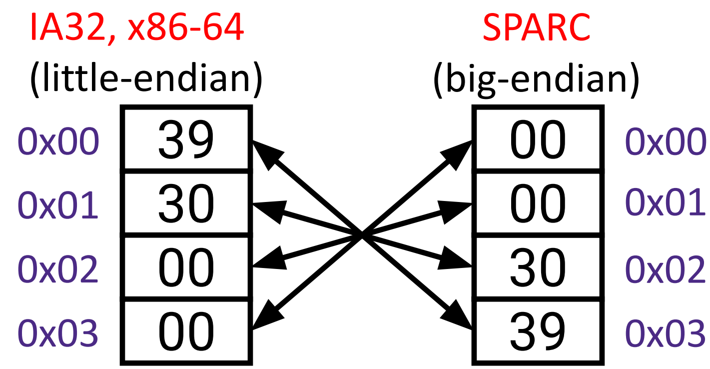
			0x100	0x101	0x102	0x103		
Big-Endian			a1	b2	c3	d4		

			0x100	0x101	0x102	0x103		
Little-Endian			d4	c3	b2	a1		

Byte Ordering

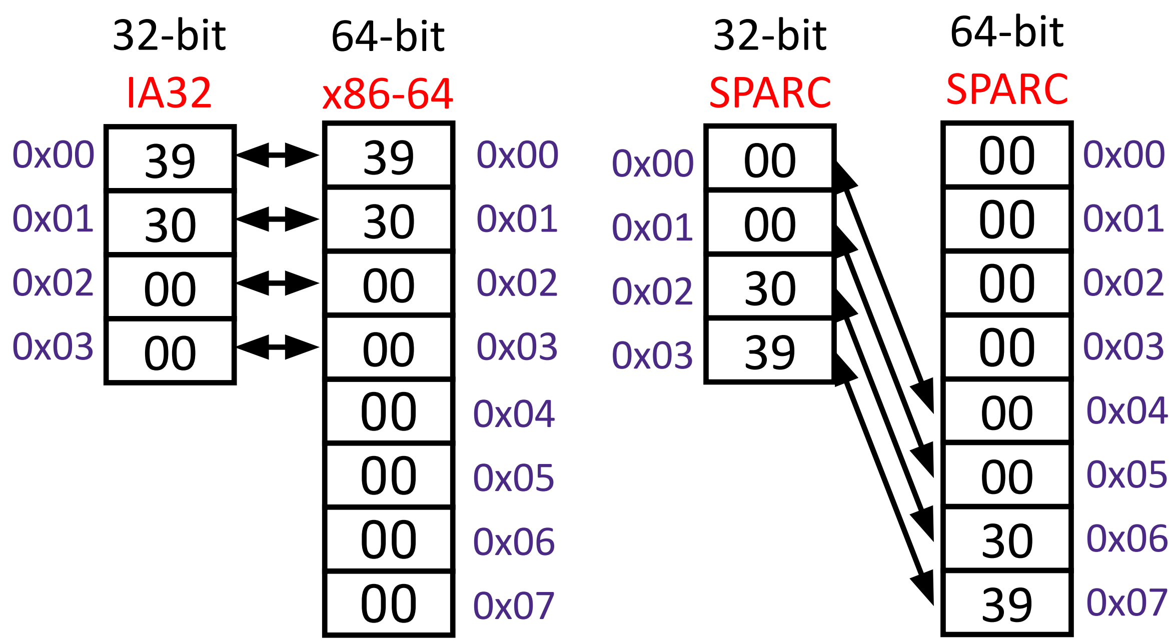
Decimal:	12345
Binary:	0011 0000 0011 1001
Hex:	3 0 3 9

```
int x = 12345;
// or x = 0x3039;
```




```
long int y = 12345;
// or y = 0x3039;
```

(A `long int` is the size of a word)



Polling Question

- We store the value `0x 01 02 03 04` as a ***word*** at address 0x100 in a big-endian, 64-bit machine
- What is the ***byte of data*** stored at address 0x104?

🤖 **0x04**
🏠 **0x40**
💡 **0x01**
✨ **0x10**
🥶 **We're lost…**

Endianness

- *Endianness only applies to memory storage*
- Often programmer can ignore endianness because it is handled for you
  - Bytes wired into correct place when reading or storing from memory (hardware)
  - Compiler and assembler generate correct behavior (software)
- Endianness still shows up:
  - Logical issues: accessing different amount of data than how you stored it (*e.g.* store `int`, access LSB as `char`)
  - Need to know exact values to debug memory errors
  - Manual translation to and from machine code (in 351)

Challenge Question

- Assume the state of memory is as shown below for a little-endian machine.

