

CSC 252: Computer Organization

Spring 2023: Lecture 1

Instructor: Yuhao Zhu

Department of Computer Science
University of Rochester

Action Items:

- **Get CSUG account**
- **Make sure you have VPN setup!!!!**







Snake
circa 2000



Snake
circa 2000



Snake
circa 2020

Computers are More Capable



Snake
circa **2000**



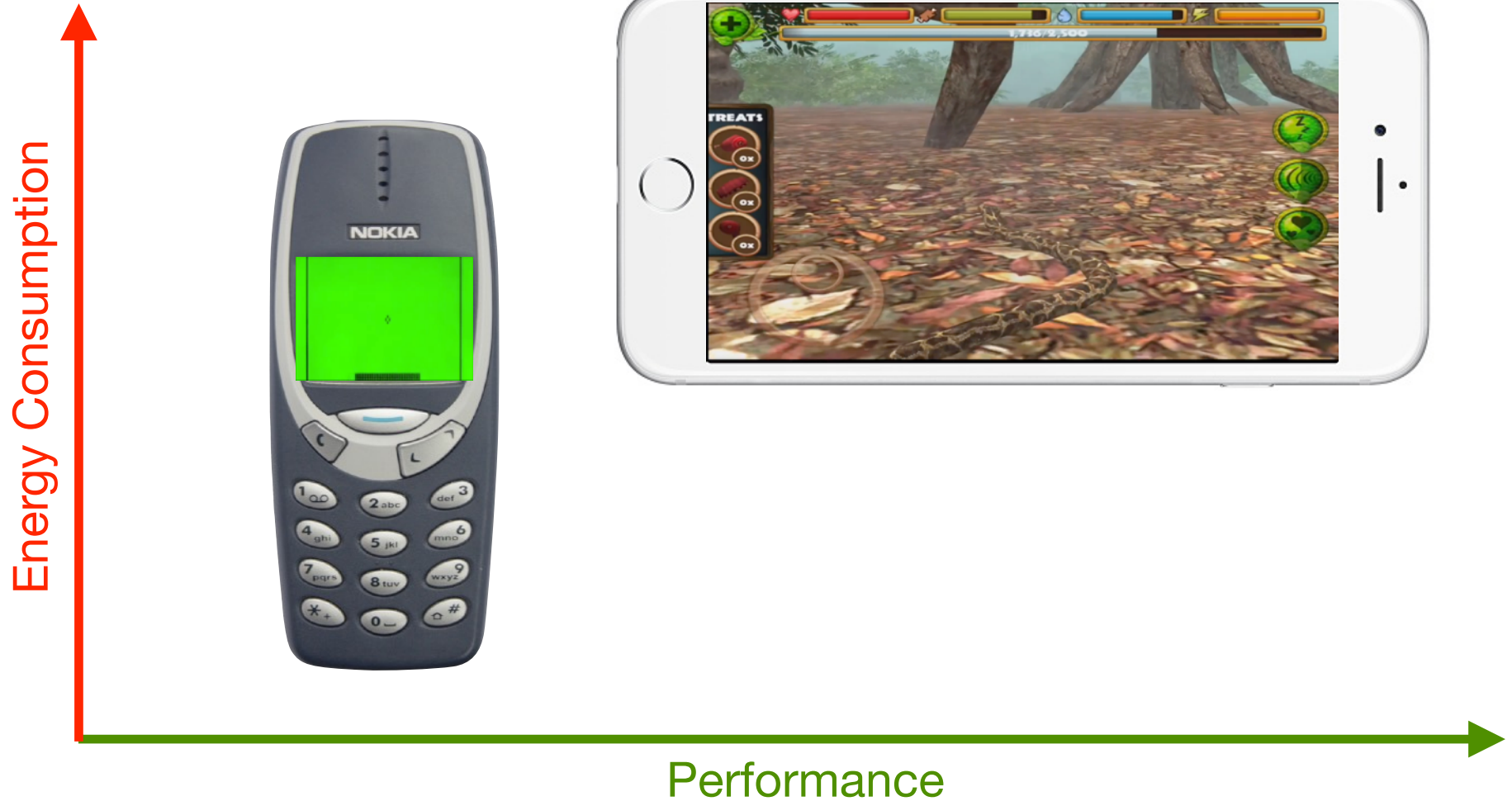
Snake
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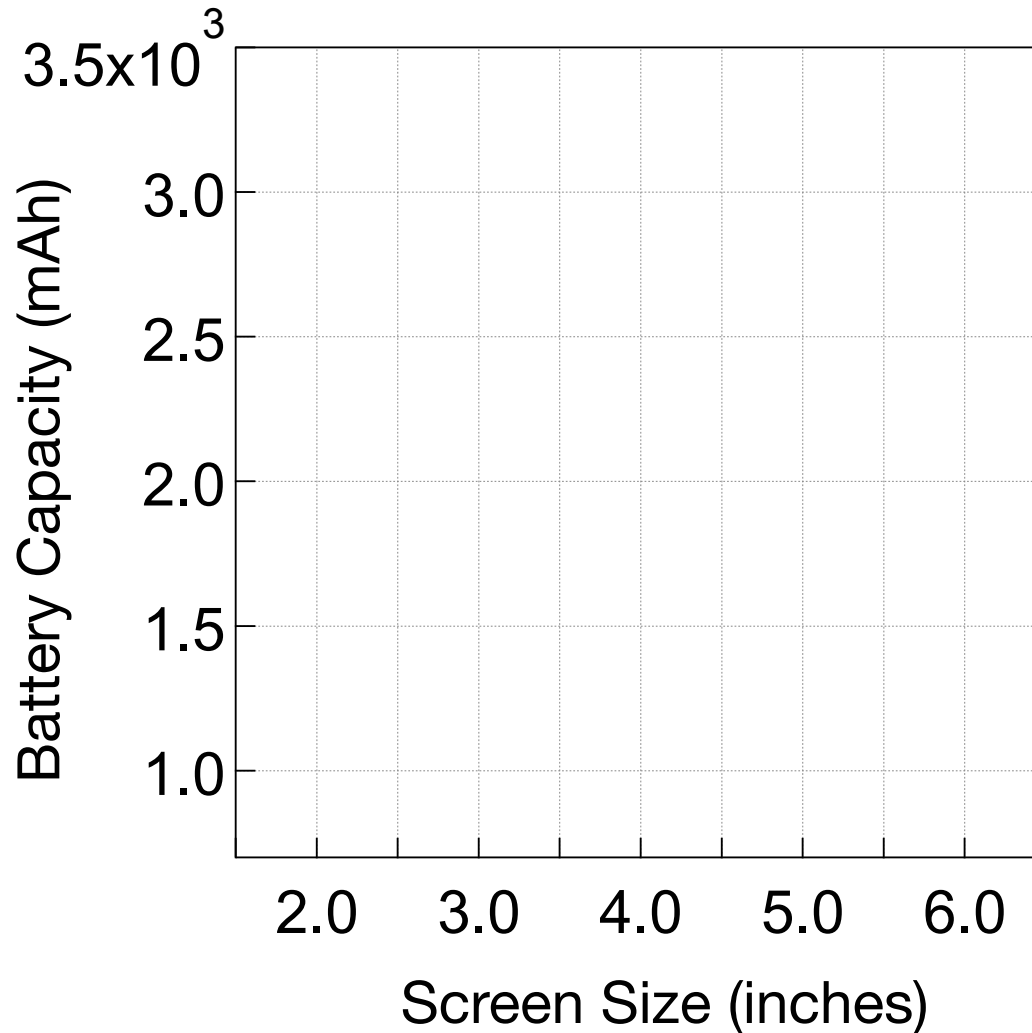
Performance

Computers are More Capable



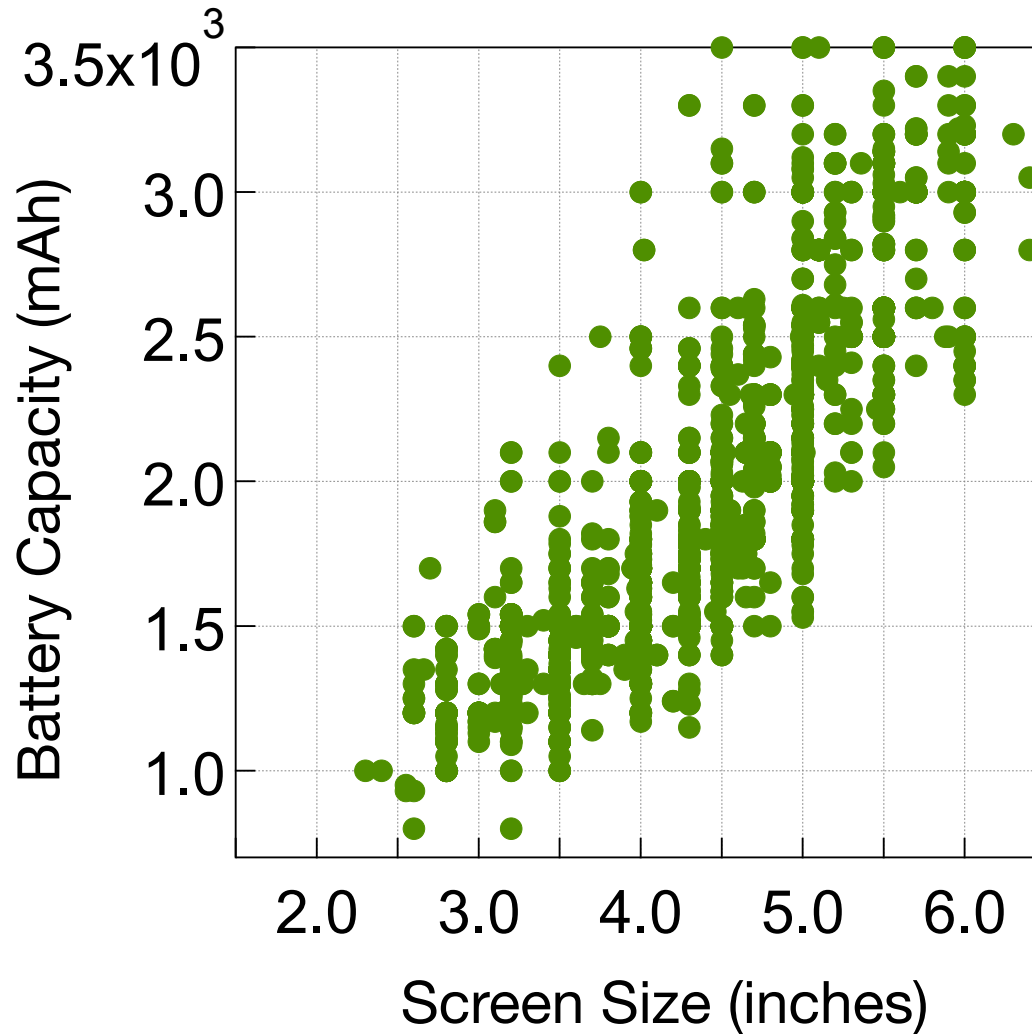
“Improving” Energy Capacity

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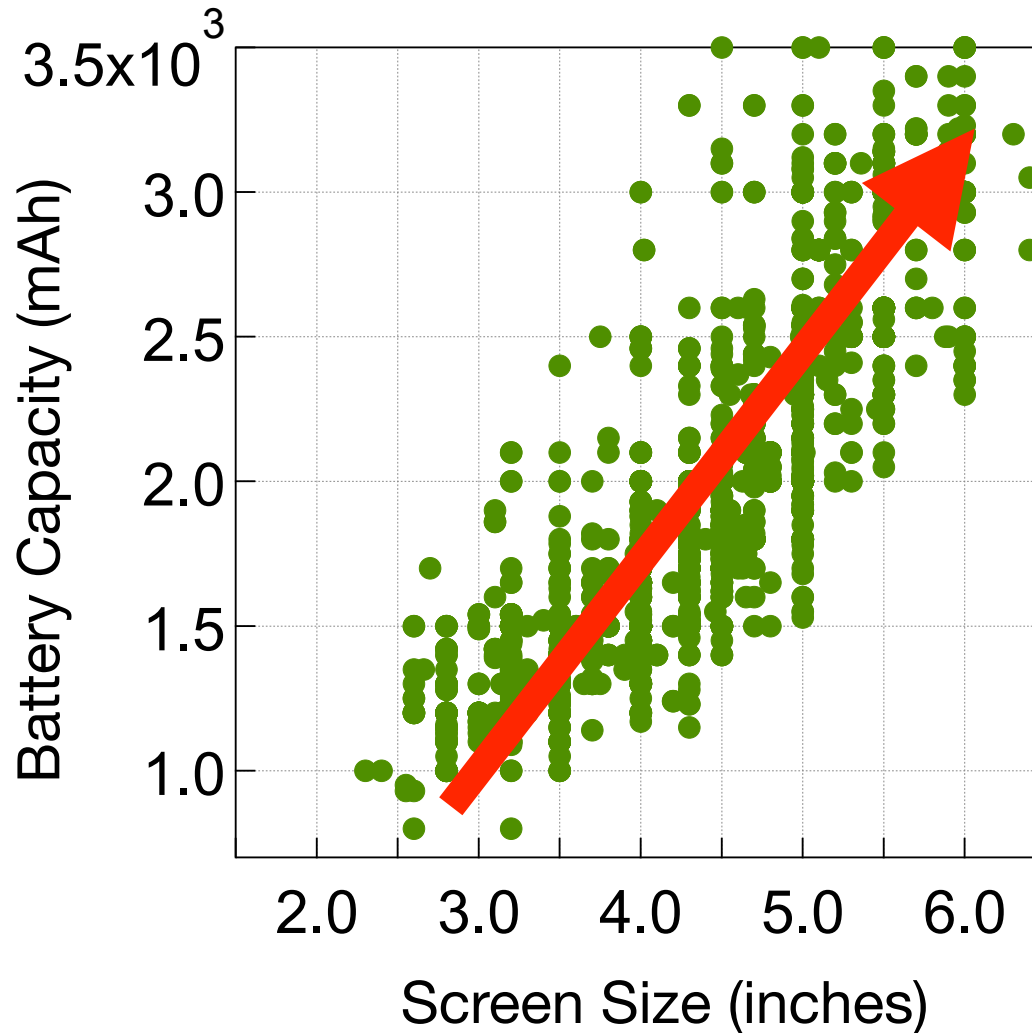
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Which Future Do You Want?

Which Future Do You Want?



Which Future Do You Want?



SMARTPHONE



PHABLET



TABLET



Which Future Do You Want?



SMARTPHONE



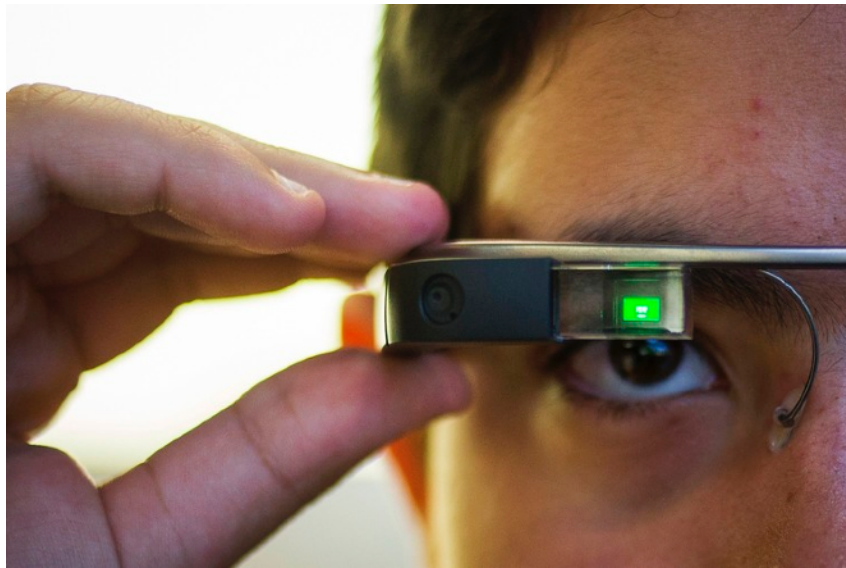
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TABLET



Which Future Do You Want?



