CSC 252: Computer Organization
Spring 2018: Lecture 1

Instructor: Yuhao Zhu

Department of Computer Science
University of Rochester

Action Items:

- **Get CSUG account**
- **Sign up for Blackboard**

Slide credits: Leo Porter, Mattan Erez, Derek Chiou, Keshav Pingali

Outline: Class Introduction

- Introduction
  - What Are You Supposed to Learn in this Class?
    - What Is Computer Systems?
  - 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)
    - Talk to Brynn Wilkins (bwilkins@cs.rochester.edu) if you don't already have one
  - **Sign up for Blackboard** (https://learn.rochester.edu/)

Where to Find Stuff

- http://cs.rochester.edu/courses/252/spring2018/
  - General info
  - Programming assignments details
  - Various course materials
  - Opportunities and “ads”
- Blackboard for ***all*** communication
  - Only place for all announcements (e.g., when an assignment is out)
  - Only place for digitized Q&A
  - Except personal issues
  - Don’t waste time: **check/search previous posts before posting**
- CSUG machines for programming assignments submissions

What is Computer Systems?

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Problem

Who scores the highest on the exam?

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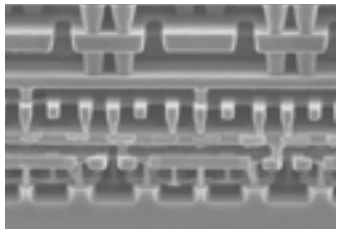

Circuit

Electrons, Resistors, Capacitors, etc.

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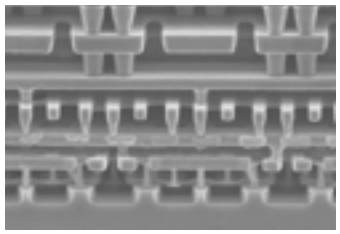

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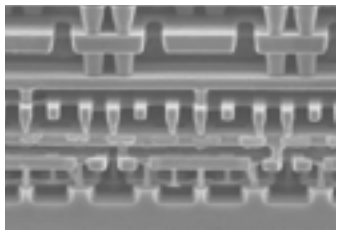
Quicksort



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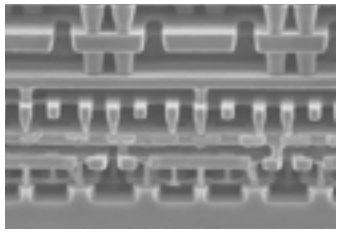

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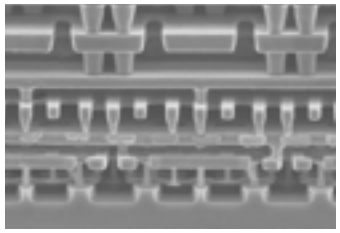

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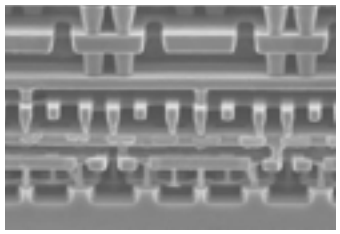

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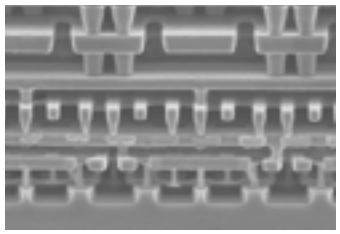

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Algorithm

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Machine Language

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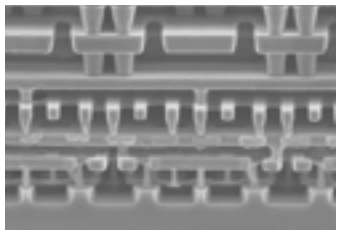

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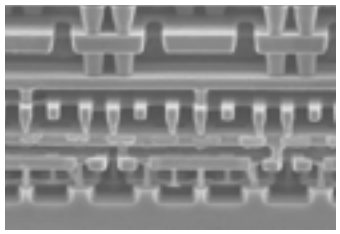

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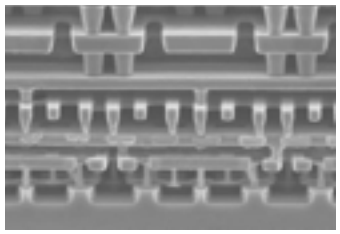

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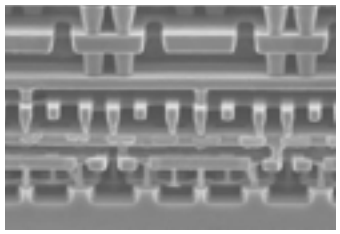

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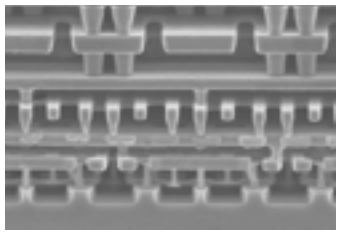
Computer Systems Match User Requirements to Hardware Technologies



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Two Fundamental Aspects of Computer Systems

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- How does a modern computer execute that program?

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

- 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
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Example: add.c