	0x100							0x107
9F	23	B7	C8	55	D0	00	04	08

- If we (1) *read* the value of an `int` at address 0x102, (2) add 8 to it, and then (3) store the new value as an `int` at address 0x104, which of the following addresses retain their original value?

A. 0x102 B. 0x104 C. 0x105 D. 0x107

But, how'd we get here?

- We'll be answering this question again and again
- Modern hardware, modern house, historic relics

- No decisions were an accident!
  - Priorities might've been misaligned, dated, inconsistent
  - Priorities might've been racist, sexist, ableist

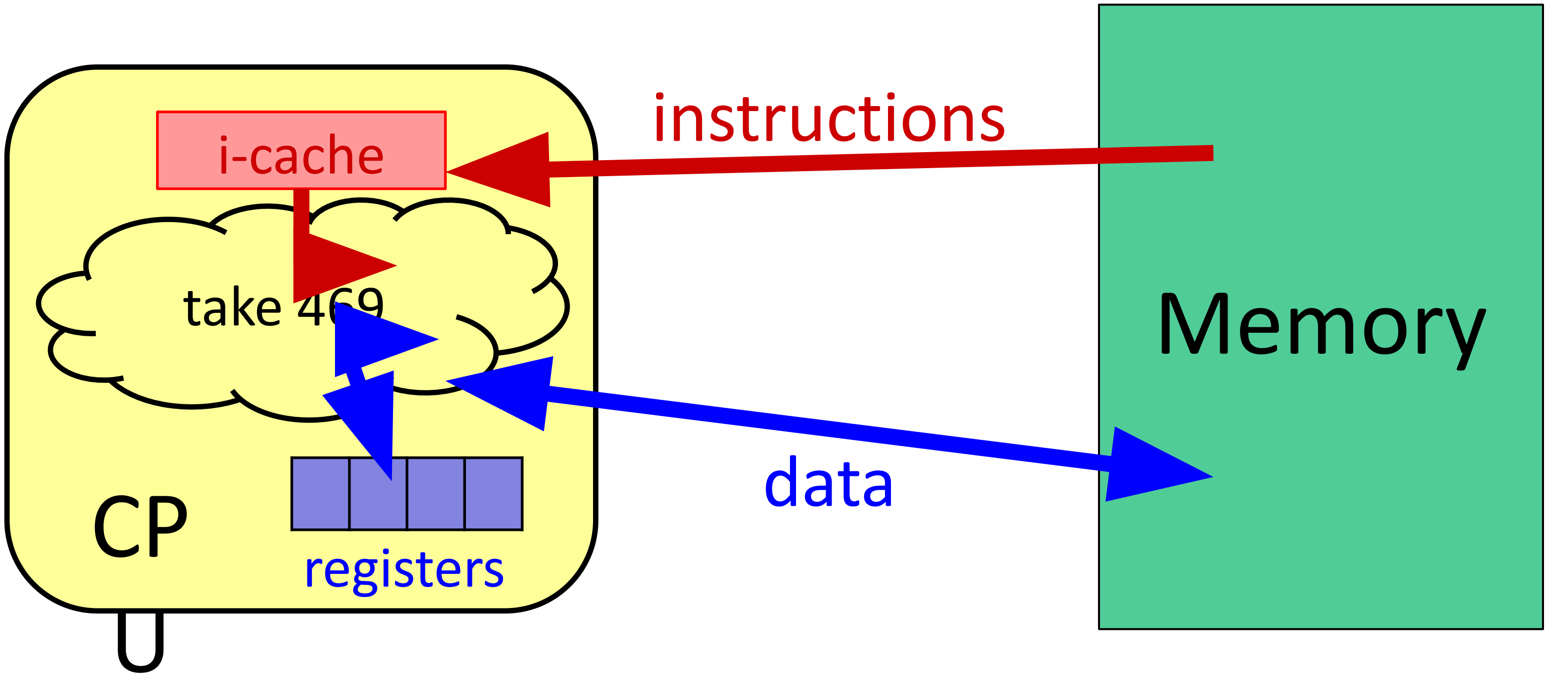
- Let's go back to modern* foundations…

*We'll go further back in a week

2021

What were the prevailing notions of computing during its modern incarnation?