LET

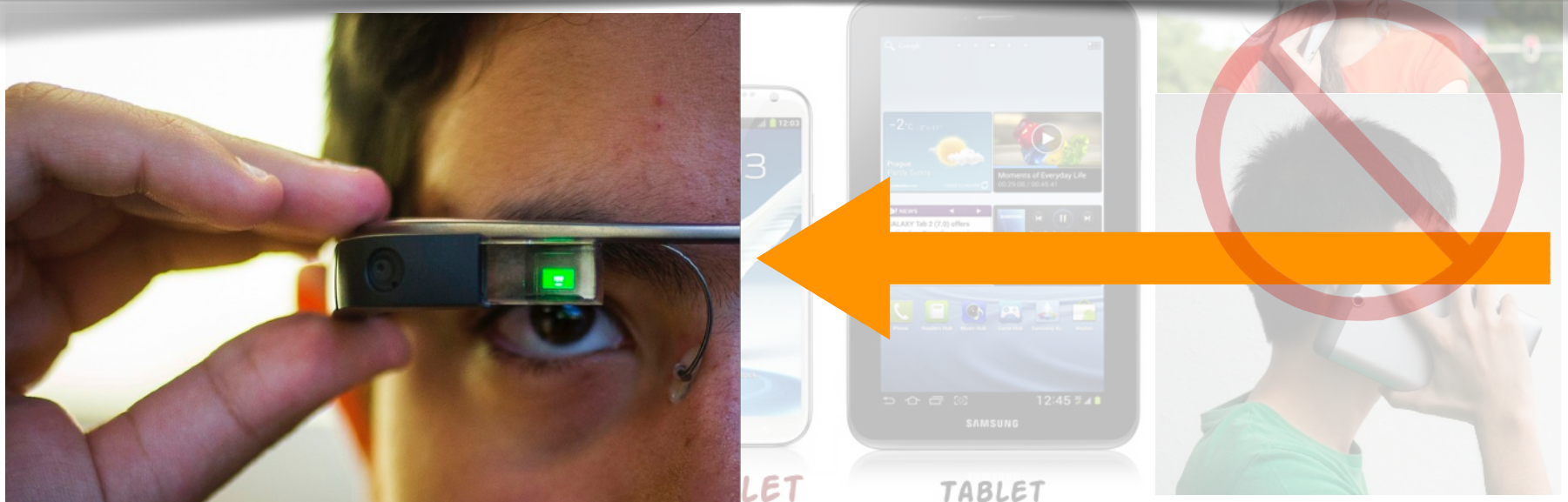


TABLET



Which Future Do You Want?

How to build ever-more capable computers but with lower energy consumption and smaller form factor?



Outline: Class Introduction

- Introduction
 - What Are You Supposed to Learn in this Class?
 - *What Is Computer Organization Anyways?*
 - Instructor & TAs
 - What Do I Expect From You?
 - How am I Going to Teach?
 - Grading, Policies

Action Items

- Get a CSUG account.
 - cycle1.csug.rochester.edu (or cycle2, cycle3)
 - If you don't already have one, go to this link: <https://accounts.csug.rochester.edu/>
 - **YOU WILL NEED VPN to access these machines if you are not using campus WiFi!! Follow the instructions (<https://tech.rochester.edu/remote-access-vpn-tutorials/>) to set up the university VPN.**
 - **TAs will help with VPN setup too.**

Where to Find Stuff

- <http://cs.rochester.edu/courses/252/spring2023/>
 - General info
 - Programming assignments details
 - Slides
 - Practice problems, past exams
- Communication through Blackboard (<https://learn.rochester.edu/>)
- CSUG machines for programming assignments submissions

What is Computer Systems?

What is Computer Systems?



Problem

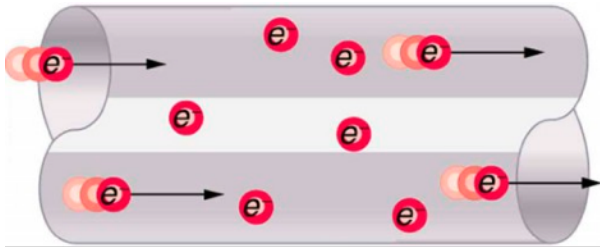
Who scores the highest on the exam?

What is Computer Systems?



Problem

Who scores the highest on the exam?



Circuit

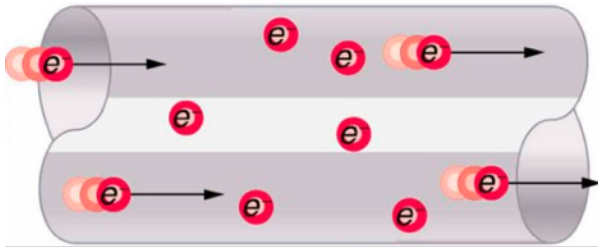
Electrons, Resistors,
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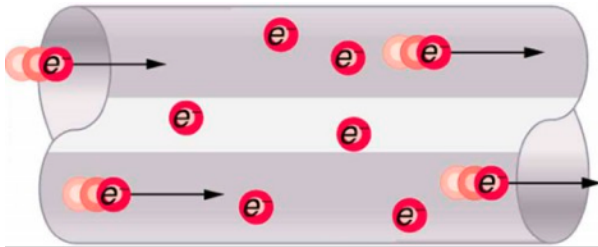
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Quicksort



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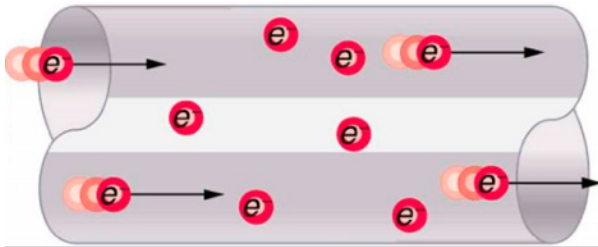


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Algorithm

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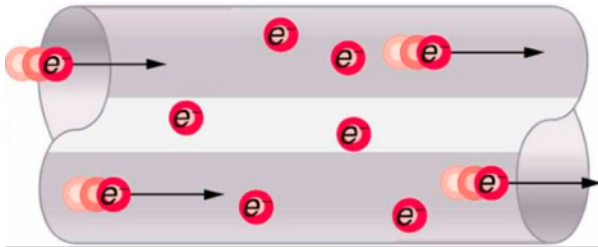
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Human-readable language (Java, C)



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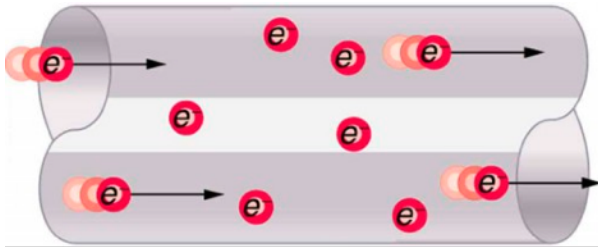
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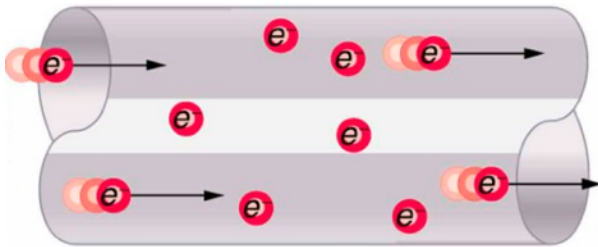
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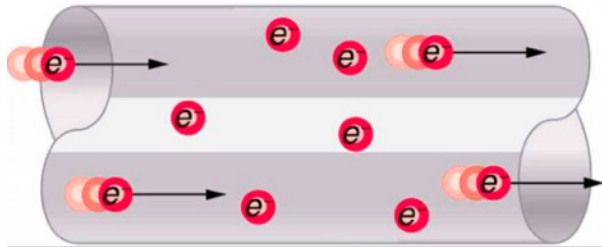
Machine Language



Circuit

Electrons, Resistors, Capacitors, etc.

What is Computer Systems?



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Instruction Set Architecture

Machine Language

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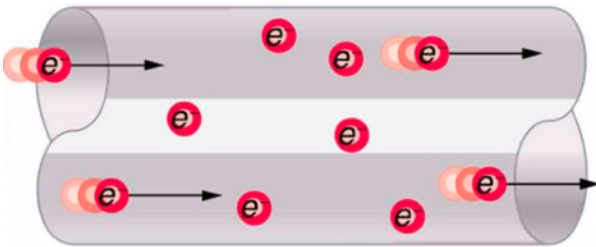
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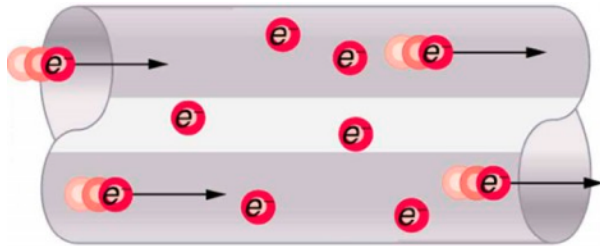
Hardware Design



Circuit

Electrons, Resistors, Capacitors, etc.

What is Computer Systems?



Problem

Algorithm

Program

Instruction Set
Architecture

Microarchitecture

Circuit

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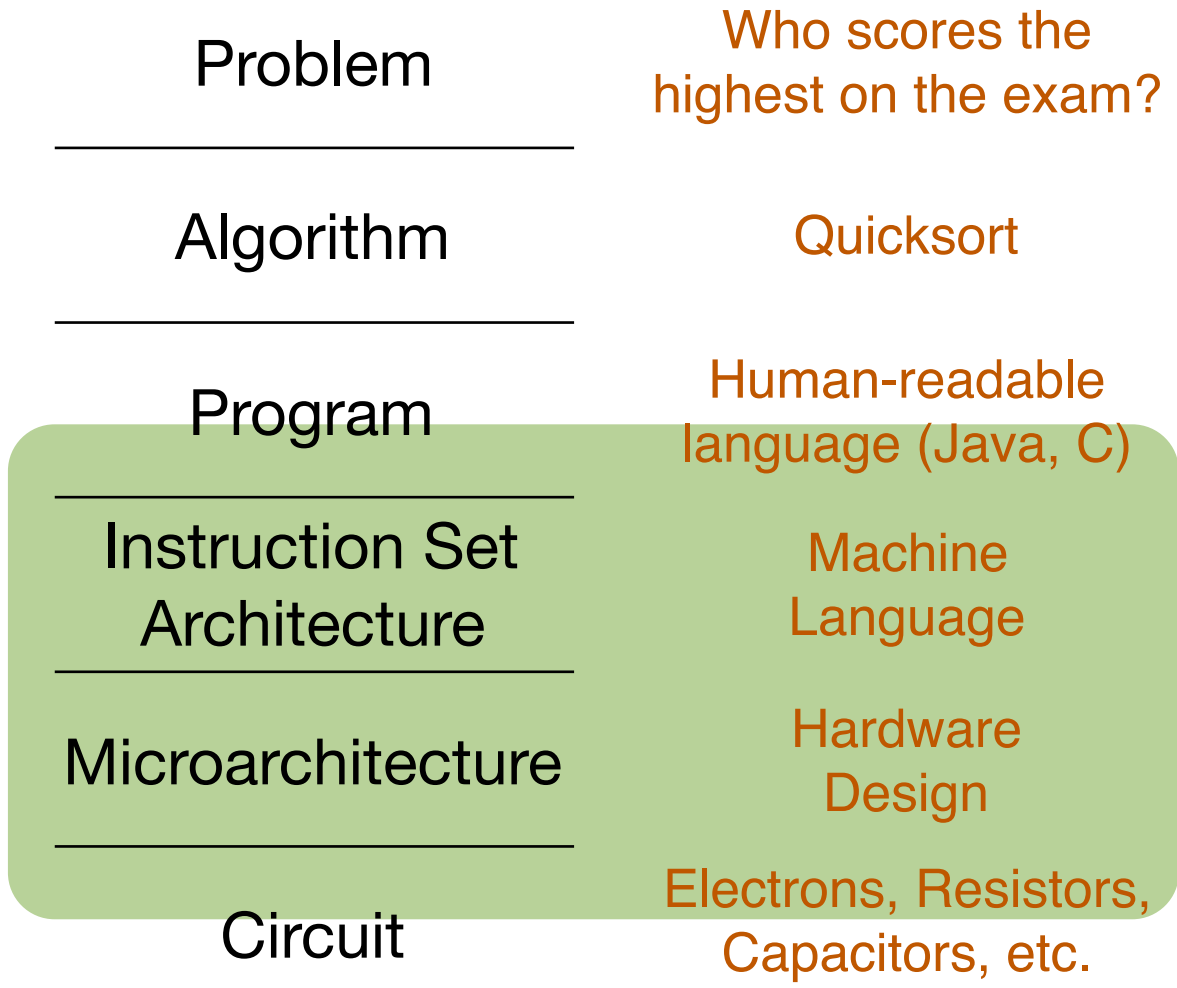
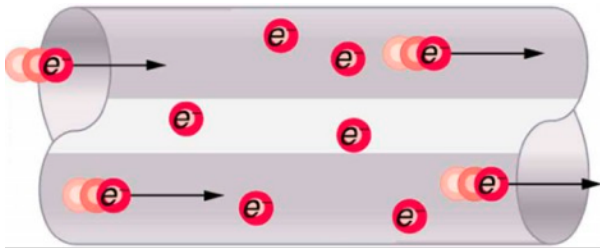
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Machine Language

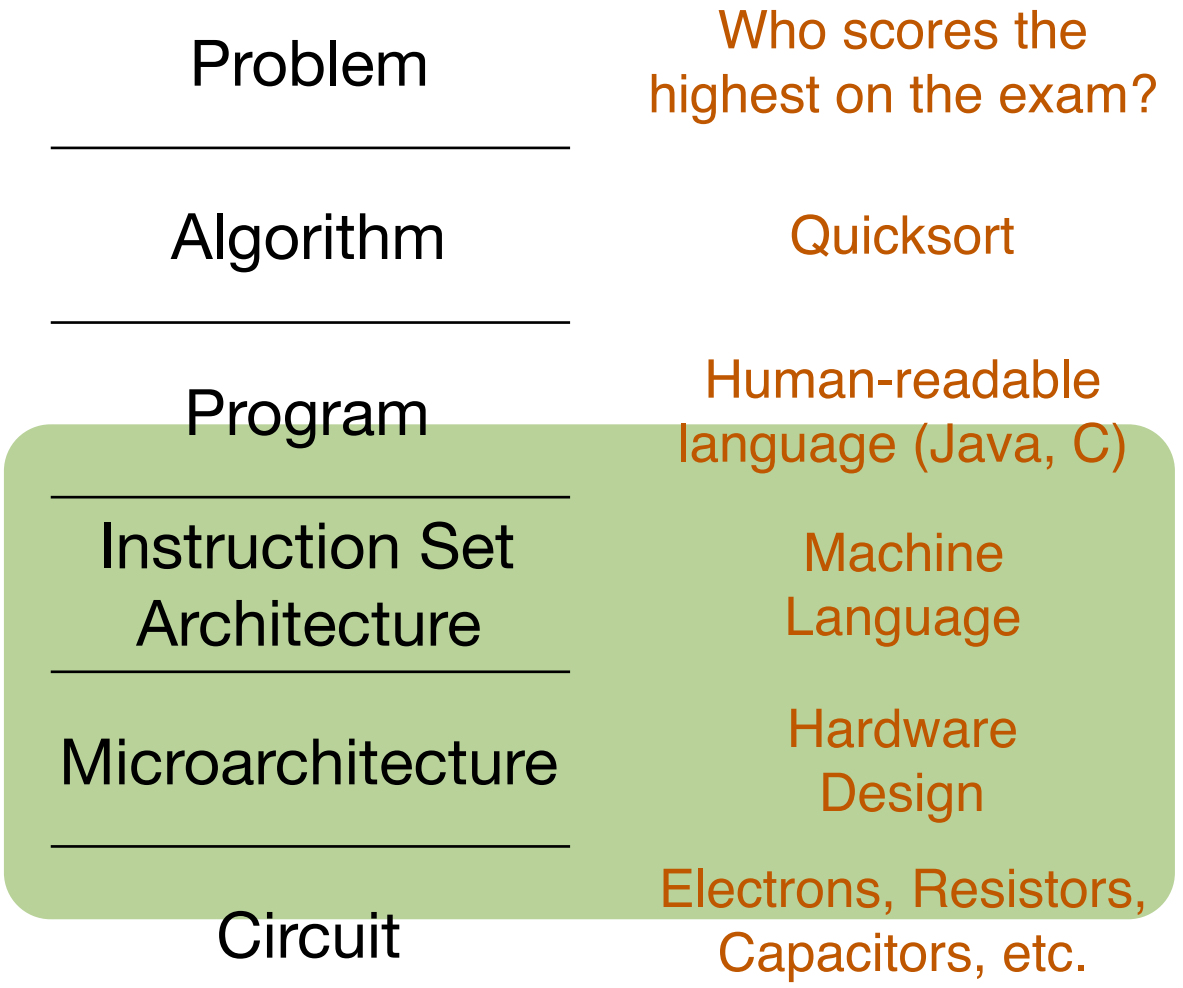
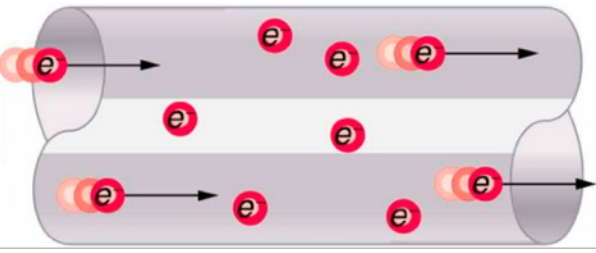
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What is Computer Systems?