(Human-readable)

```
#include <stdio.h>
int main() {
  int a = 1;
  int b = 2;
  int c = a + b;
  printf(“%d\n”, c);
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Executable Binary
(Machine-readable)

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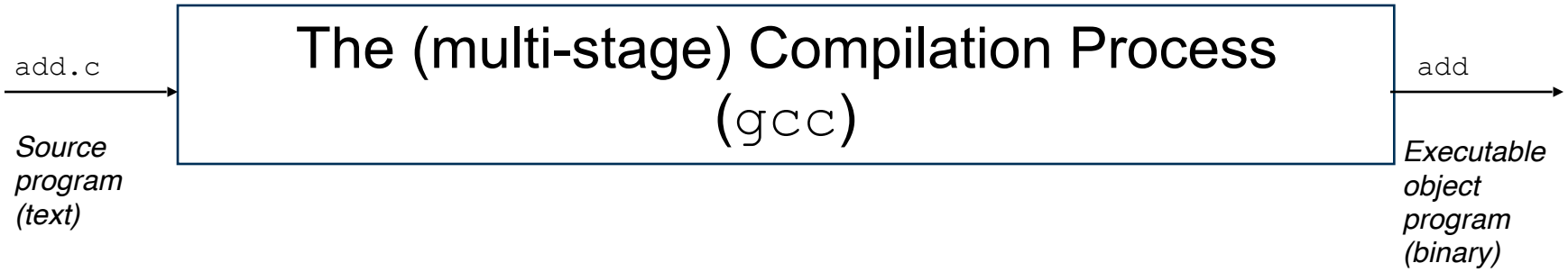
The “Translation” Process



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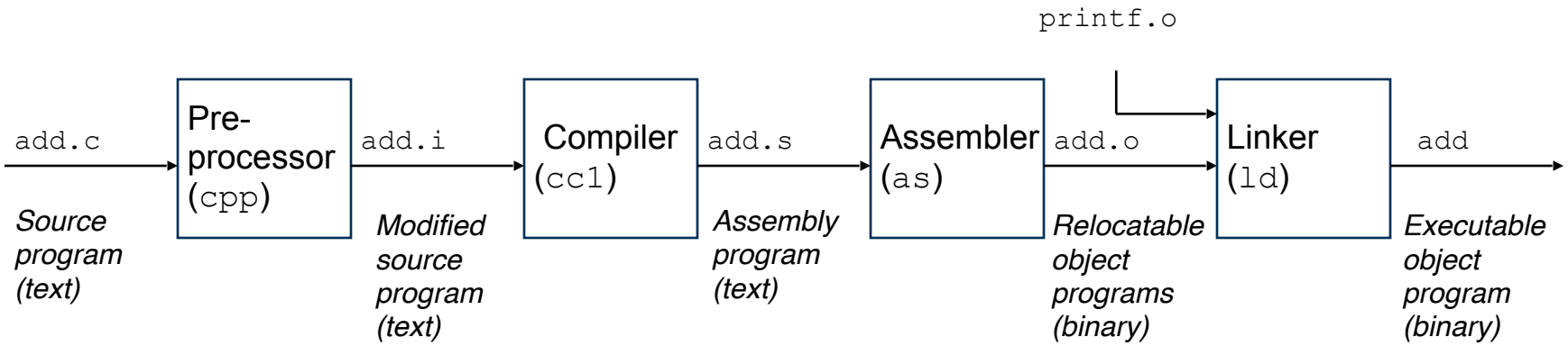

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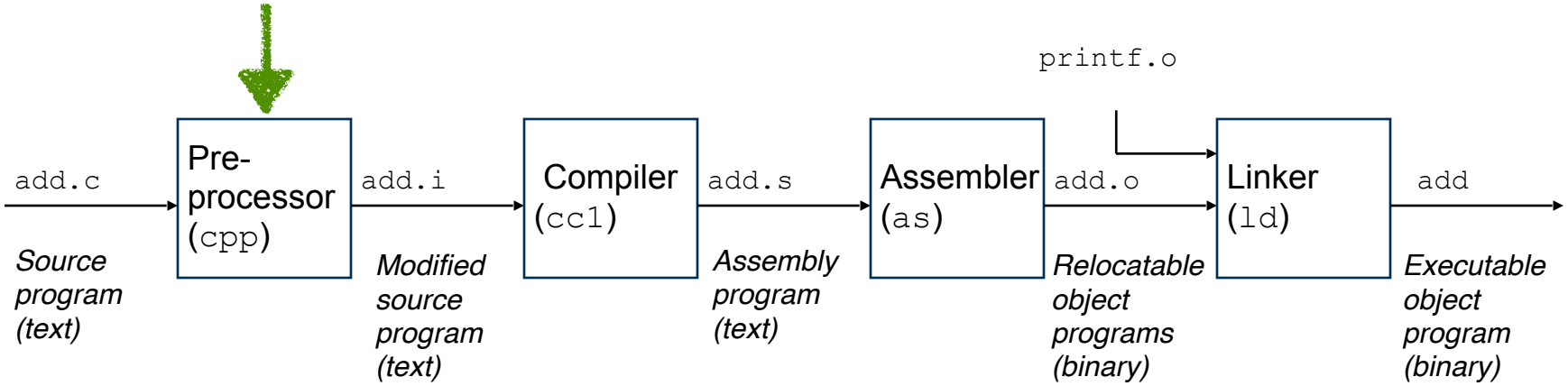