Hardware: 351 View (version 1)



- More CPU details:
  - Instructions are held temporarily in the instruction cache
  - Other data are held temporarily in registers
- Instruction fetching is hardware-controlled
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(Modern) Hardware: Historic View

- **Computer**: one who computes

The women of Bletchley Park, Credit: BBC

(Modern) Hardware: Historic View

- **Computer**: one who computes

The women of Bletchley Park, Credit: BBC

- Mostly white cis-women
- “Boring, repetitive work”, doing math quickly

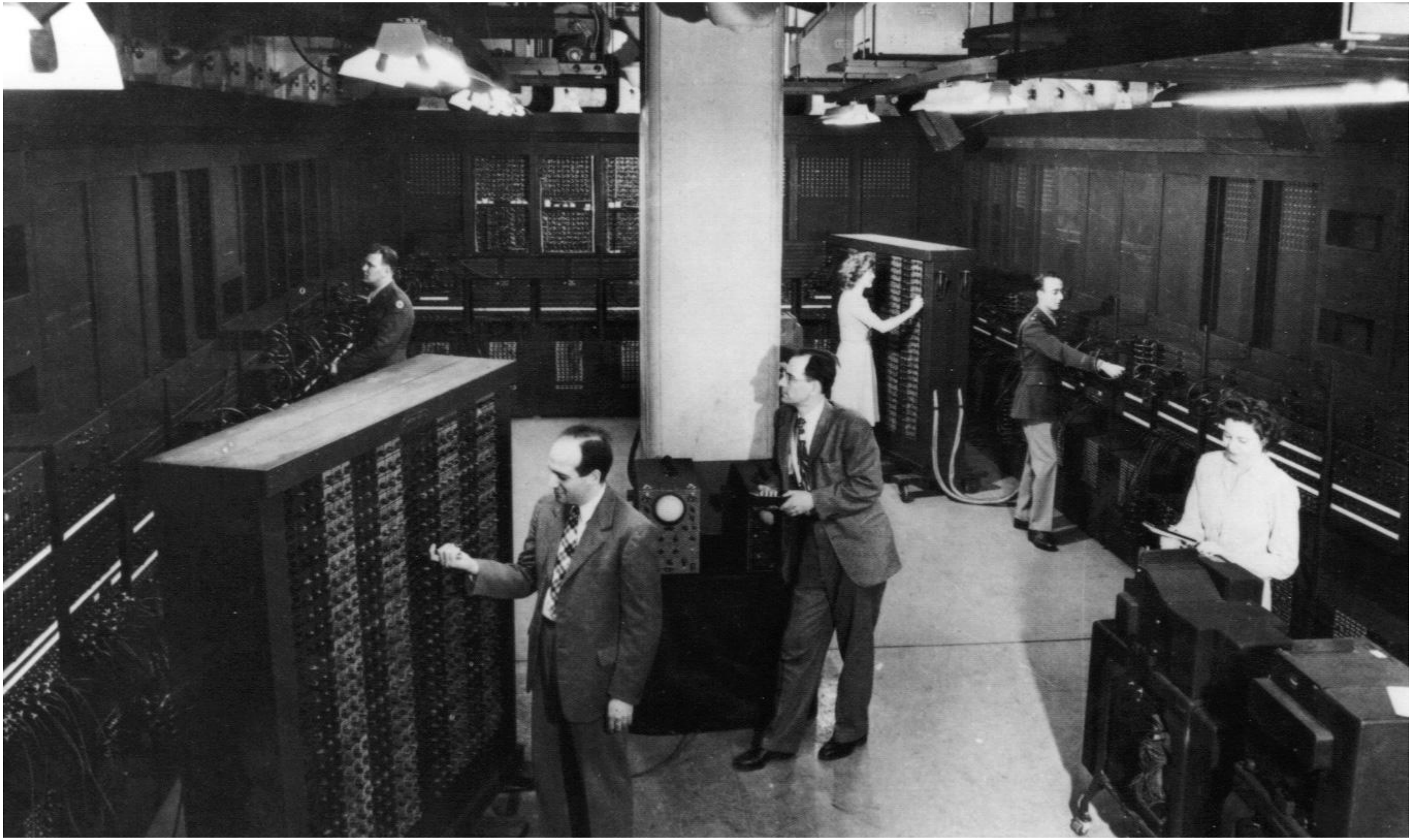
Computing in the US

- **Computer**: one who computes
- Observatory calculations @ Harvard (1870s)