Computer Systems Match User Requirements to Hardware Technologies

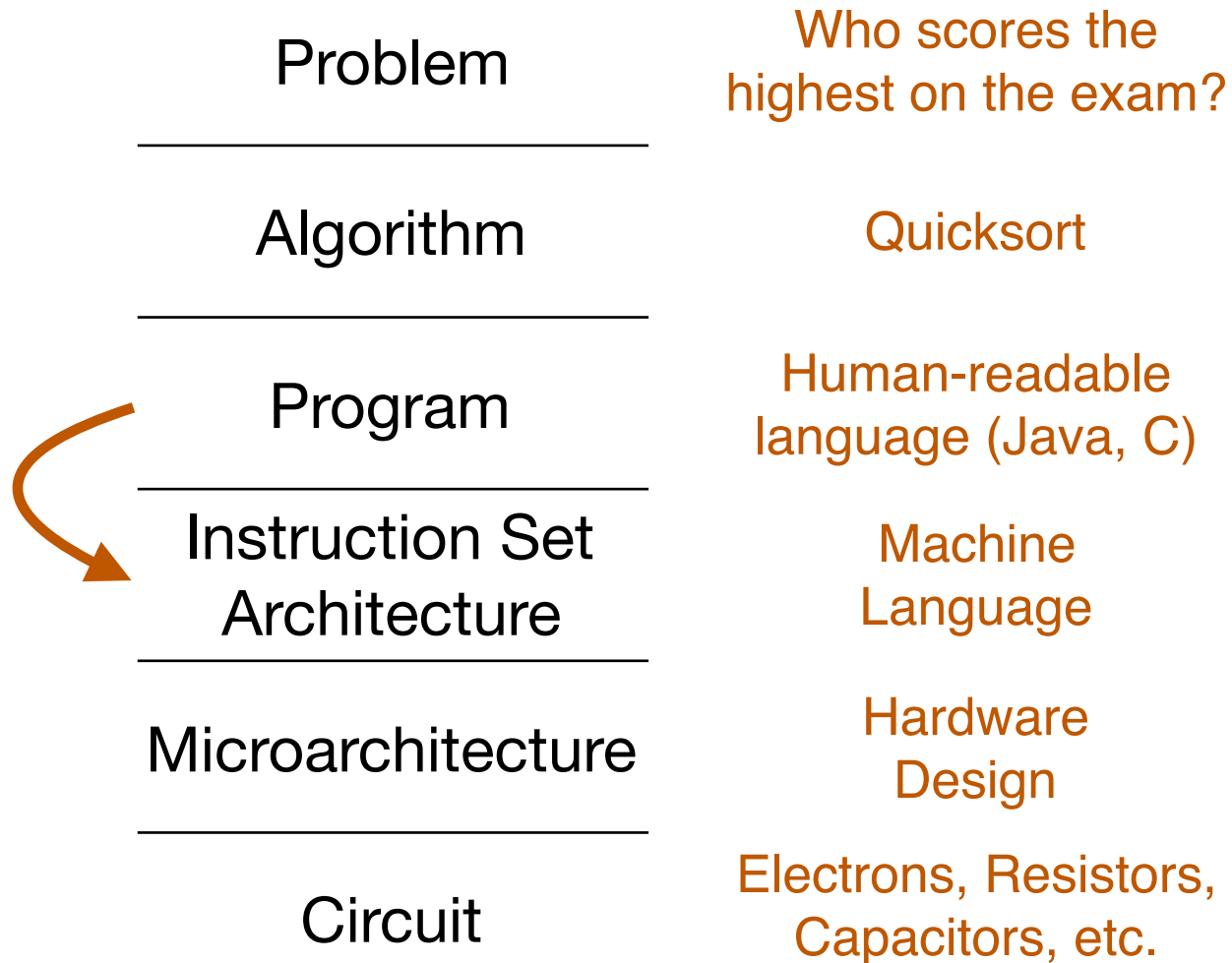


Two Fundamental Aspects of Computer Systems

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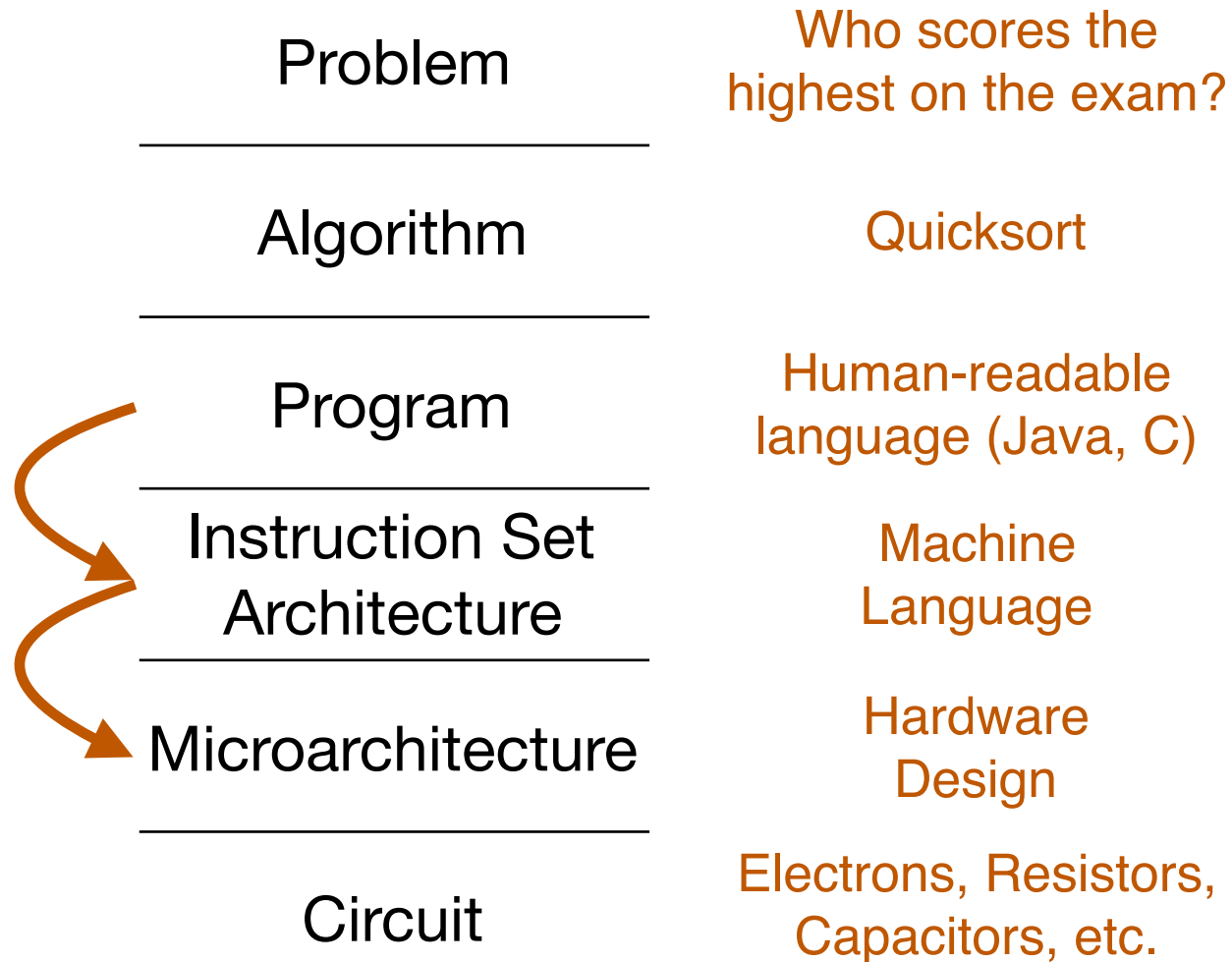
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- How is a human-readable program translated to a representation that computers can understand?



Two Fundamental Aspects of Computer Systems

- How is a human-readable program translated to a representation that computers can understand?
- How does a modern computer execute that program?



The “Translation” Process, a.k.a., **Compilation**

C Program

```
void add() {  
    int a = 1;  
    int b = 2;  
    int c = a + b;  
}
```

**Pre-processor
Compiler**



Assembly program

```
movl    $1, -4(%rbp)  
movl    $2, -8(%rbp)  
movl    -4(%rbp), %eax  
addl    -8(%rbp), %eax
```