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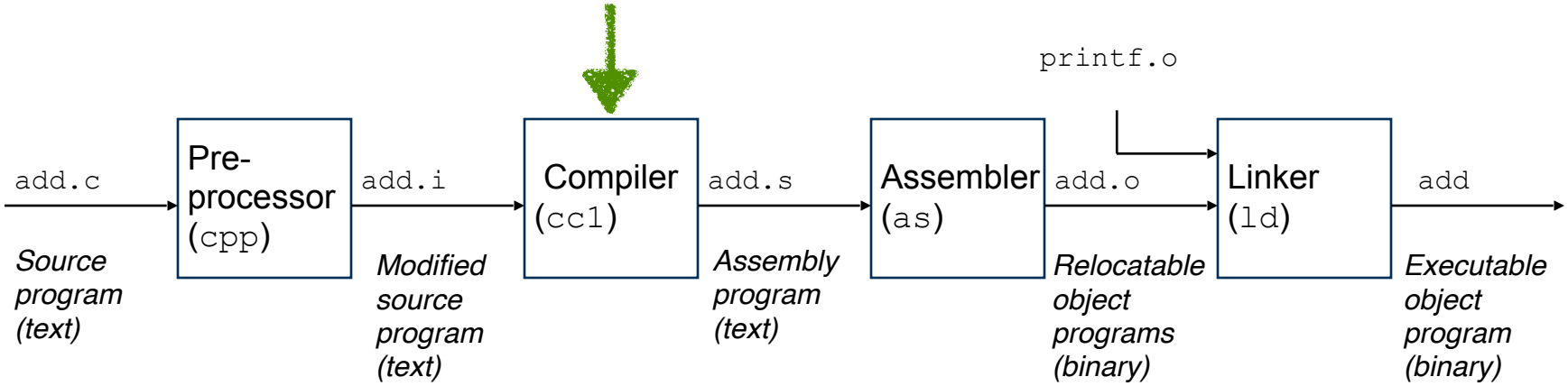

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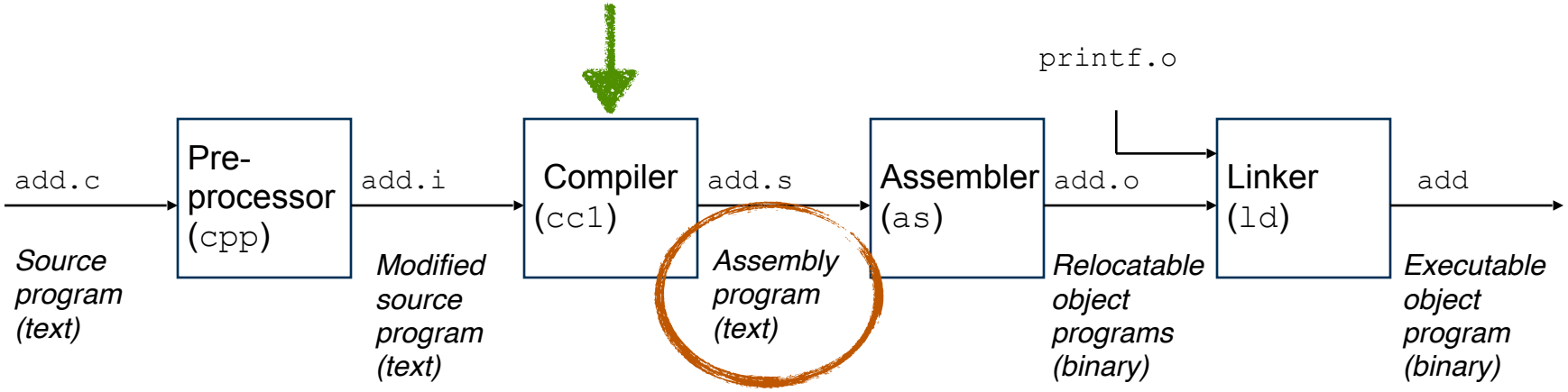

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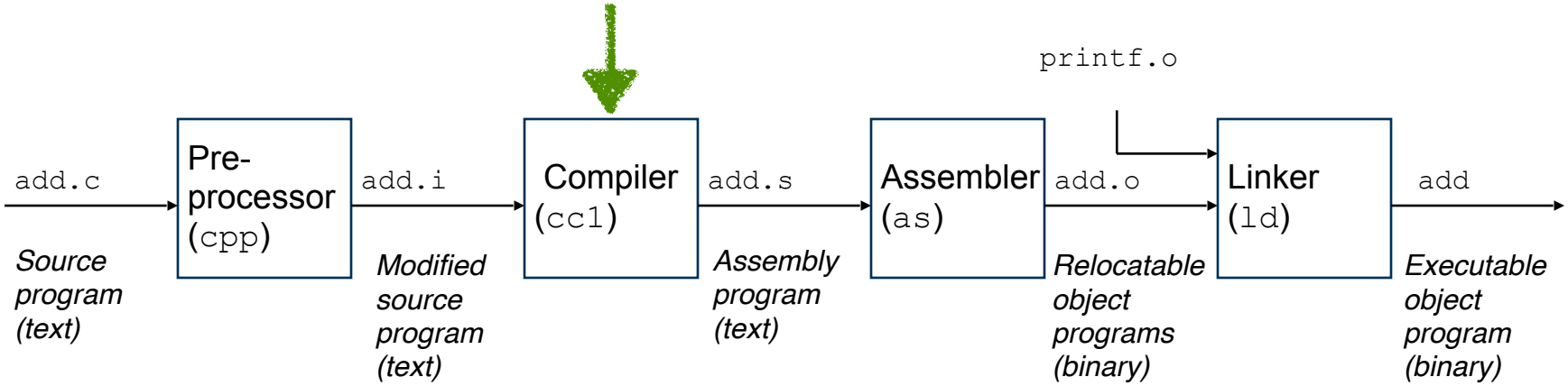

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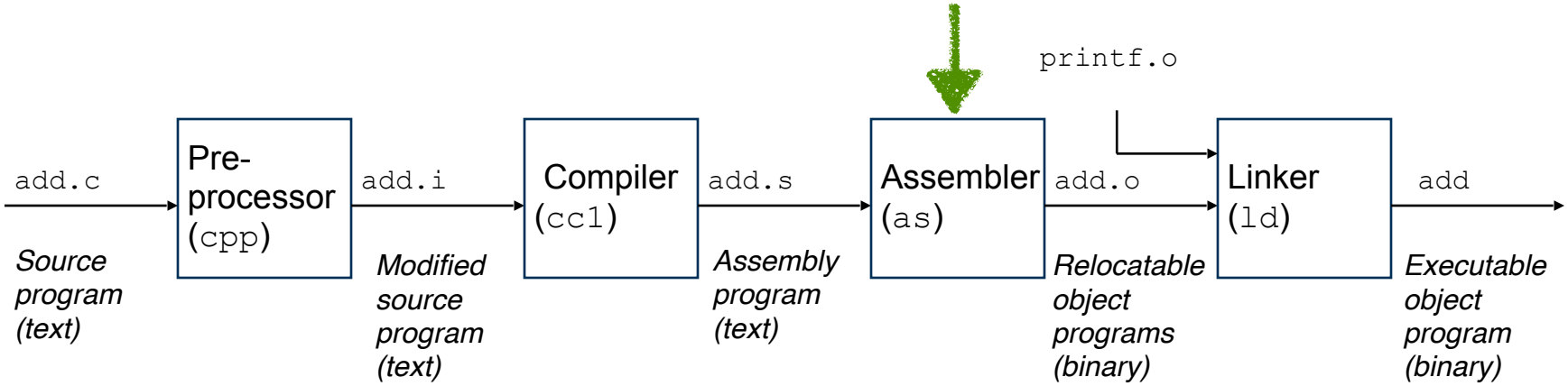

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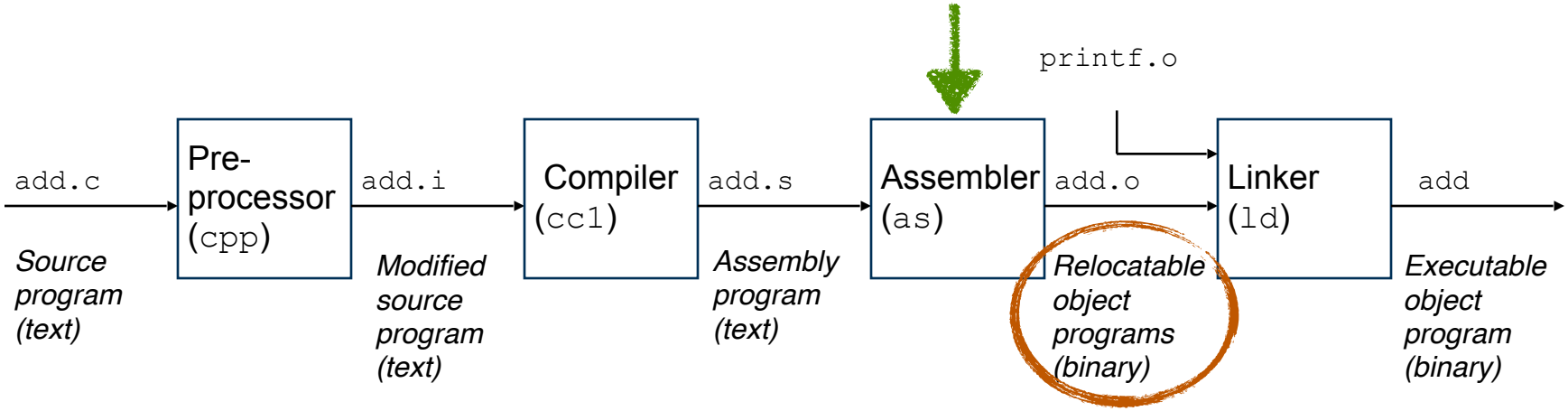