Human Computers at NACA, Credit: NASA

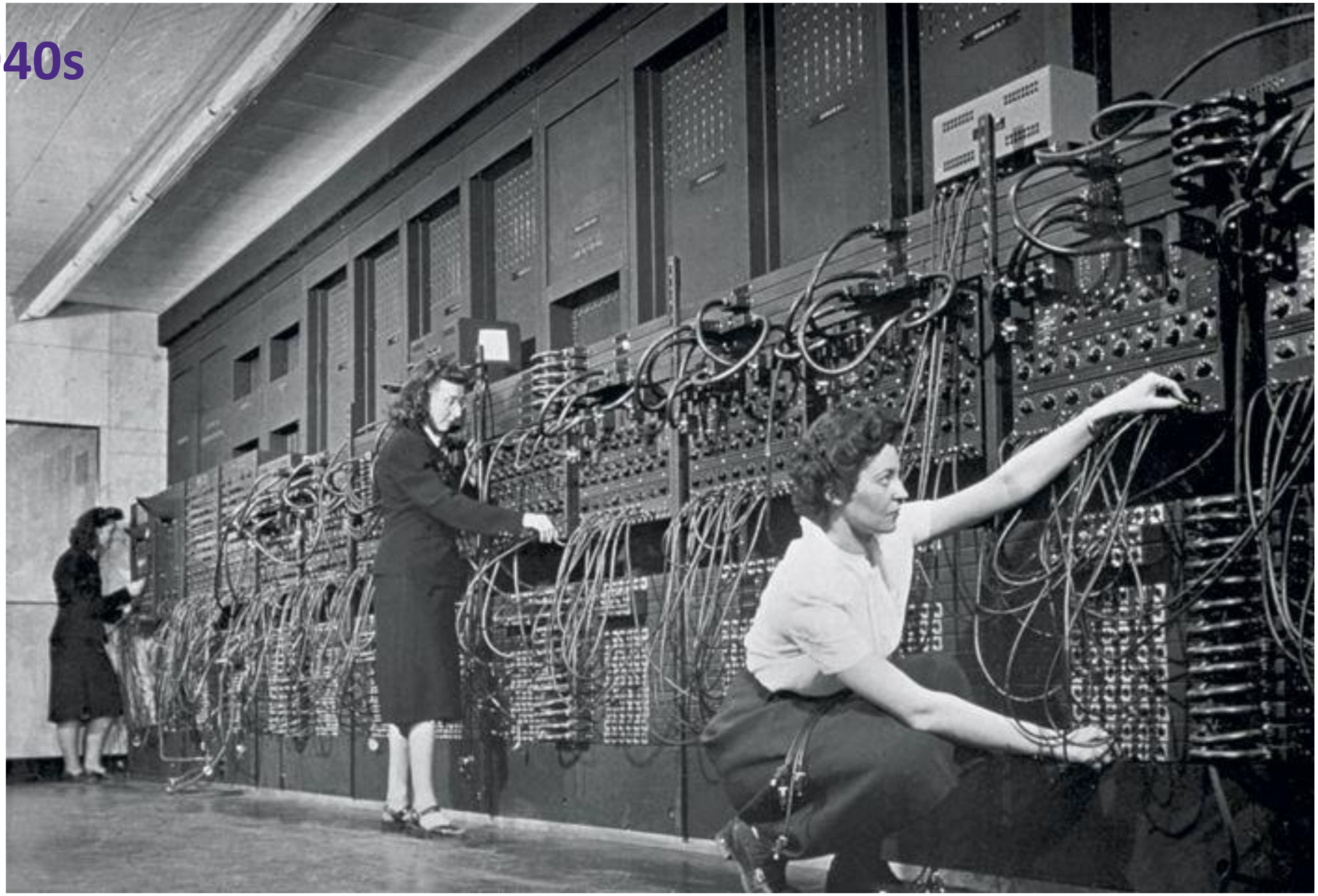
Human Computers at JPL, Credit: JPL

The ENIAC: Augmenting/Automating



Programming, historically

1940s



Jean Jennings (left), Marlyn Wescoff (center), and Ruth Lichterman program ENIAC at the University of Pennsylvania, circa 1946.
Photo: Corbis
http://fortune.com/2014/09/18/walter-isaacson-the-women-of-eniac/

The Computer Girls

BY LOIS MANDEL

A trainee gets $8,000 a year ...a girl "senior systems analyst" gets $20,000—and up! Maybe it's time to investigate....

Ann Richardson, IBM systems engineer, designs a bridge via computer. Above (left) she checks her facts with fellow systems engineer, Marvin V. Fuchs. Right, she feeds facts into the computer. Below, Ann demonstrates on a viewing screen how her facts designed the bridge, and makes changes with a "light pen."