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Assembler
Linker



Executable Binary

```
00011001 ...
01101010 ...
11010101 ...
01110001 ...
```


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Executable Binary

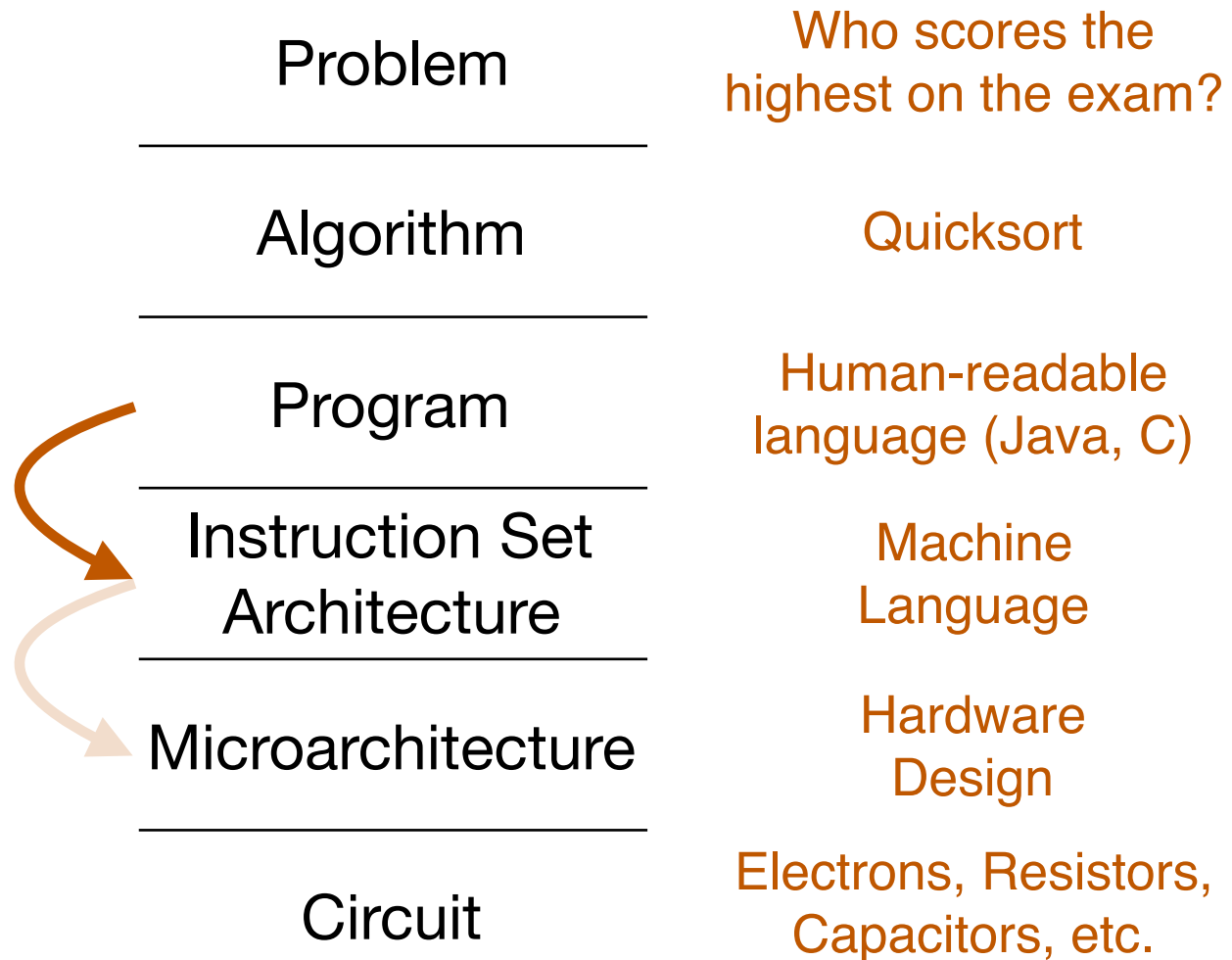
```
00011001 ...
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11010101 ...
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```

- It translates a text file to an executable binary file (a.k.a., executable) consisting of a sequence of **instructions**
- Why binary? Computers understand only 0s and 1s
 - The subject of next lecture

Back to Layers of Transformation...

How is a human-readable program translated to a representation that computers can understand?

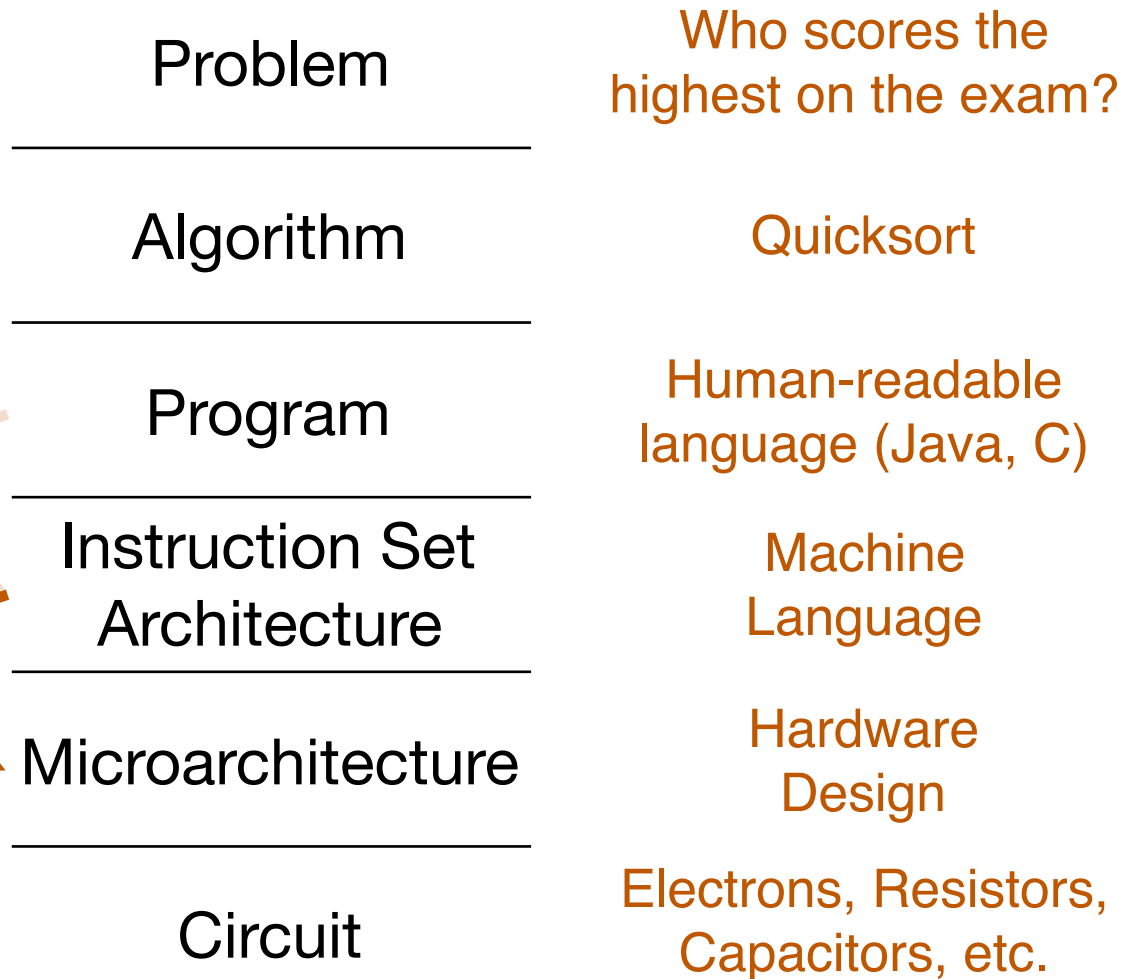
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Back to Layers of Transformation...

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How does a modern computer execute that program?



The Single Most Important Idea of Computers

- Executables (i.e., instructions) are stored in “memory”
- Processors read instructions from memory and execute instructions one after another

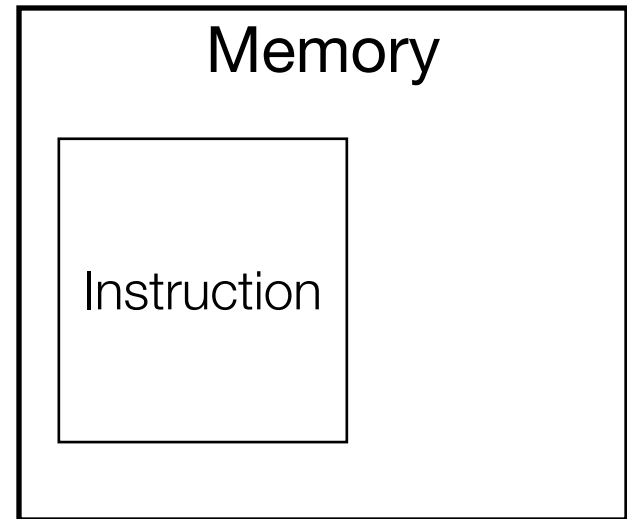
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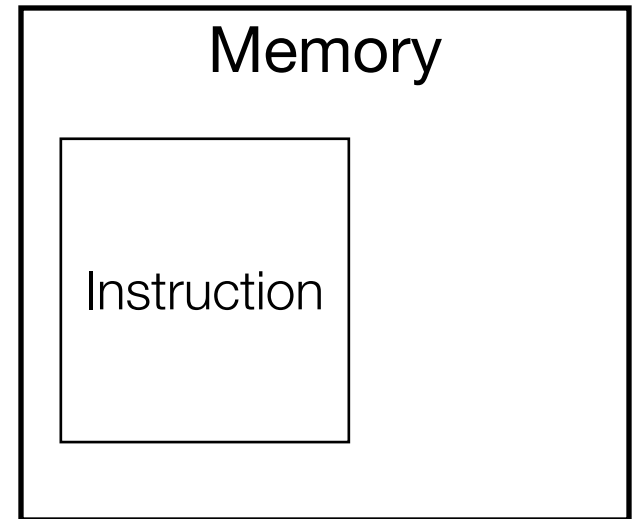
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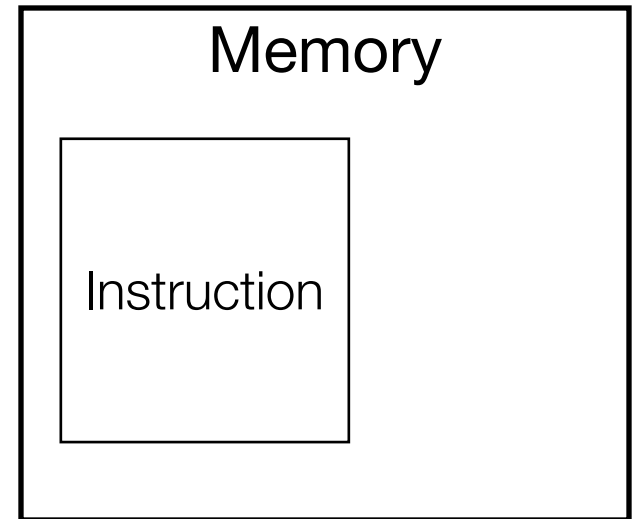
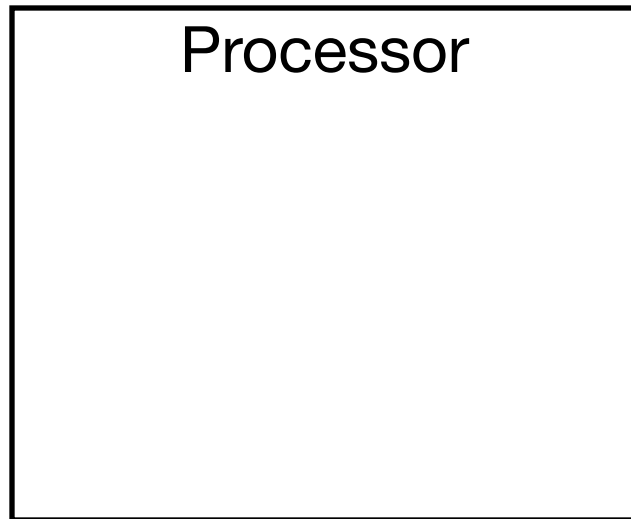
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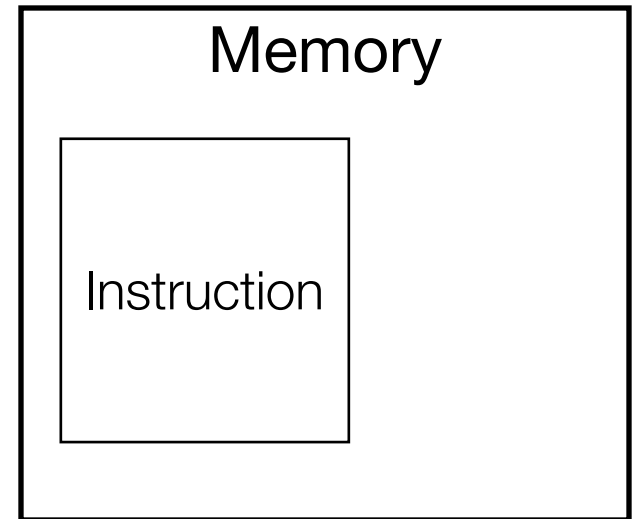
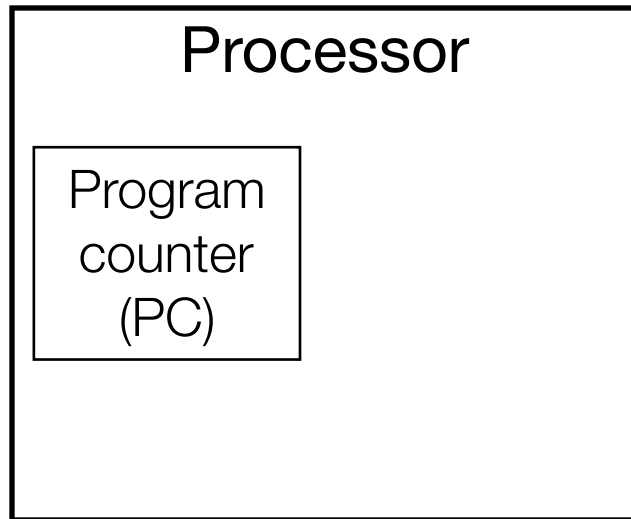
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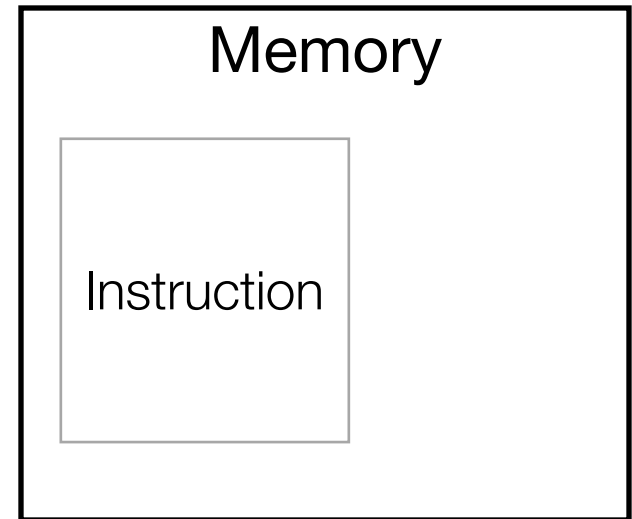
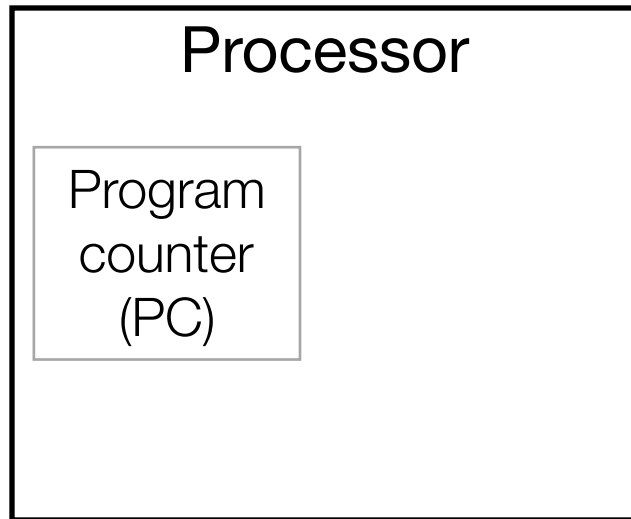
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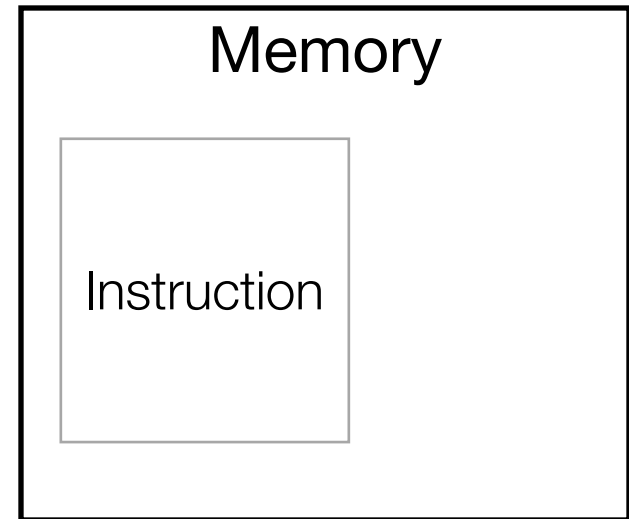
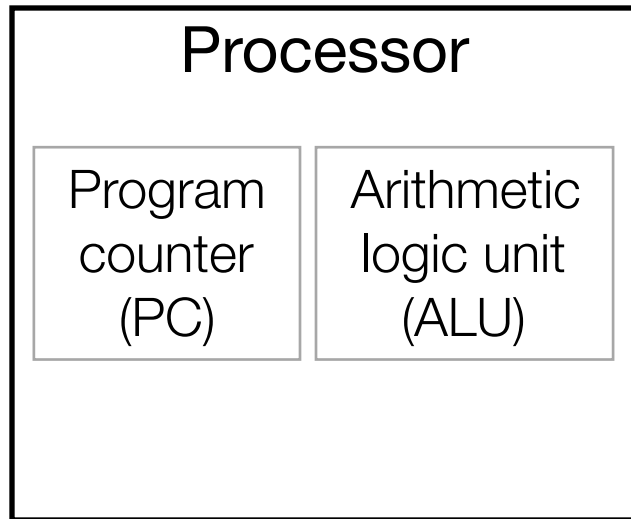
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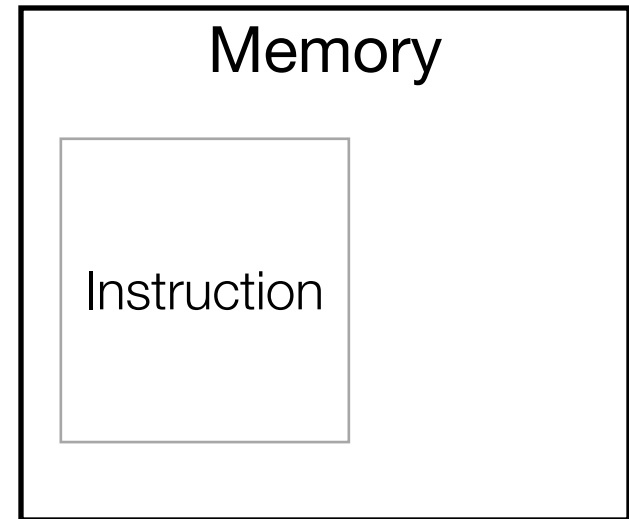
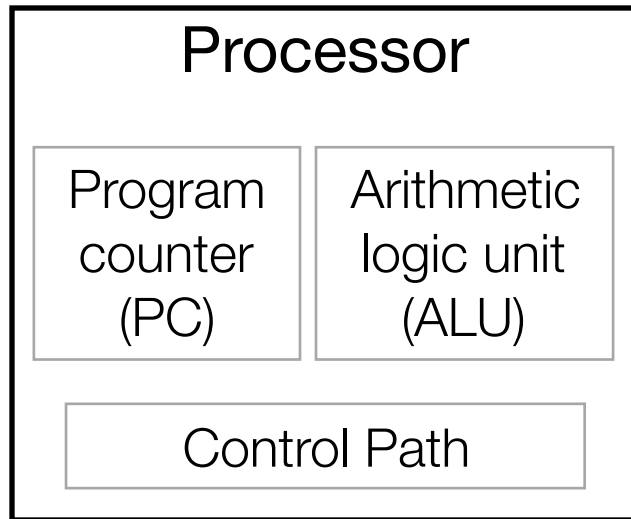
High-level Organization of Computer Hardware a.k.a., The Von Neumann Model



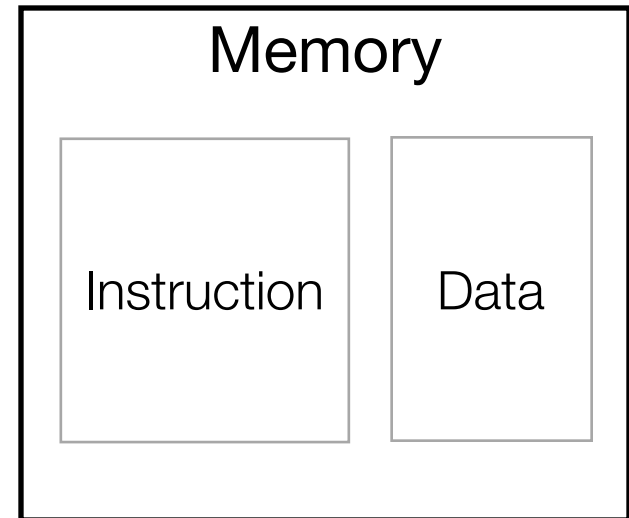
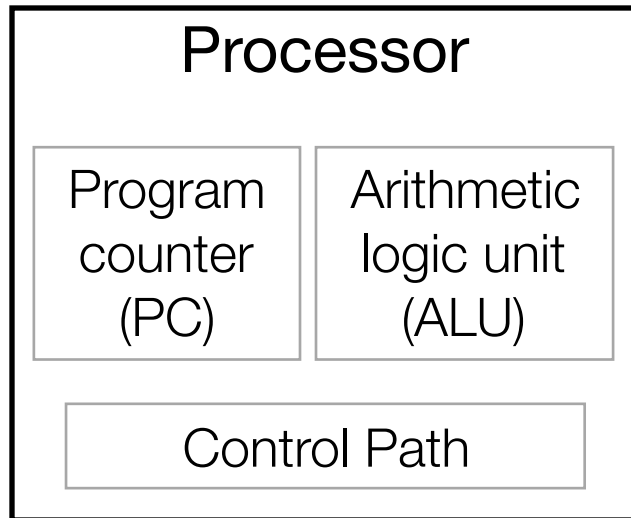
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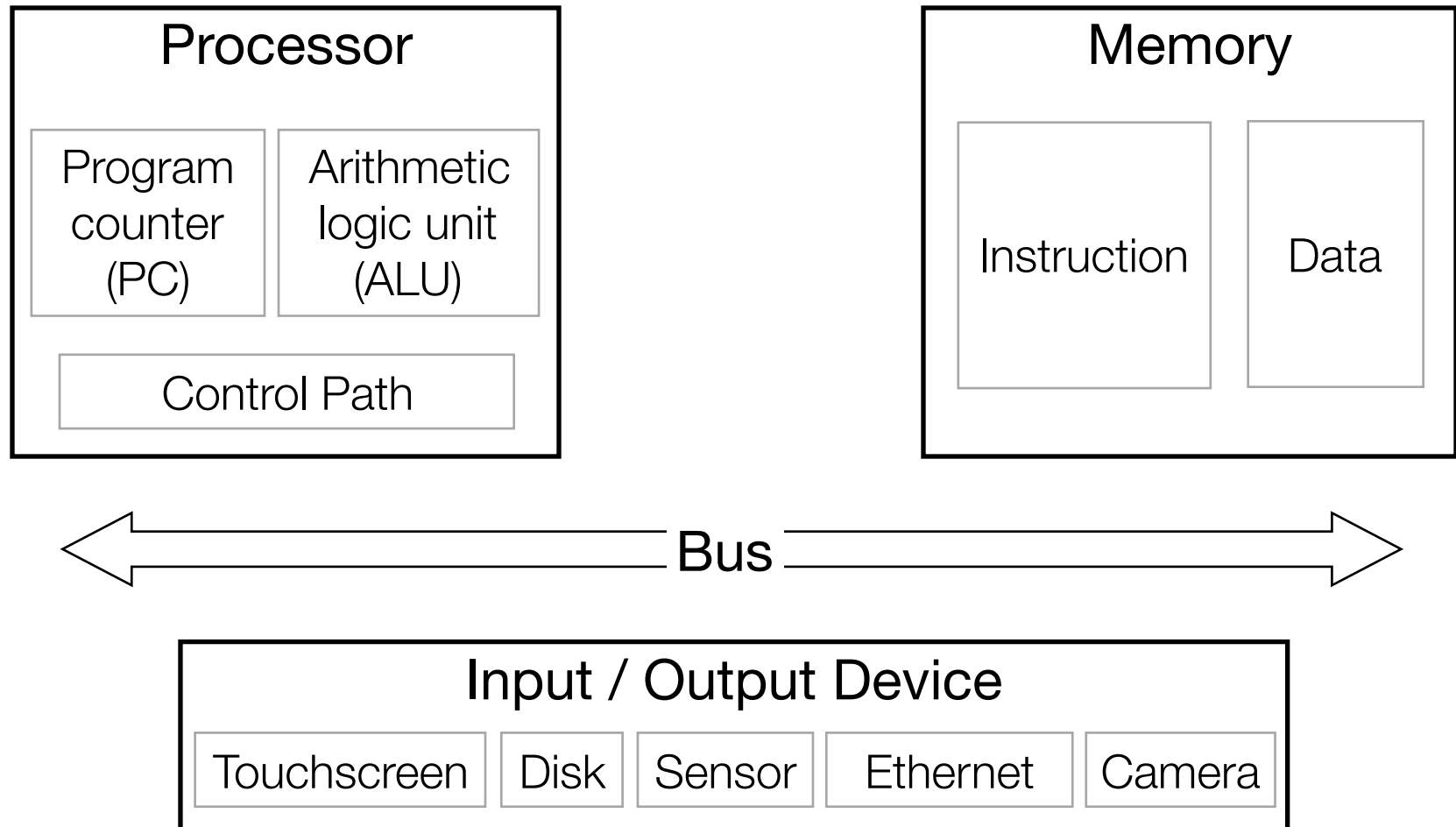