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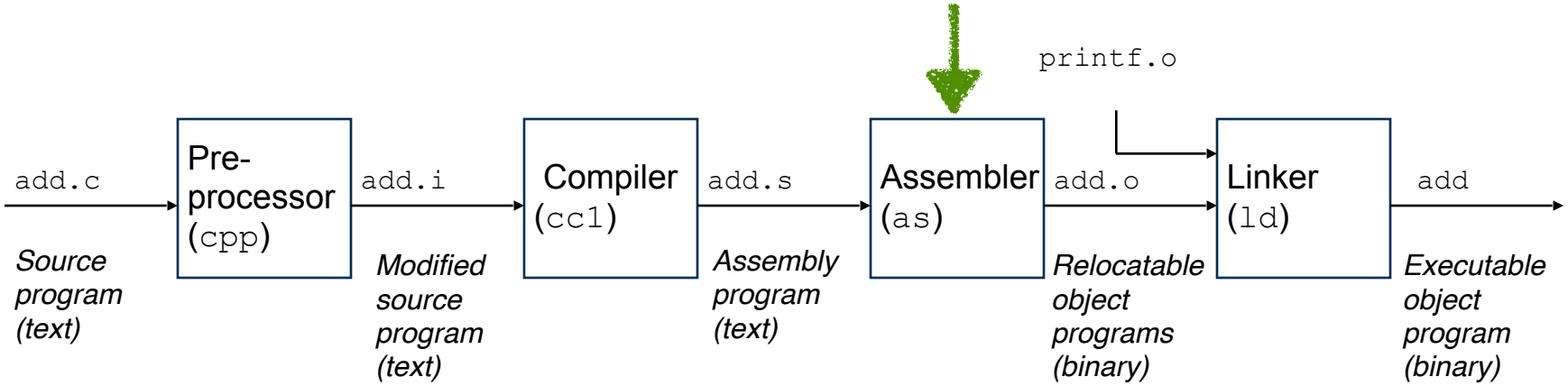

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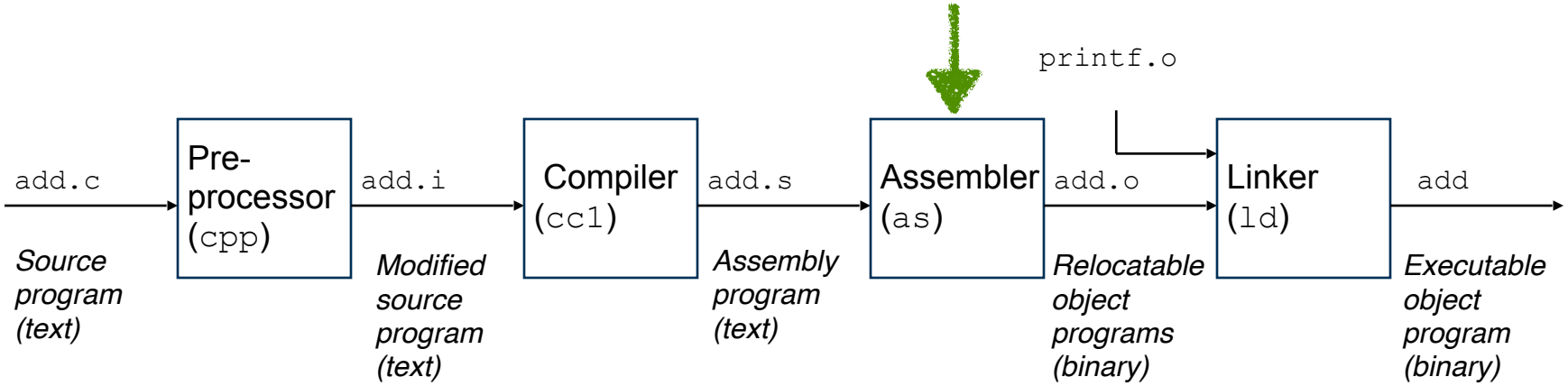

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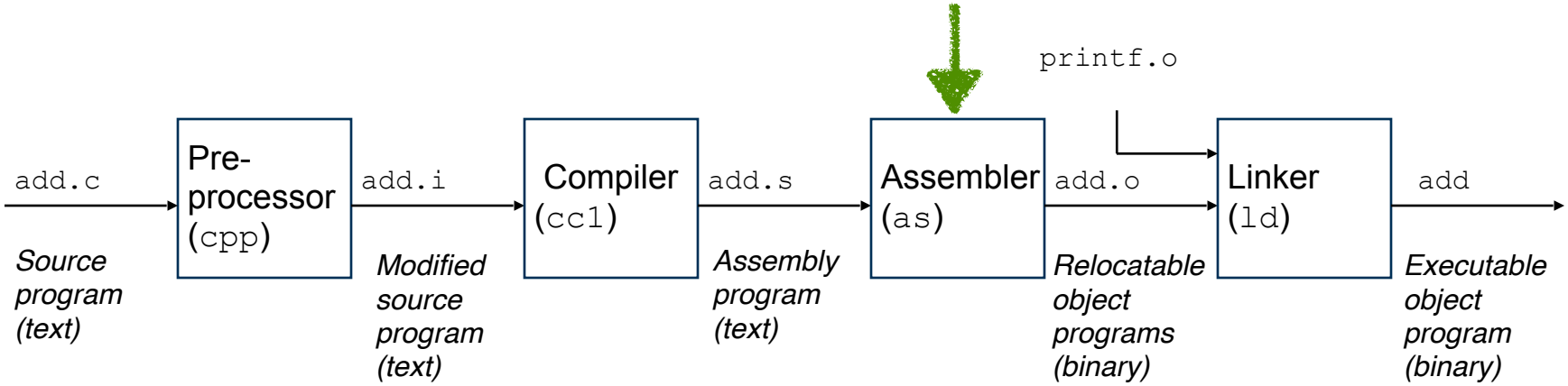

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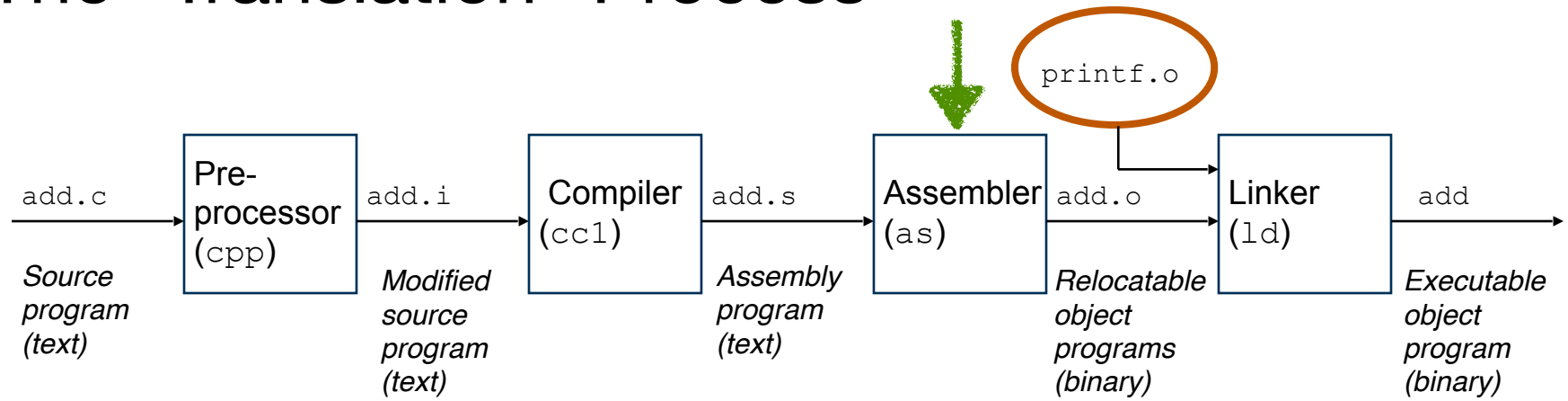

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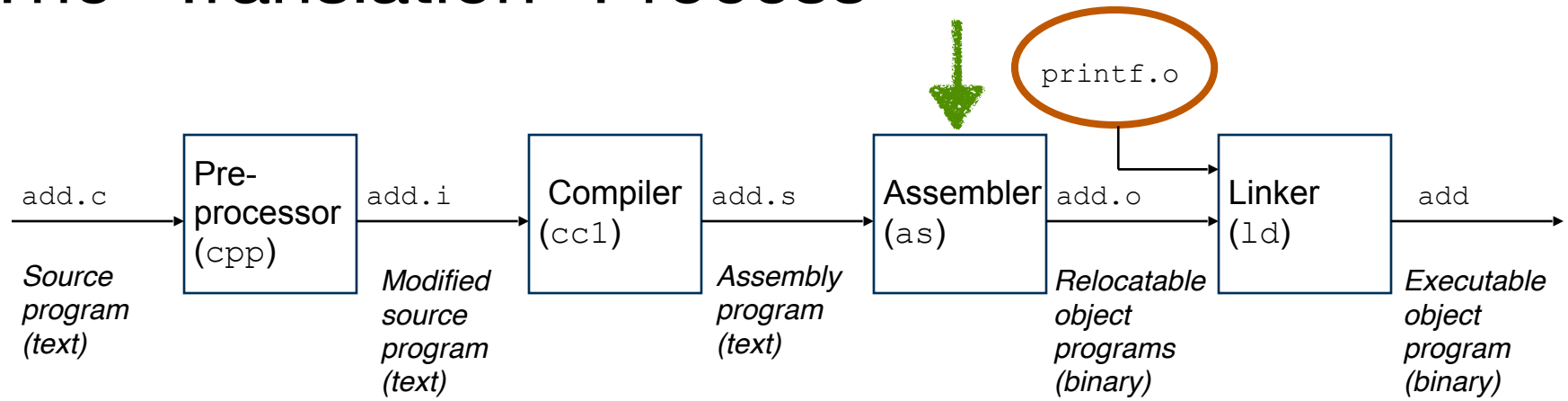