Twenty years ago, a girl could be a secretary, a school teacher . . . maybe a librarian, a social worker or a nurse. If she was really ambitious, she could go into the professions and compete with men . . . usually working harder and longer to earn less pay for the same job.

Now have come the big, dazzling computers—and a whole new kind of work for women: programming. Telling the miracle machines what to do and how to do it. Anything from predicting the weather to sending out billing notices from the local department store.

And if it doesn't sound like woman's work—well, it just is.

("I had this idea I'd be standing at a big machine and pressing buttons all day long," says a girl who programs for a Los Angeles bank. I couldn't have been further off the track. I figure out how the computer can solve a problem, and then instruct the machine to do it."

"It's just like planning a dinner," explains Dr. Grace Hopper, now a staff scientist in systems programming for Univac. (She helped develop the first electronic digital computer, the Eniac, in 1946.) "You have to plan ahead and schedule everything so it's ready when you need it. Programming requires patience and the ability to handle detail. Women are 'naturals' at computer programming."

What she's talking about is *aptitude*—the one most important quality a girl needs to become a programmer. She also needs a keen, logical mind. And if that zeroes out the old Billie Burke-Gracie Allen image of femininity, it's about time, because this is the age of the Computer Girls. There are twenty thousand of them in the United *(cont. on page 54)*

2021

"People like Grace Hopper were very consciously mobilizing gender stereotypes to get women in."

Janet Abbate, *Recoding Gender*

Modern Hardware: Historic Relics

1. "Boring, repetitive work" should be automated for efficiency/profit
   - Two narratives, both true: Automation/Augmentation
   - Consistently eliminating jobs of marginalized folks

Historic Robots

- *Robot:* (Czech) compulsory service
  - Slav *robota*: servitude, hardship
- Robots: tool to replace “unskilled” work, servants

The robots are coming! When they do, you'll command a host of push-button servants.

You'll Own "Slaves" by 1965

By O. O. Binder

IN 1863, Abe Lincoln freed the slaves. But by 1965, slavery will be back! We'll all have personal slaves again, only this time we won't fight a Civil War over them. Slavery will be here to stay.

Don't be alarmed. We mean robot "slaves." Let's take a peek into the future

Robots will dress you, comb your hair and serve meals in a jiffy.

to see what the Robot Age will bring. It is a morning of 1965. . .

You are gently awakened by soft chimes from your robot clock, which also turns up the heat, switches on radio news and signals your robot valet, whom you've affectionately named "Jingles." He turns on your shower, dries you with a blast of warm air, and runs an electric shaver over your stubble. Jingles helps you dress, tying your necktie perfectly and parting your hair within a millimeter of where you like it.

Down in the kitchen, Steela, the robot cook, opens a door in her own alloy body and withdraws eggs, toast and coffee from her built-in stove. Then she dumps the dishes back in and you hear her internal dishwasher bubbling as you leave for the garage.

In your robot car you simply set a dial for your destination and relax. Your automatic auto does the rest—following a radar beam downtown, passing other cars, slowing down in speed zones, gently applying radar brakes when necessary, even gassing up when your tank is empty. You give a friendly wave to robot traffic cops who break up all traffic jams with electronic speed and perception. Suddenly you hear gun shots. A thief is emptying his gun at a robot cop, who just keeps coming, bullets bouncing from his steel chest. The panicky thug races away in his car but the robot cop shifts himself into eighth gear and overtakes the bandit's car on foot.

If you work at an office, your robot secretary takes dictation on voice tapes and types internally at the same time, handing you your letter as soon as you say "yours truly." If you go golfing, the secretary answers the phone, records any messages, and also delivers any prerecorded message of yours.

At home, your robot reciter reads books to you from your microfilm library. His eye can see microscopic prints. Or you play chess with a robot companion, matching your wits against an electronic brain.

In 1956 research scientists already devised robot game players who always won against human opponents. Of course the 1965 robots can be adjusted as you wish by buttons for high, average or low skill.

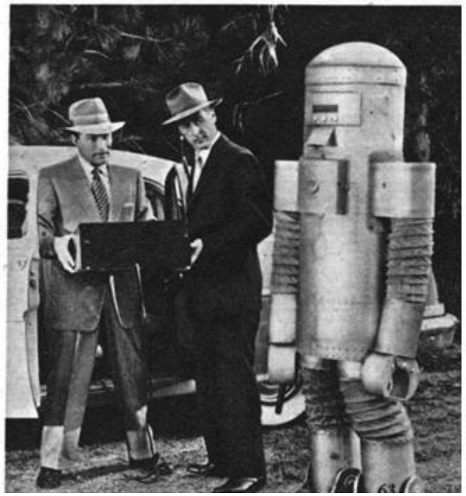
When a heavy snow falls you don't have to shovel the walk. Neither does your robot caretaker. He merely sprays cheap atomic heat around the grounds, melting the snow as fast as it falls. Yours is a robot home, too, turning all day on a foundation turntable to enjoy the utmost benefits of the sun.