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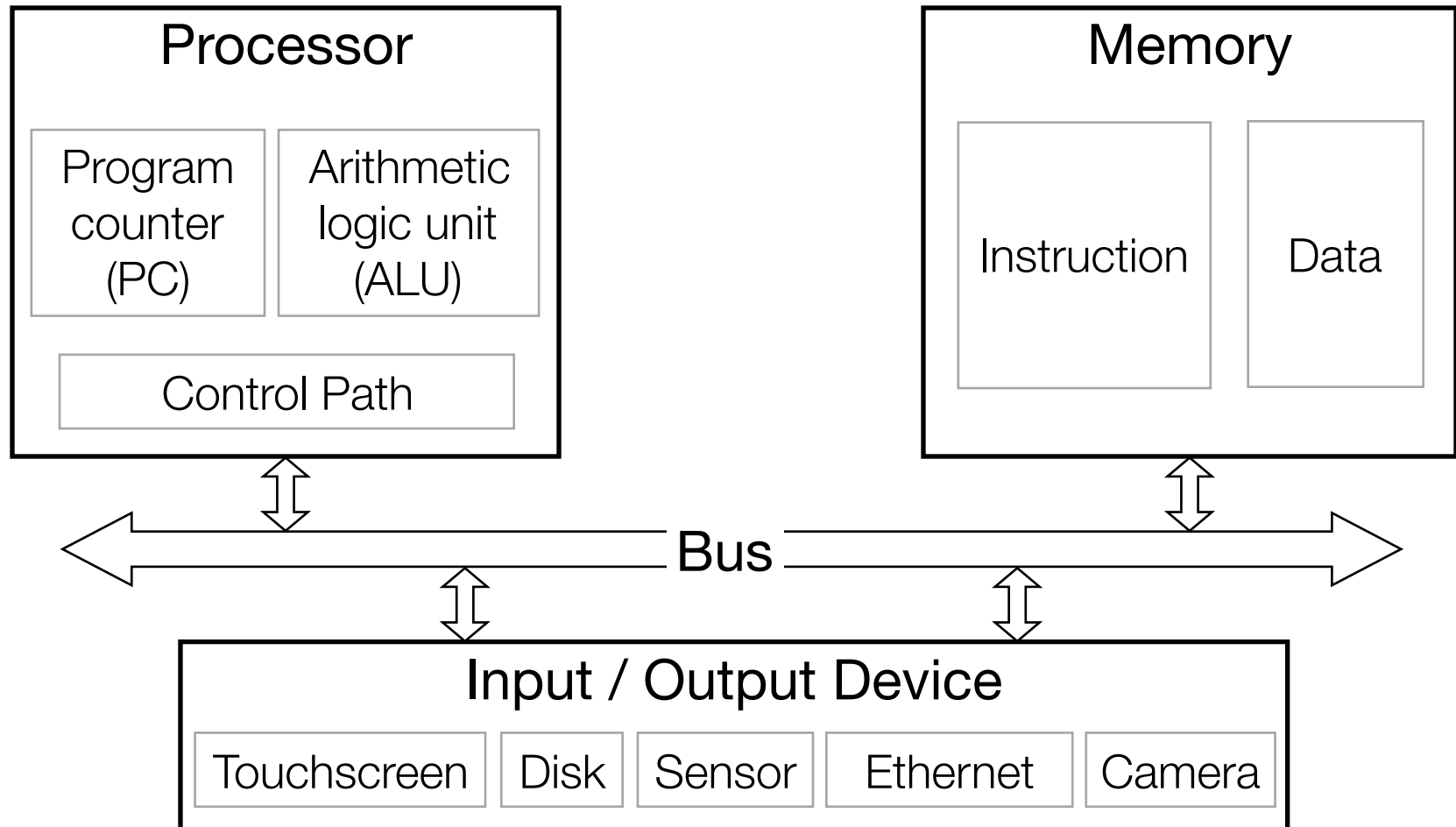
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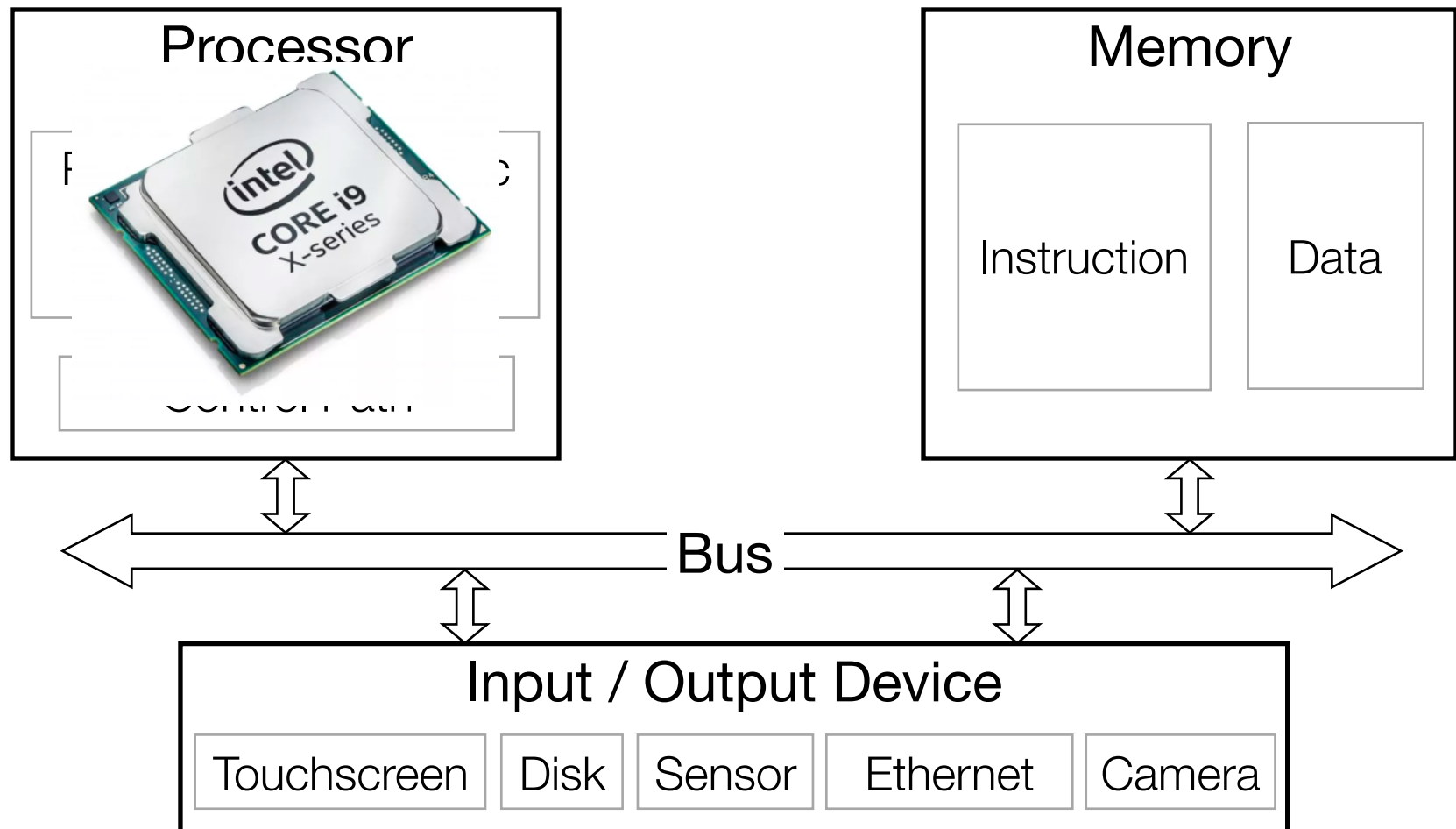
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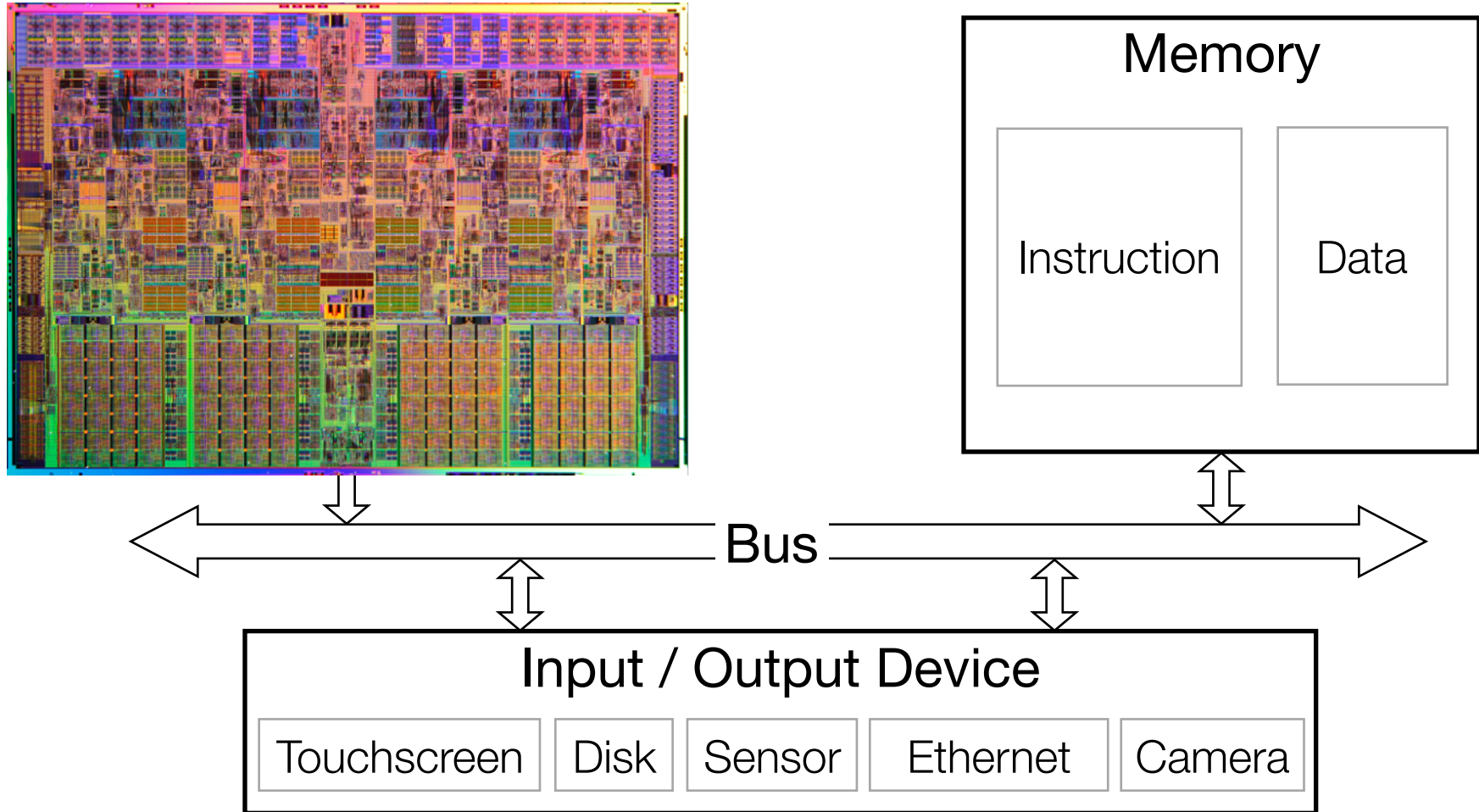
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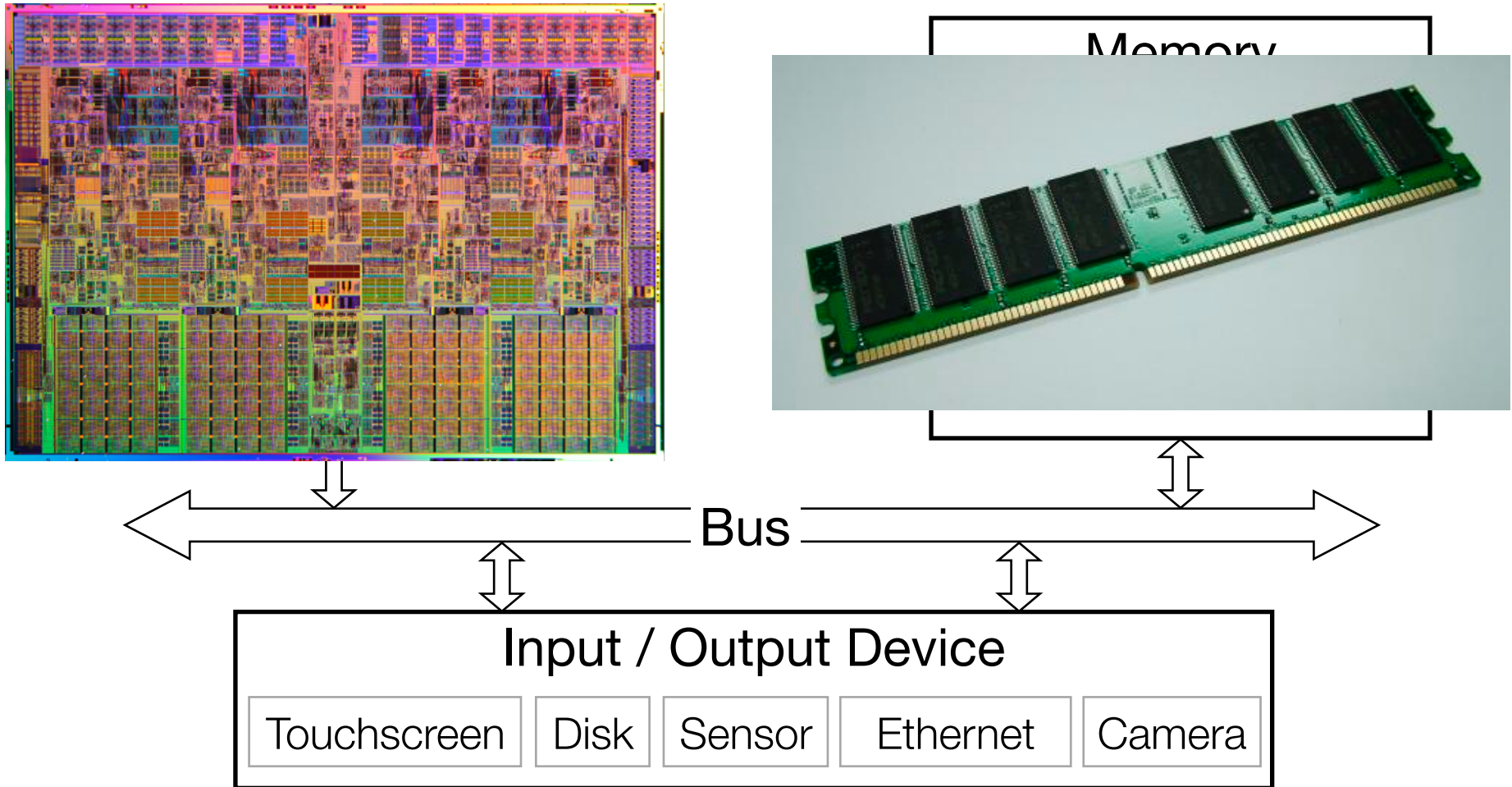
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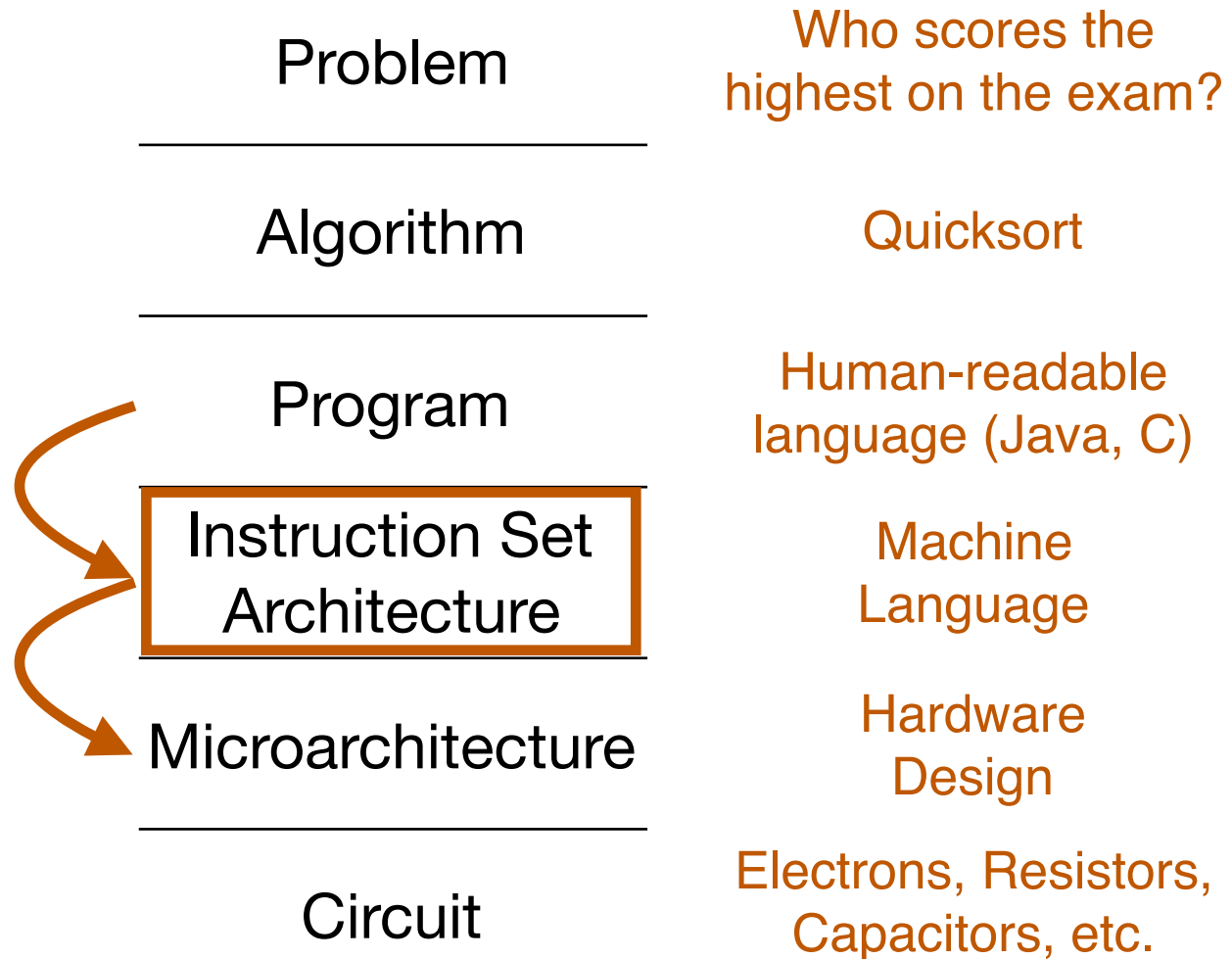
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Back to Layers of Transformation...

How is a human-readable program translated to a representation that computers can understand?

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Instruction Set Architecture

- The programmer's view of the computer is called the "instruction set architecture" (*ISA*)

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callq   _printf
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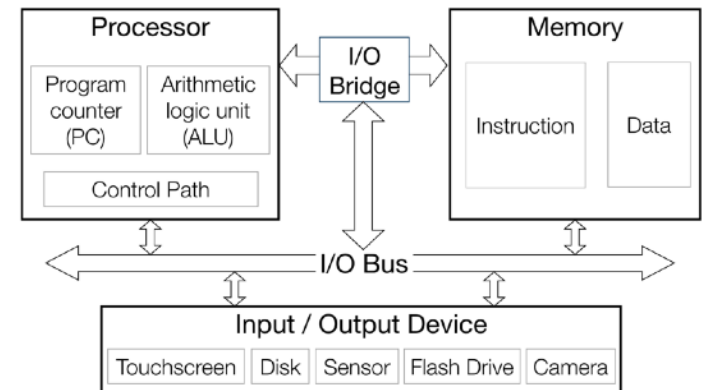
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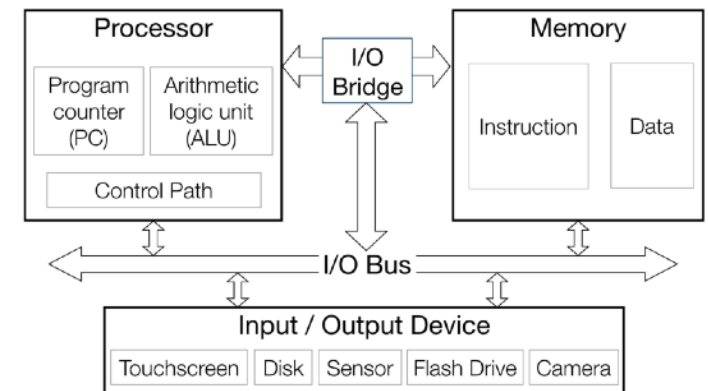
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- ISAs *abstract* away details of microarchitecture

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Abstraction

- Think of car versus engine, transmission, brakes, ...

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- Leaving out one or more properties of a complex object so as to focus on others
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Abstraction

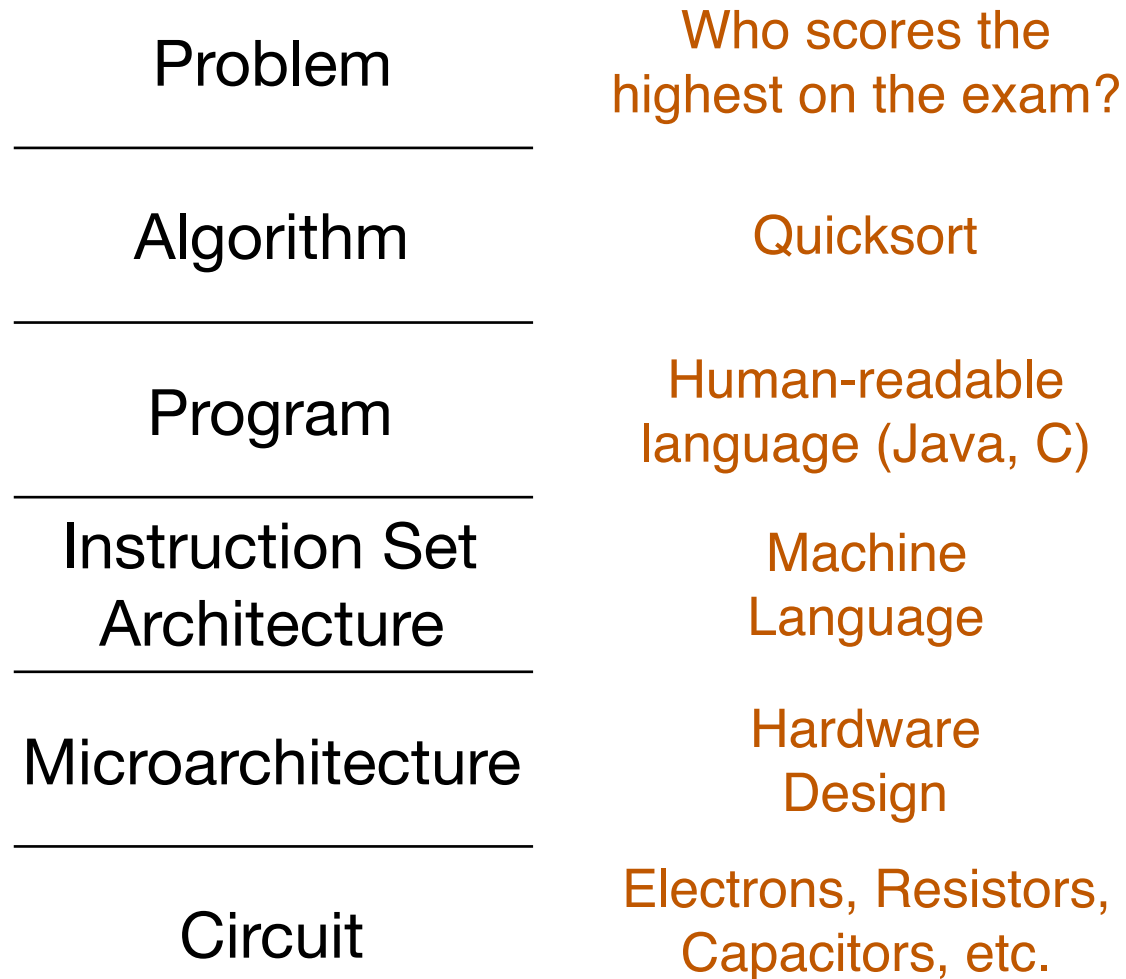
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 - ISA leaves out *how* “ADD” is implemented
 - ISA also leaves out *how long* an “ADD” instruction takes
- **Bad abstractions throw away essential features of problem**
 - Topologist is someone who does not know the difference between a doughnut and a coffee cup
 - Bad ISAs don't tell you whether the hardware can do multiplication

Every Layer in CS is an Abstraction

Problem	Who scores the highest on the exam?
Algorithm	Quicksort
Program	Human-readable language (Java, C)
Instruction Set Architecture	Machine Language
Microarchitecture	Hardware Design
Circuit	Electrons, Resistors, Capacitors, etc.

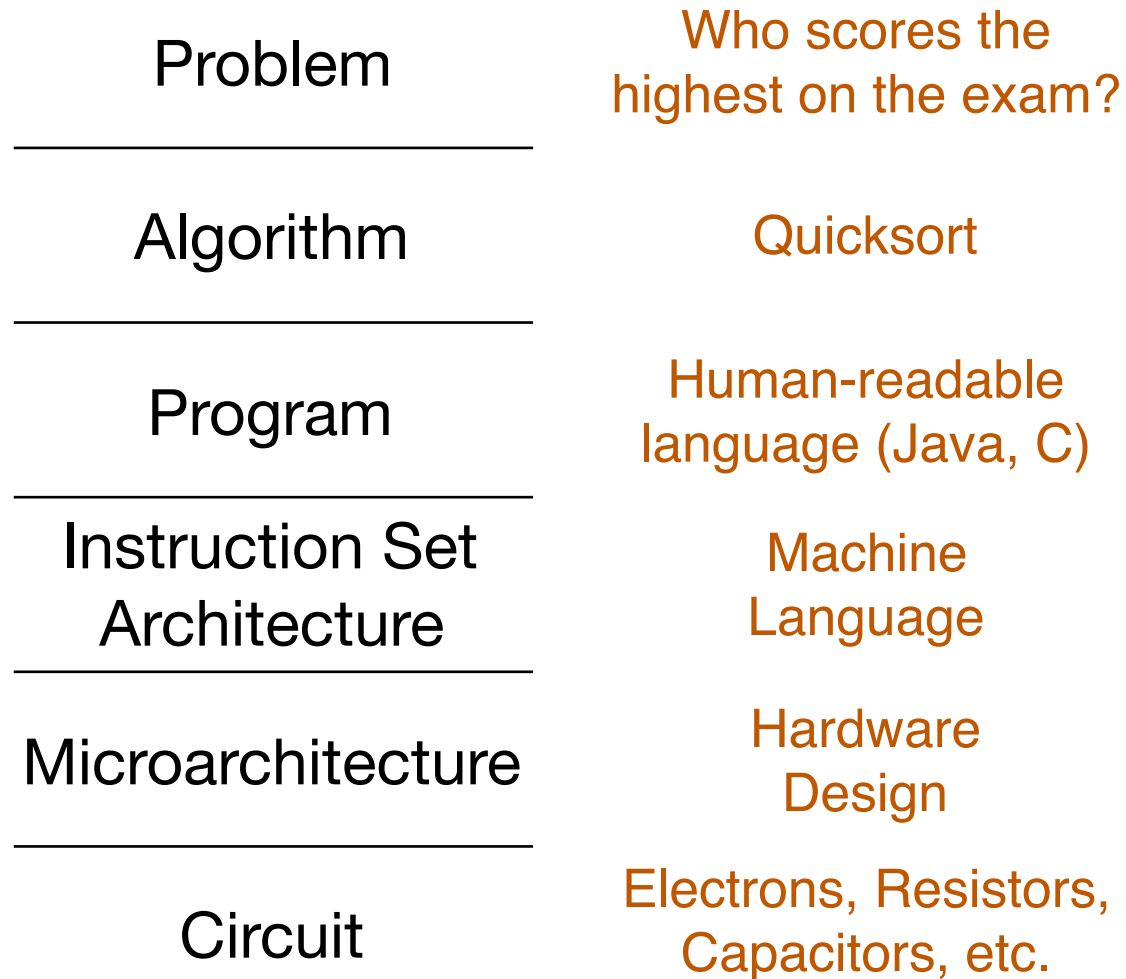