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Relocatable Binary for `printf.o`

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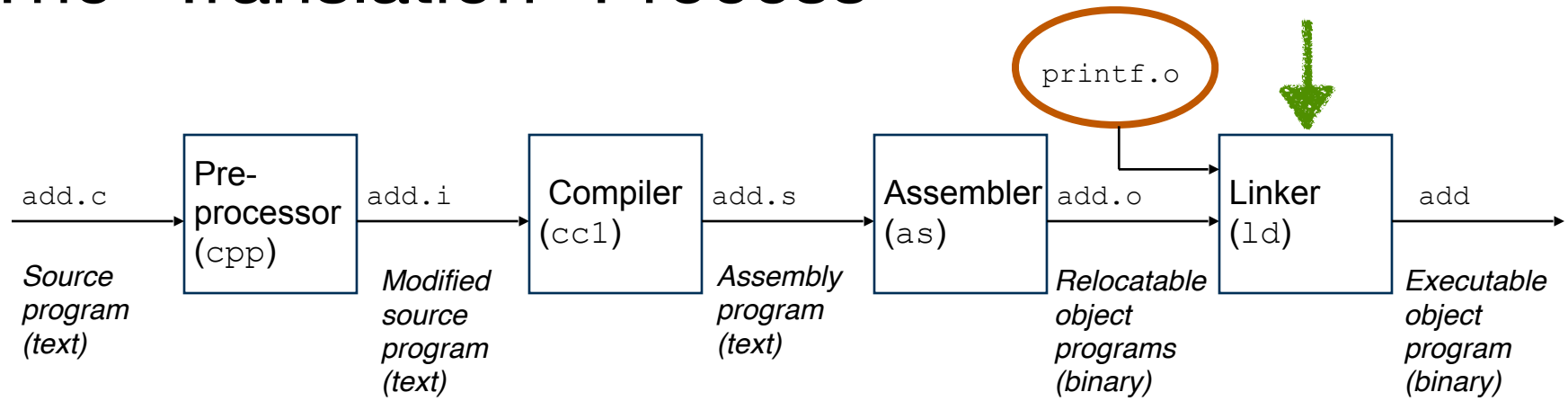

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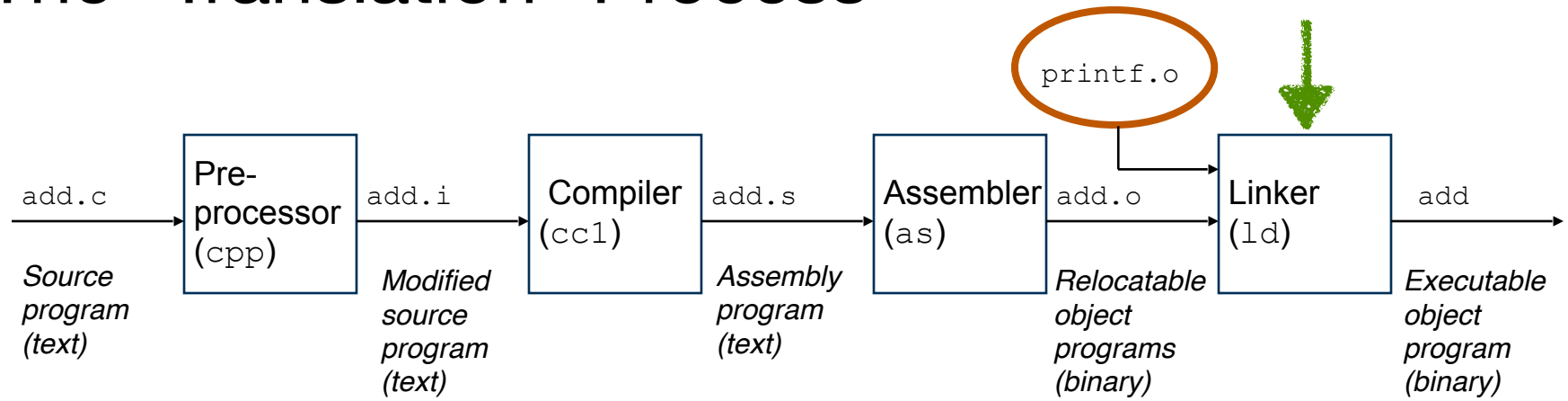

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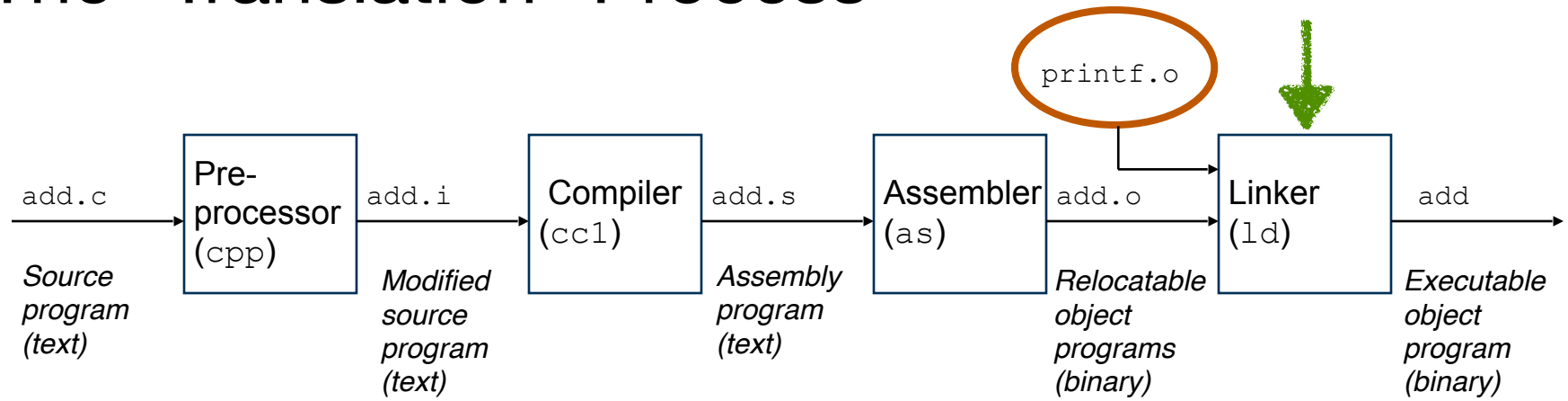

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Relocatable Binary for `printf.o`

Executable Binary