At bedtime, you snap on the robot guard who detects any burglars electronically. It's a cheaper version of the robot alarm system in 1956, guarding precious documents like the original Constitution, in the National Archives Building.

During the night, no mice or rats can escape the super-sensitive ears and infra-red eyes of your roving robot cat. Back in 1956 scientists experimented with the first robot animals, such as the robot mole that could follow light beams, the robot moth dancing around flames and robot mice finding their way out of mazes.

Fanciful, this picture of the near future? A foretaste of such robot wonders

Metal star of Zombies Of The Stratosphere heeds his masters in science-fiction movie.



It was racist, and continues to be

Twitter Engineering
@TwitterEng

We're starting with a set of words we want to move away from using in favor of more inclusive language, such as:

Avoid non-inclusive language	⇒	Prefer inclusive versions
Whitelist	⇒	Allowlist
Blacklist	⇒	Denylist
Master/slave	⇒	Leader/follower, primary/replica, primary/standby
Grandfathered	⇒	Legacy status
Gendered pronouns (e.g. guys)	⇒	Folks, people, you all, y'all
Gendered pronouns (e.g. he/him/his)	⇒	They, them, their
Man hours	⇒	Person hours, engineer hours
Sanity check	⇒	Quick check, confidence check, coherence check
Dummy value	⇒	Placeholder value, sample value

12:52 PM · Jul 2, 2020 · Twitter Web App

*This isn't to praise Twitter, this was the first list I found

Modern Hardware: Historic Relics

1. "Boring, repetitive work" should be automated
   - Two narratives, both true: Automation/Augmentation
   - Consistently eliminating jobs of marginalized folks
   - This relic remains!
2. Boring, repetitive work = "robot work"
   - Performed by those deemed *less than human*
   - Robot work should be done by robots (non-human)
     - *"Robot work" anything unvalued by the powerful*
   - If the task can't be automated, use people (less-human)
     - Frequently, this ends up being marginalized people, who later have their jobs automated