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- Depend on which layer you want to live at, you have different views of the computer



Every Layer in CS is an Abstraction

- Depend on which layer you want to live at, you have different views of the computer
- This course expands your layers of abstractions



Instruction Set Architecture

- There used to be many ISAs
 - x86, ARM, Power/PowerPC, Sparc, MIPS, IA64, z
 - Very consolidated today: ARM for mobile, x86 for others

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 - Very consolidated today: ARM for mobile, x86 for others
- **There are even more microarchitectures**
 - Apple/Samsung/Qualcomm have their own microarchitecture (implementation) of the ARM ISA
 - Intel and AMD have different microarchitectures for x86

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- x86, ARM, PC, Sparc
- Very cons ARM for others

- There are microarc

- Apple/Sa mm have ARM ISA
- Intel and rent micro or x86



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- **There are even more microarchitectures**
 - Apple/Samsung/Qualcomm have their own microarchitecture (implementation) of the ARM ISA
 - Intel and AMD have different microarchitectures for x86
- **ISA is lucrative business: ARM's Business Model**
 - Patent the ISA, and then license the ISA
 - Every implementer pays a royalty to ARM
 - Apple/Samsung pays ARM whenever they sell a smartphone

Instruction Set Architecture

- Little research on ISA, much more microarch. research
 - ISA is stable now. “One ISA rules them all.”
 - Free, open ISA: RISC V (<https://riscv.org/>)



- Instead, focus on optimizing the implementation.

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 - Can a microarchitecture designed for ISA *X* execute ISA *Y*?

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- Interesting question: can we have one microarchitecture (implementation) for different ISAs?
 - Can a microarchitecture designed for ISA X execute ISA Y ?
 - Yes but you need something that translates programs written in ISA Y to ISA X while you are executing it: *dynamic binary translator*

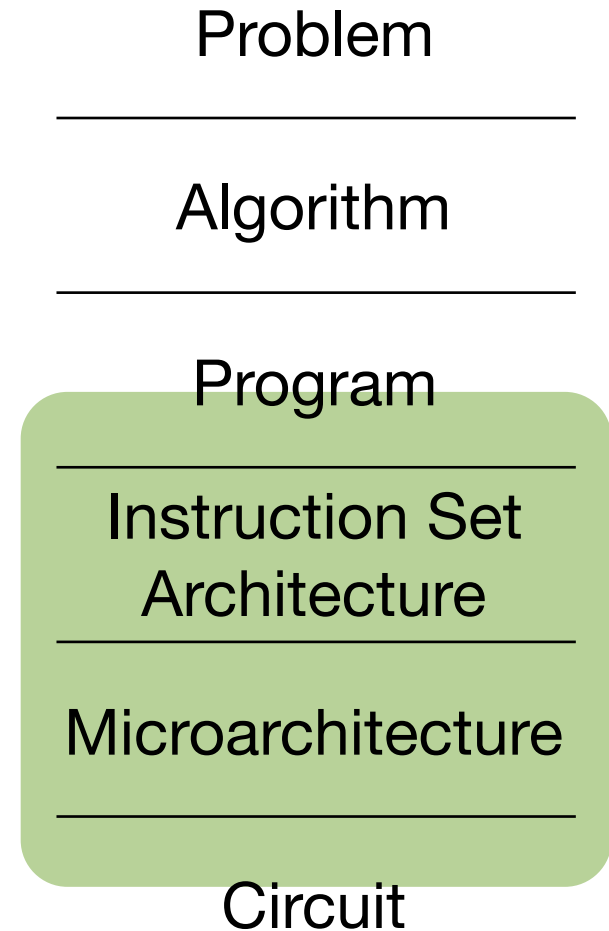
Instruction Set Architecture

- Little research on ISA, much more microarch. research
 - ISA is stable now. “One ISA rules them all.”