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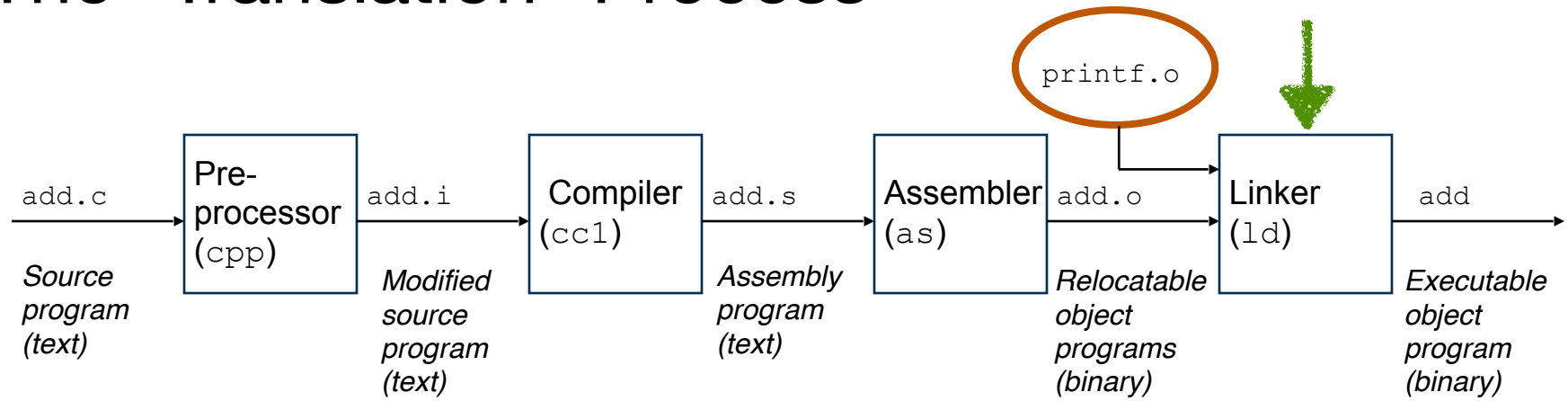
The "Translation" Process

Questions?



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Back to Layers of Transformation…

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

How does a modern computer execute that program?

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The Fundamental Idea of Computers

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

Assembly program: add.s