Programming, historically

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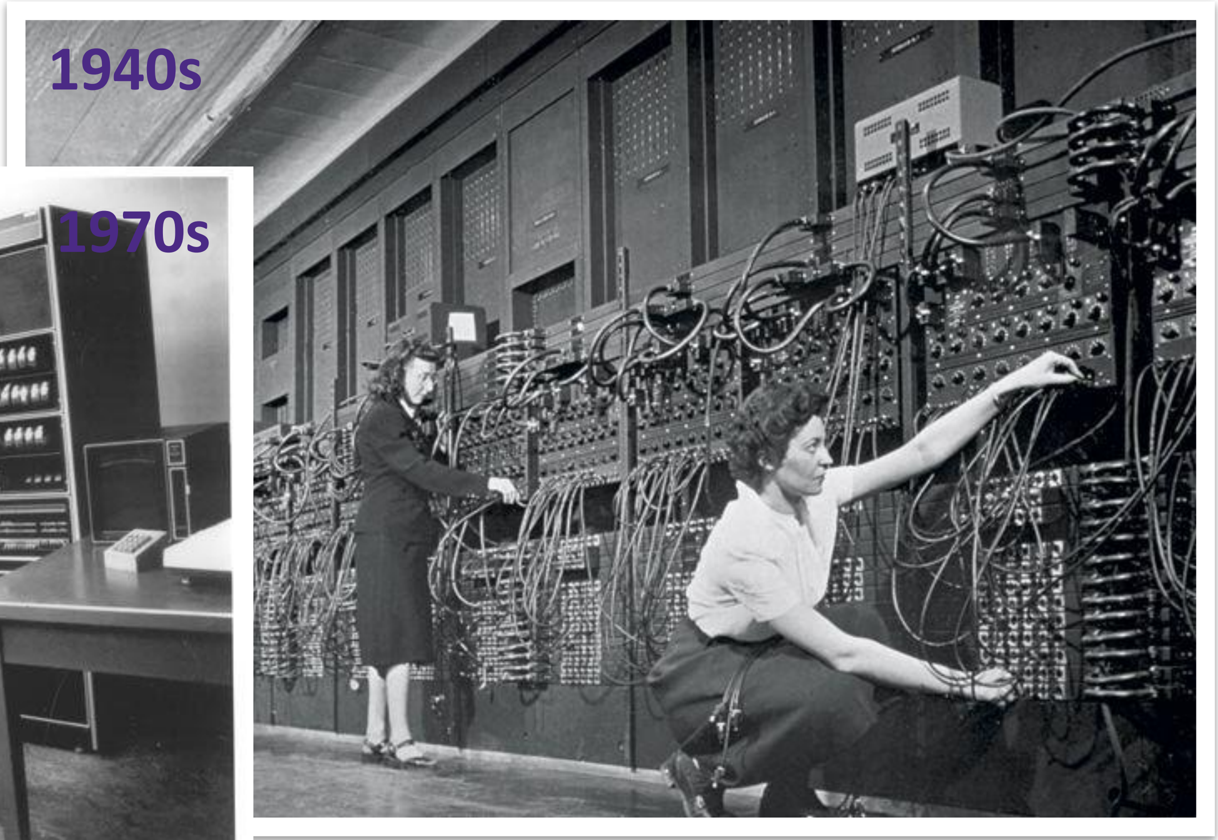
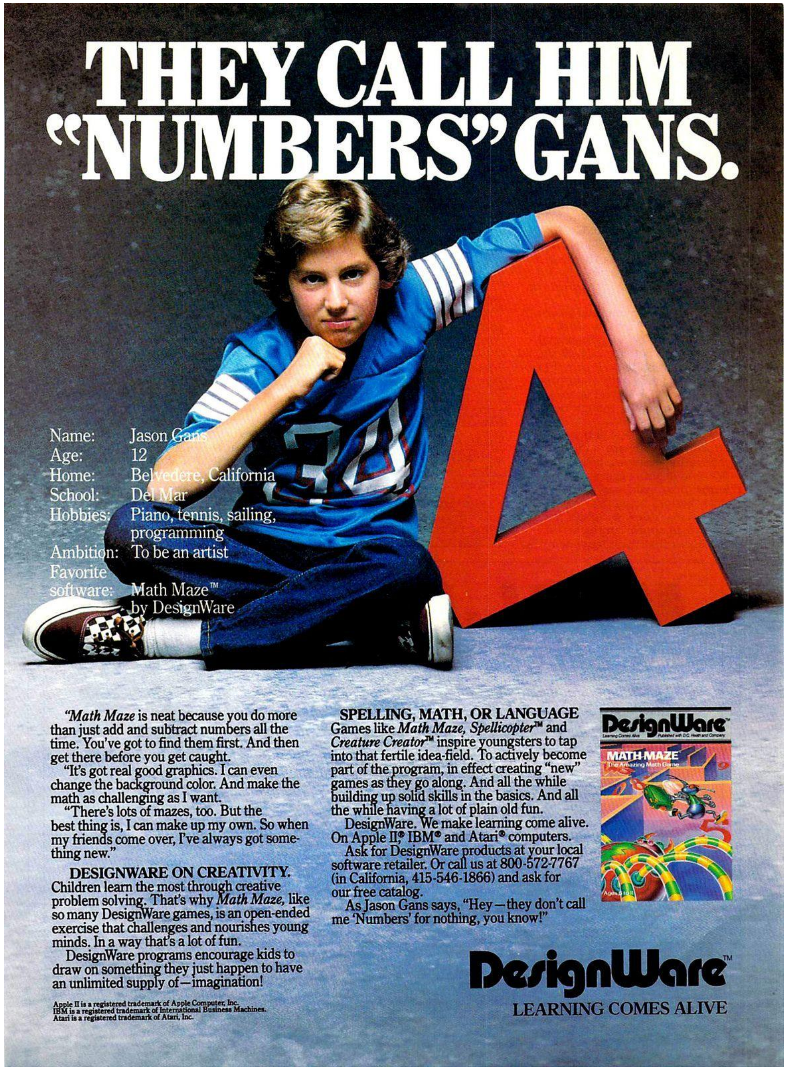


Jean Jennings (left), Marlyn Wescoff (center), and Ruth Lichterman program ENIAC at the University of Pennsylvania, circa 1946.
Photo: Corbis
http://fortune.com/2014/09/18/walter-isaacson-the-women-of-eniac/