 - Free, open ISA: RISC V (<https://riscv.org/>)



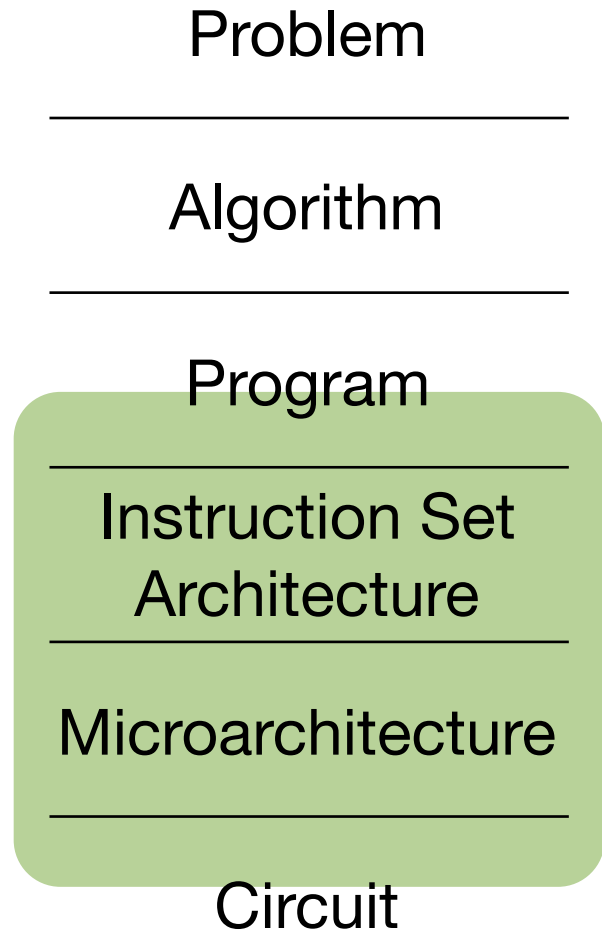
- Instead, focus on optimizing the implementation.
- Interesting question: can we have one microarchitecture (implementation) for different ISAs?
 - Can a microarchitecture designed for ISA X execute ISA Y ?
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 - E.g., Transmeta executes x86 ISA programs on their own ISA

The Role of a Computer System Designer



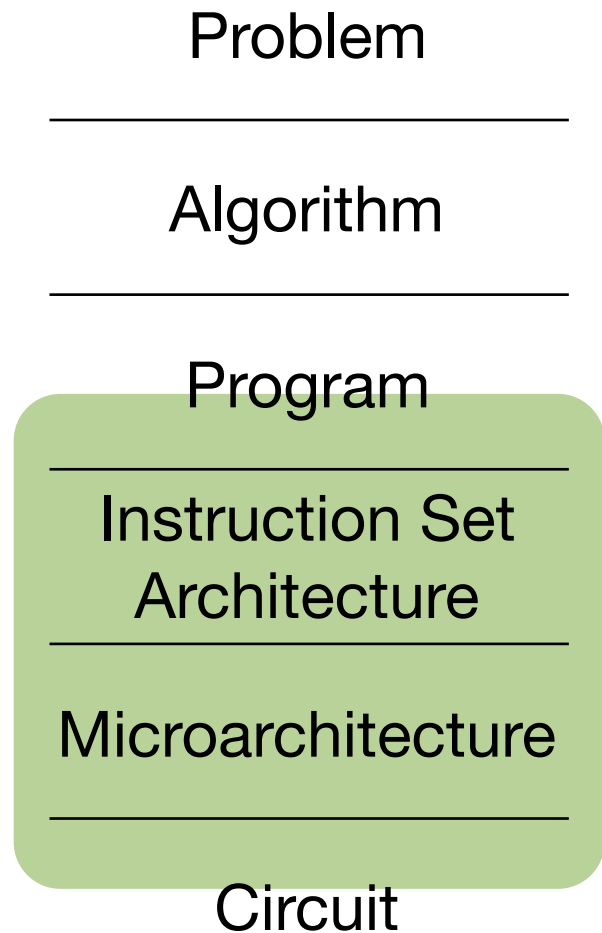
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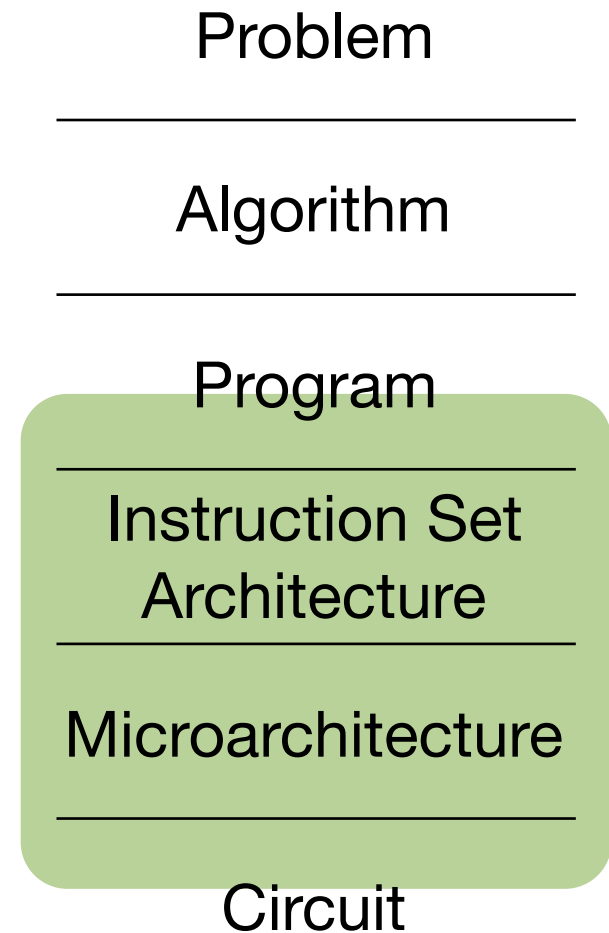
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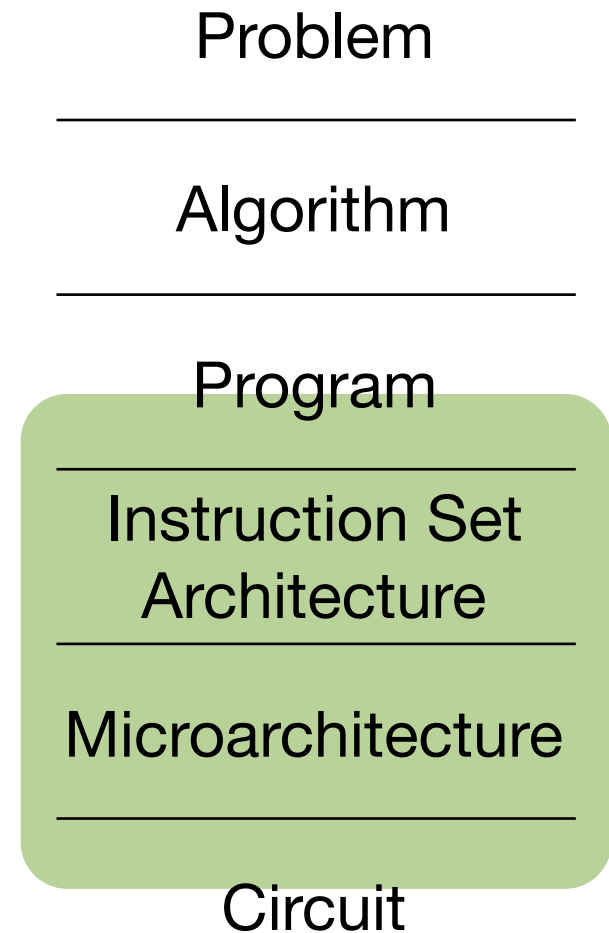
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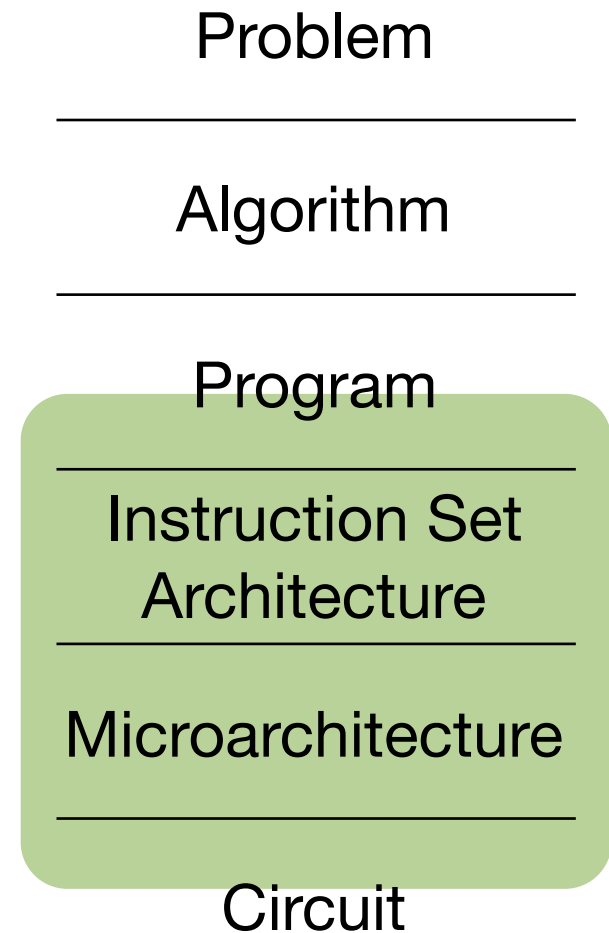
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Questions?

Who Are We?

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- Myself: Yuhao Zhu
 - WH 3501, yzhu@rochester.edu
 - Office hours Tuesday 4pm — 5pm.
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- **Coming to office hours does NOT mean you are weak!**

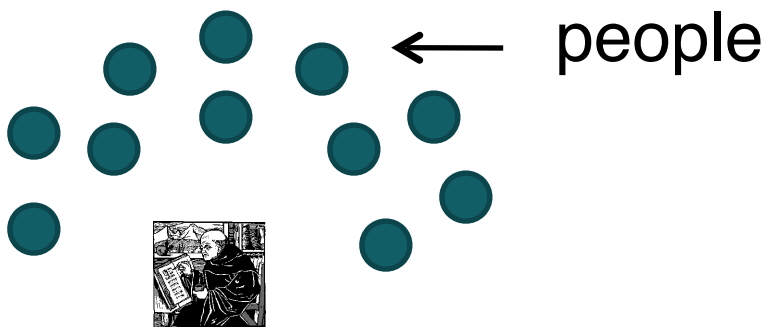
A Word about Lectures and Medieval Times

- Lecture: It's a large part of what you pay for
- But why do we have the "lecture" format?
 - Why does someone stand at the front and tell you things?
 - Why do you take "notes" on what they say?

All The Way Back to Medieval Times..



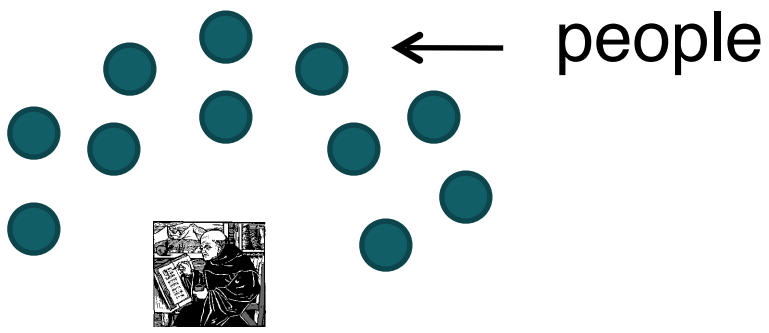
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Lecture Halls



Modern Times

- You don't have to trust the monk!
 - The printing press: a revolutionizing development
 - The web: order your knowledge up for yourself on Amazon!
- Read books and analyze for **YOURSELF!**
 - If I rephrase it for you, what purpose does that serve?



amazon.com[®]

FAQ: "But, wouldn't it be more efficient if you just taught us with the right answer to begin with?"

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- Have you ever heard of a workout class where the instructor did all the exercises while everyone else just watched attentively?
- To learn, you must do the work with your own muscle (brain)!



Textbook

- Required textbook
 - Bryant and O'Hallaron's *Computer Systems: A Programmer's Perspective* (3rd edition)