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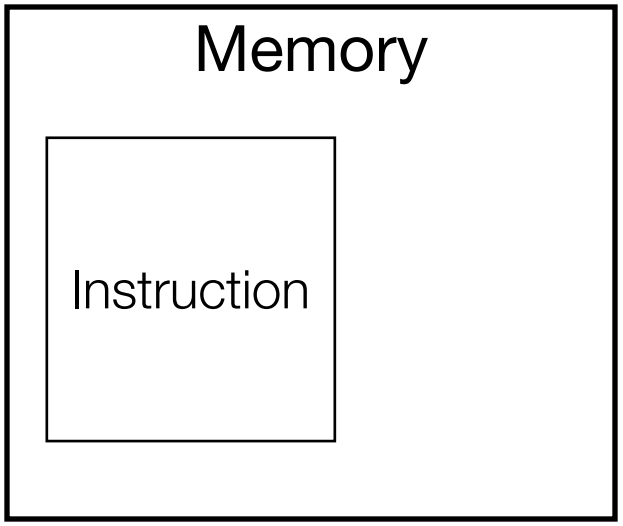

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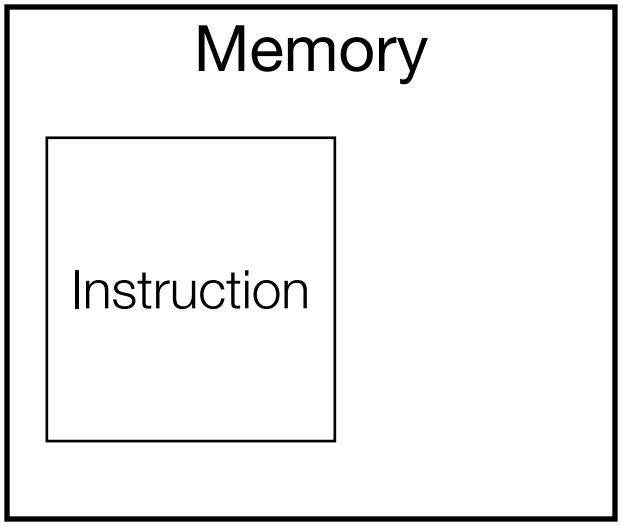

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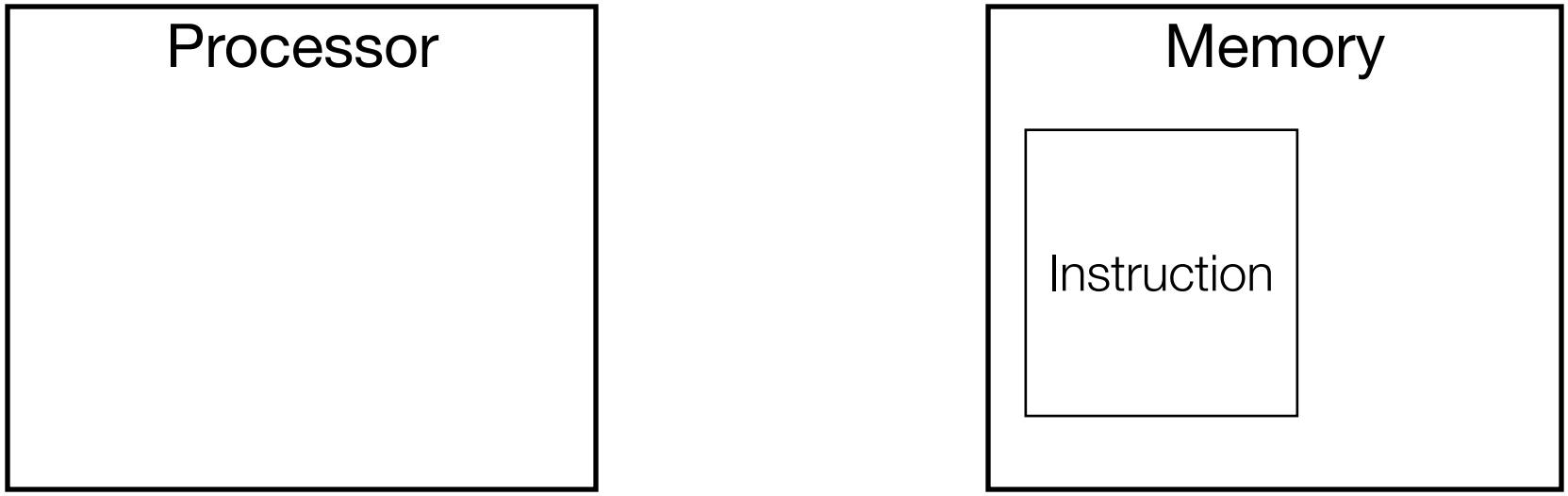

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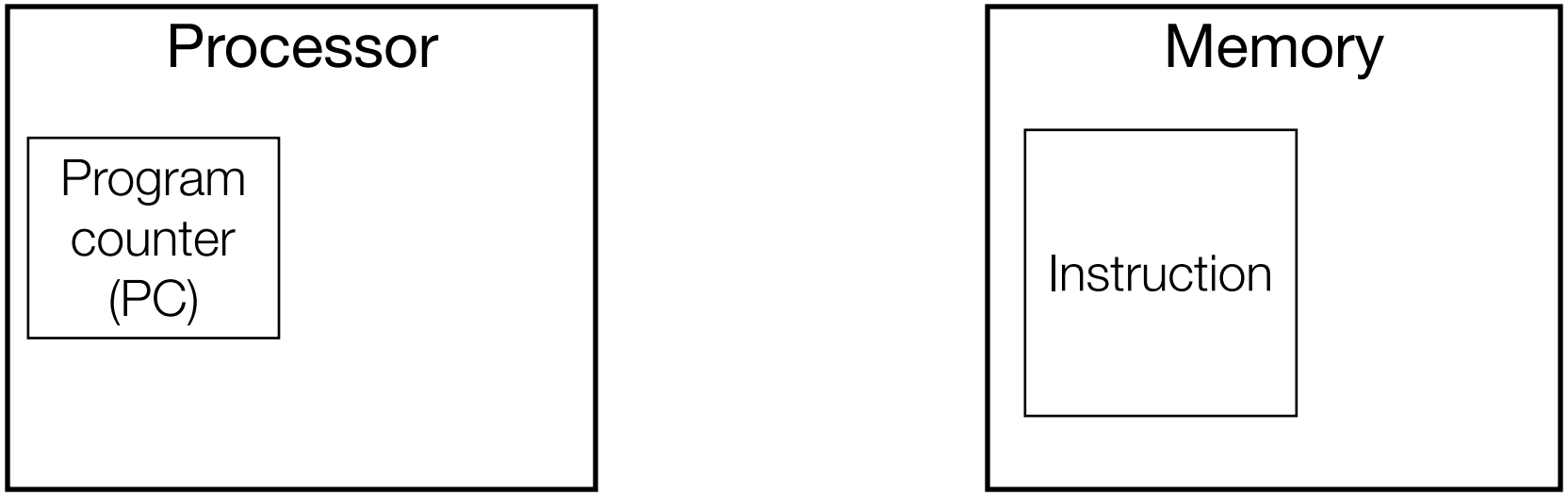
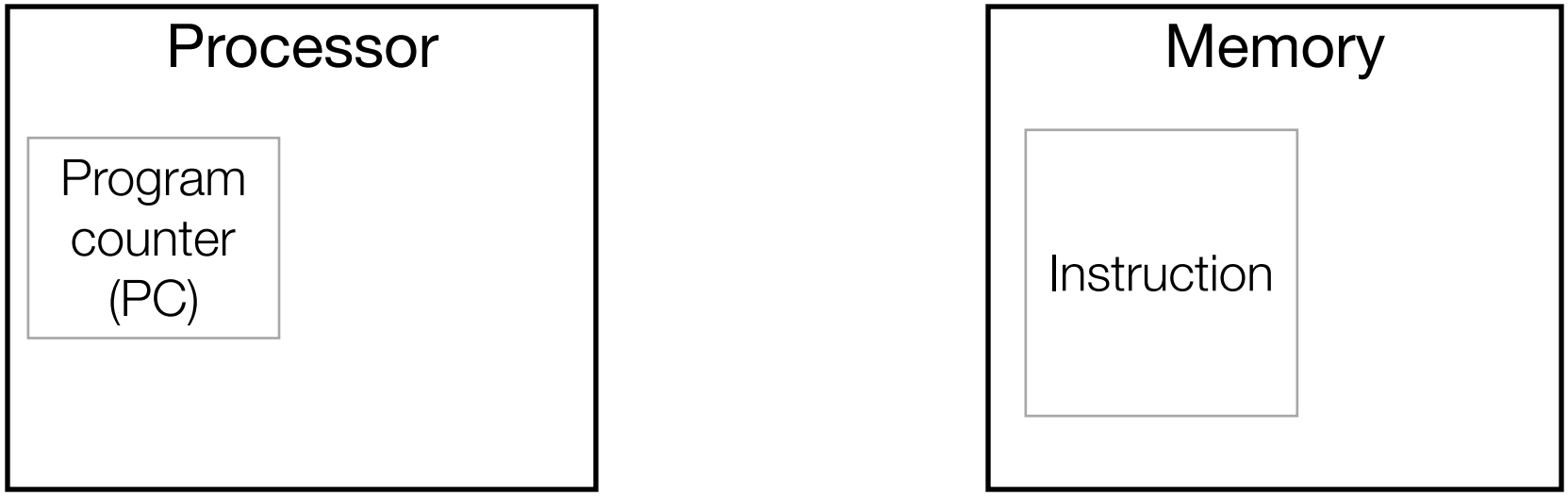


High-level Organization of Computer Hardware a.k.a., The Von Neumann Model