Modern Robots: Personal Computers

The advent of personal computing

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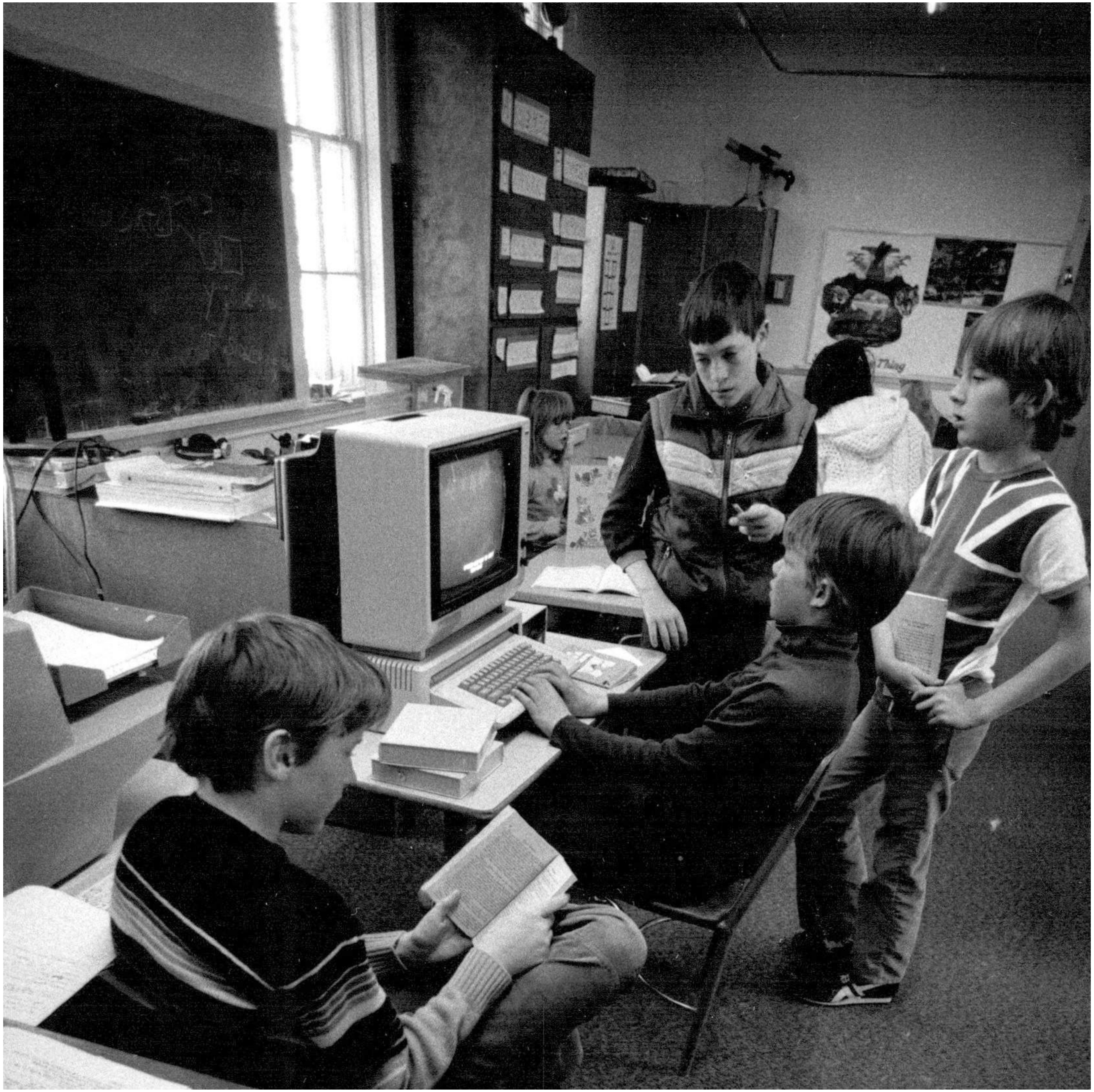

Modern Hardware: Historic Relics

1. "Boring, repetitive work" should be automated
   - Two narratives, both true: Automation/Augmentation
   - Consistently eliminating jobs of marginalized folks
2. Boring, repetitive work is "robot work"
   - Robot work should be performed by robots
     - *"Robot work" anything unvalued by the powerful, once including computing, programming*
   - If the task can't be automated, use people
     - Frequently, this ends up being marginalized people
3. Augmentation is highly valued, and exclusive
   - "Boring, repetitive work" is more available

- We'll get to earlier computational machines later!

Breakout rooms!

- Join any breakout corresponding to your section
  - Section AA – Any room from A1 to A6
- I'll bring y'all back in 5 minutes

Do you see these norms today? Where?

We'll share out with Ohyay reactions!