- Some recommended (but not required) textbooks
 - *Introduction to Computing Systems: From Bits and Gates to C and Beyond*, 2/e. This is where I learnt Computer Systems.
 - *Structured Computer Organization*, 6/e. More emphasis on SW.
 - *Computer Organization and Design: The Hardware Software Interface*, ARM Edition. More emphasis on hardware.

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- 1 comprehensive final exam, 35%

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- Share ideas but not artifacts (e.g., code, sketch)

Programming Environment

- Develop code (or at least test it) on the CSUG Linux boxes (csug.rochester.edu)
 - Microsoft Visual Studio could be nice, but it's not what we use
 - The lack of Unix knowledge is a major problem according to our industry contacts
- Projects will be mostly in C and x86 assembly.
- We only accept ANSI-C that can be compiled by the default GCC on the CSUG Linux boxes

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Loved how the final exam was set up. Actually made me THINK.

Programming Assignments and Exams

The assignments were often very different from what we were learning in the course, causing a lot of frustration in the beginning. People had to rely on outside sources to get a grounding of how to do an assignment.

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This is a feature, not a bug.

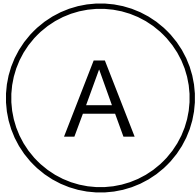
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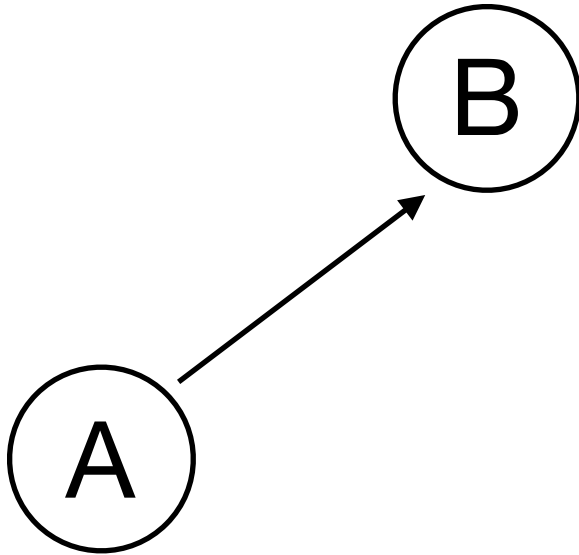
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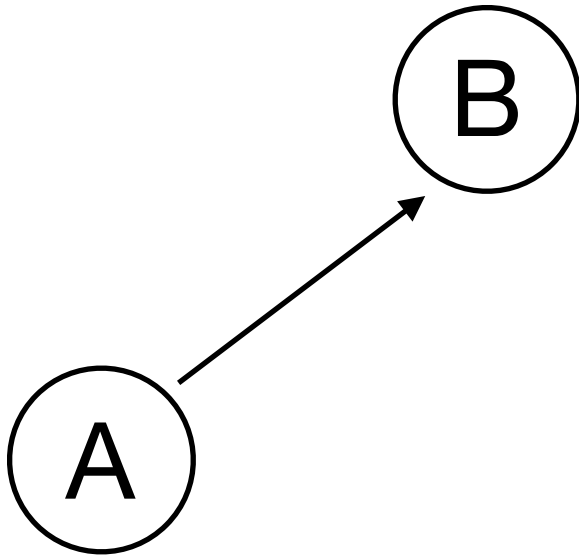
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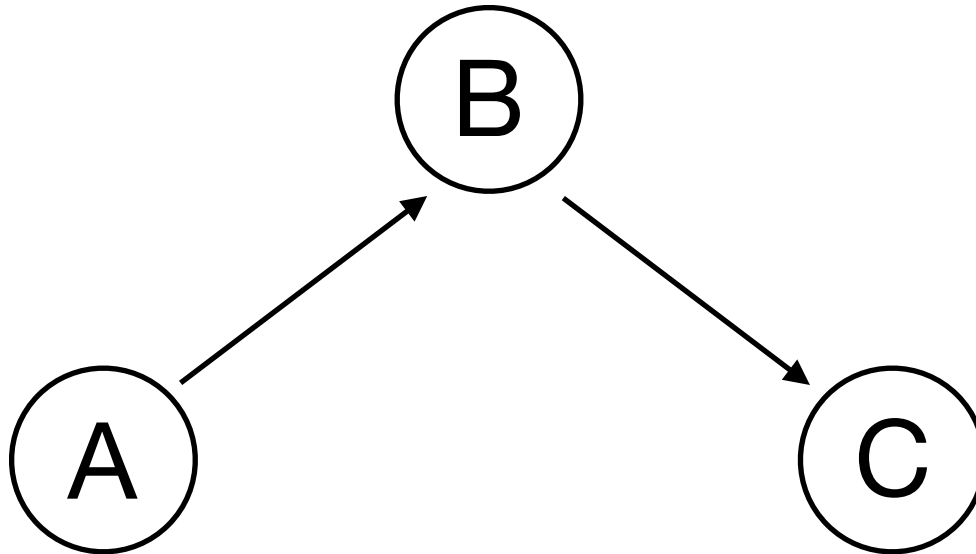
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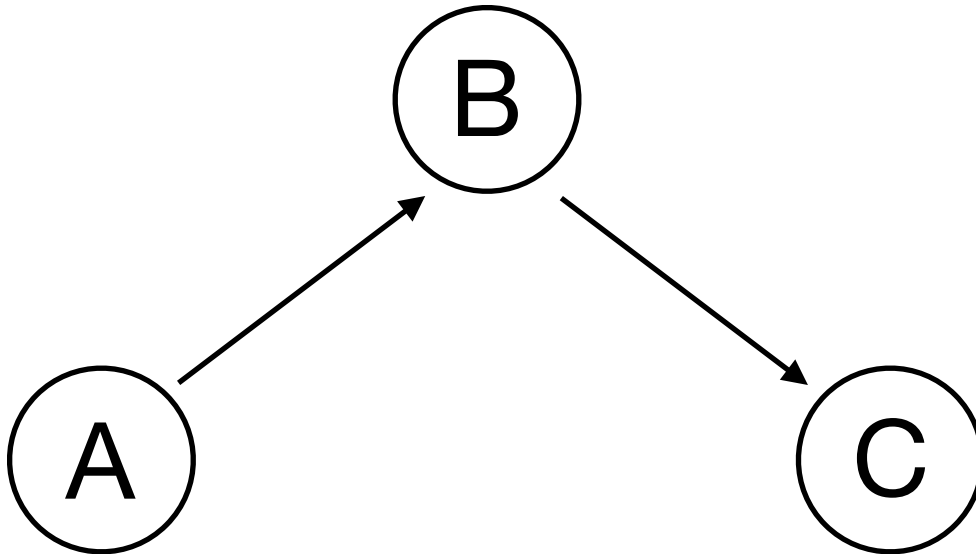
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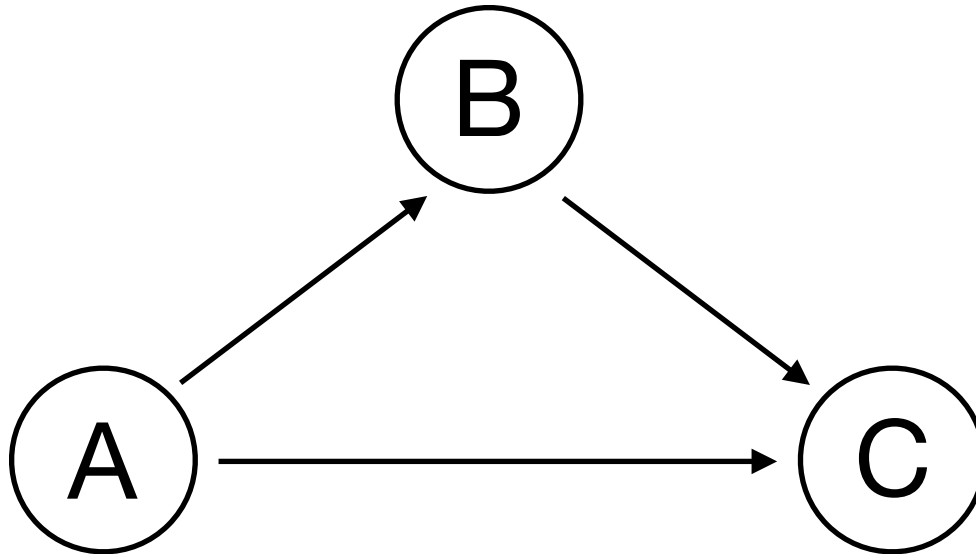
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What Should You Expect From Us?

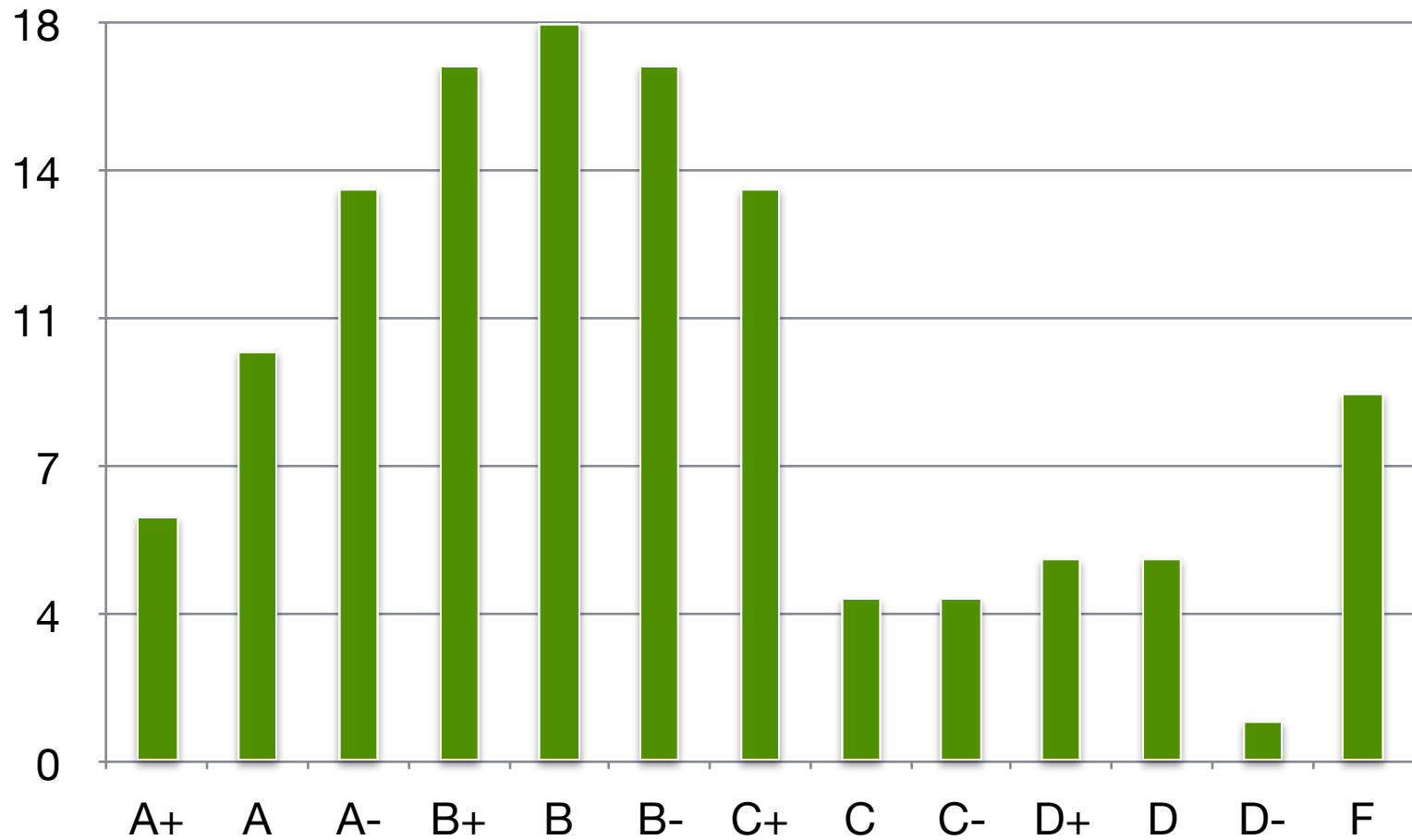
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- *Think of us as your friends, not enemies*
 - I'd love to give you an A, but give me a reason to do that

Final Grades Spring 2018



Final Grades Spring 2019