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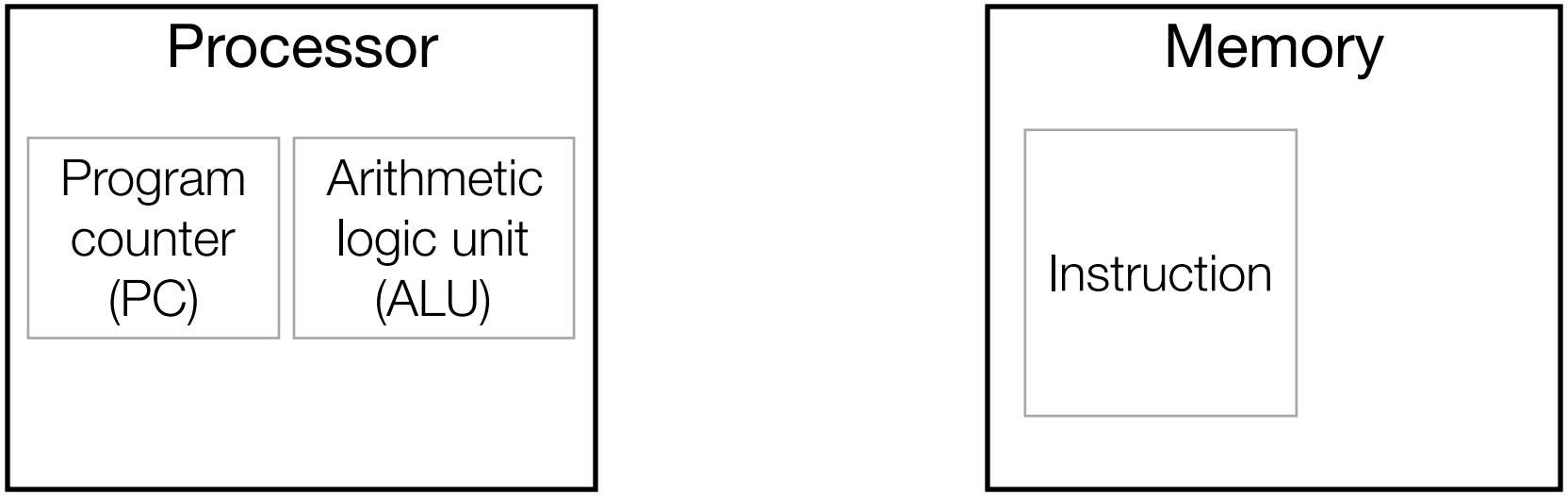

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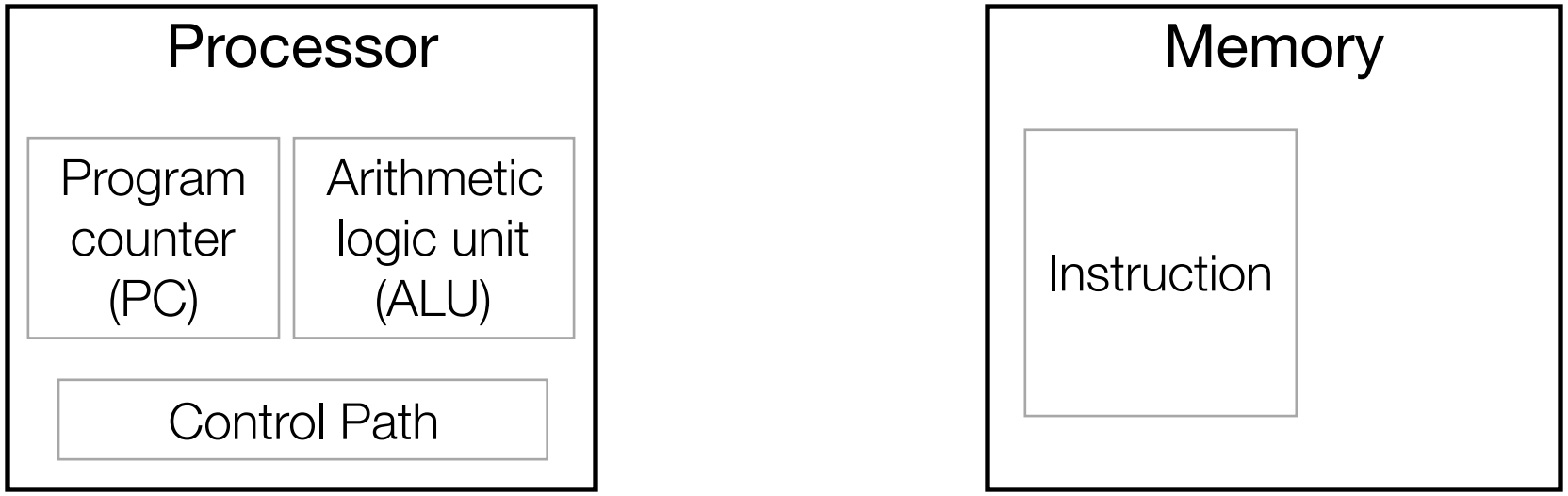

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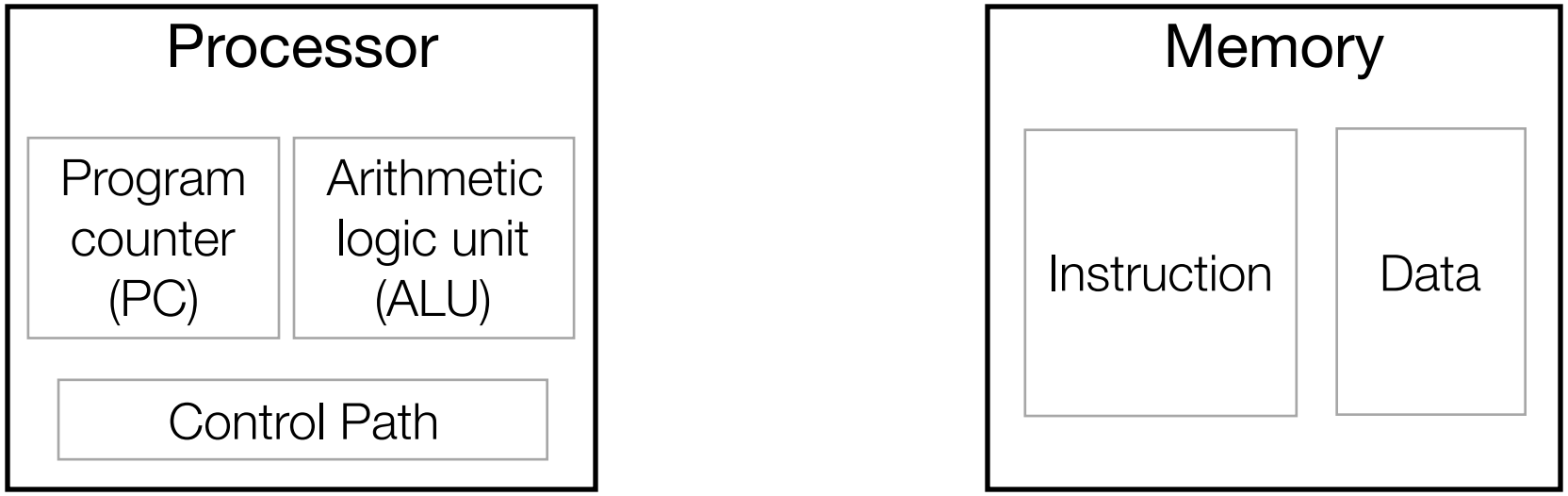

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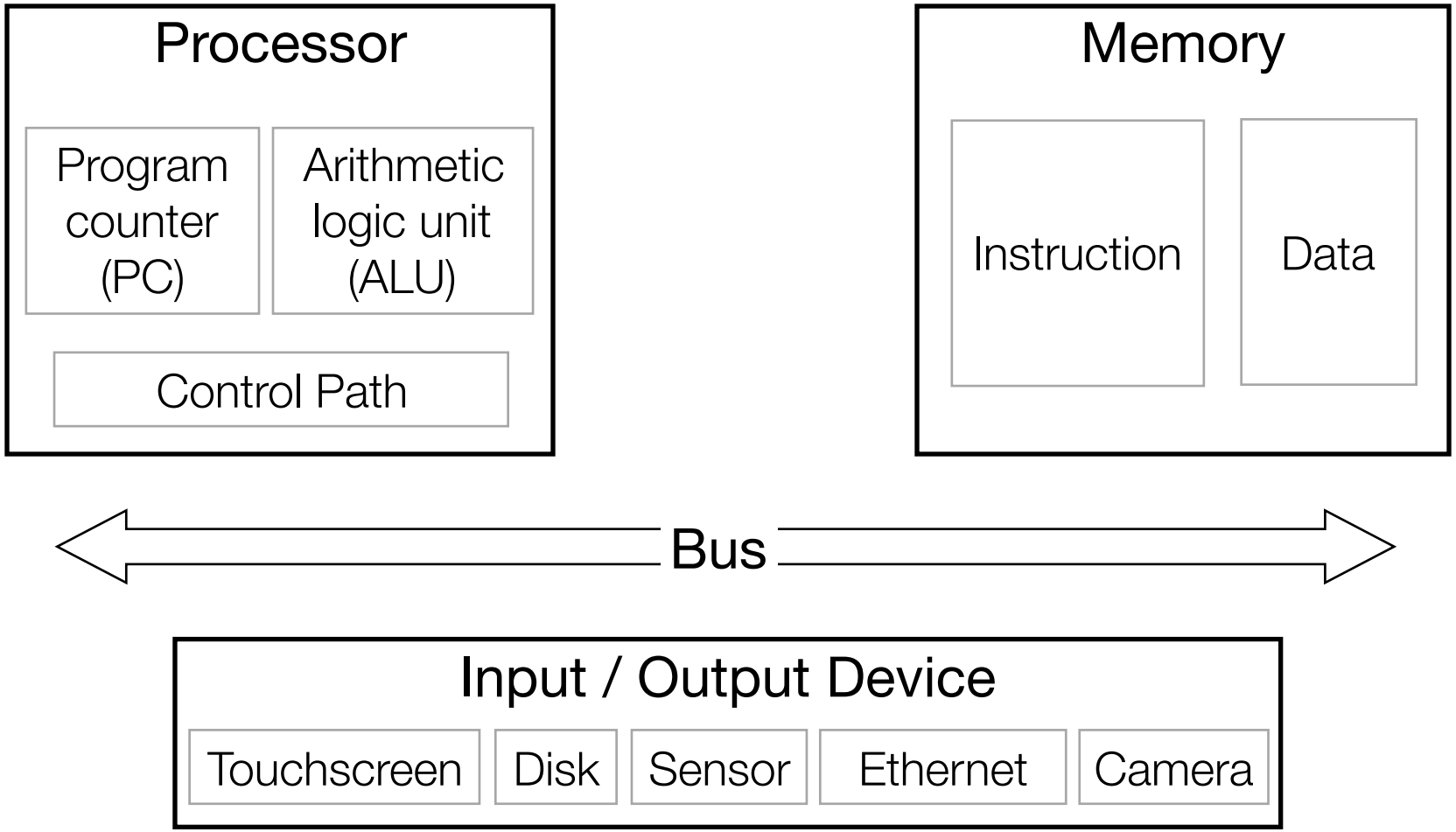

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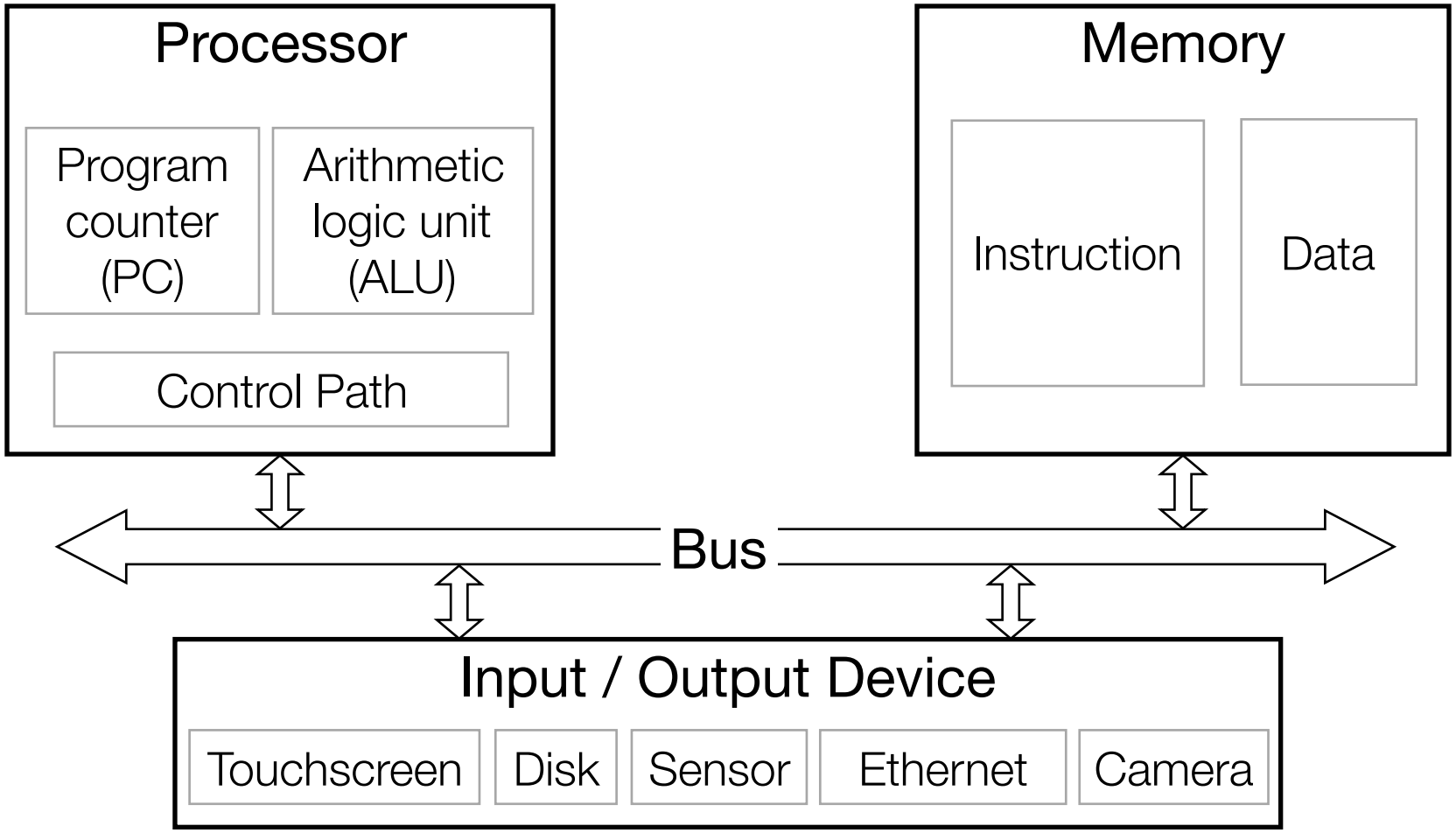

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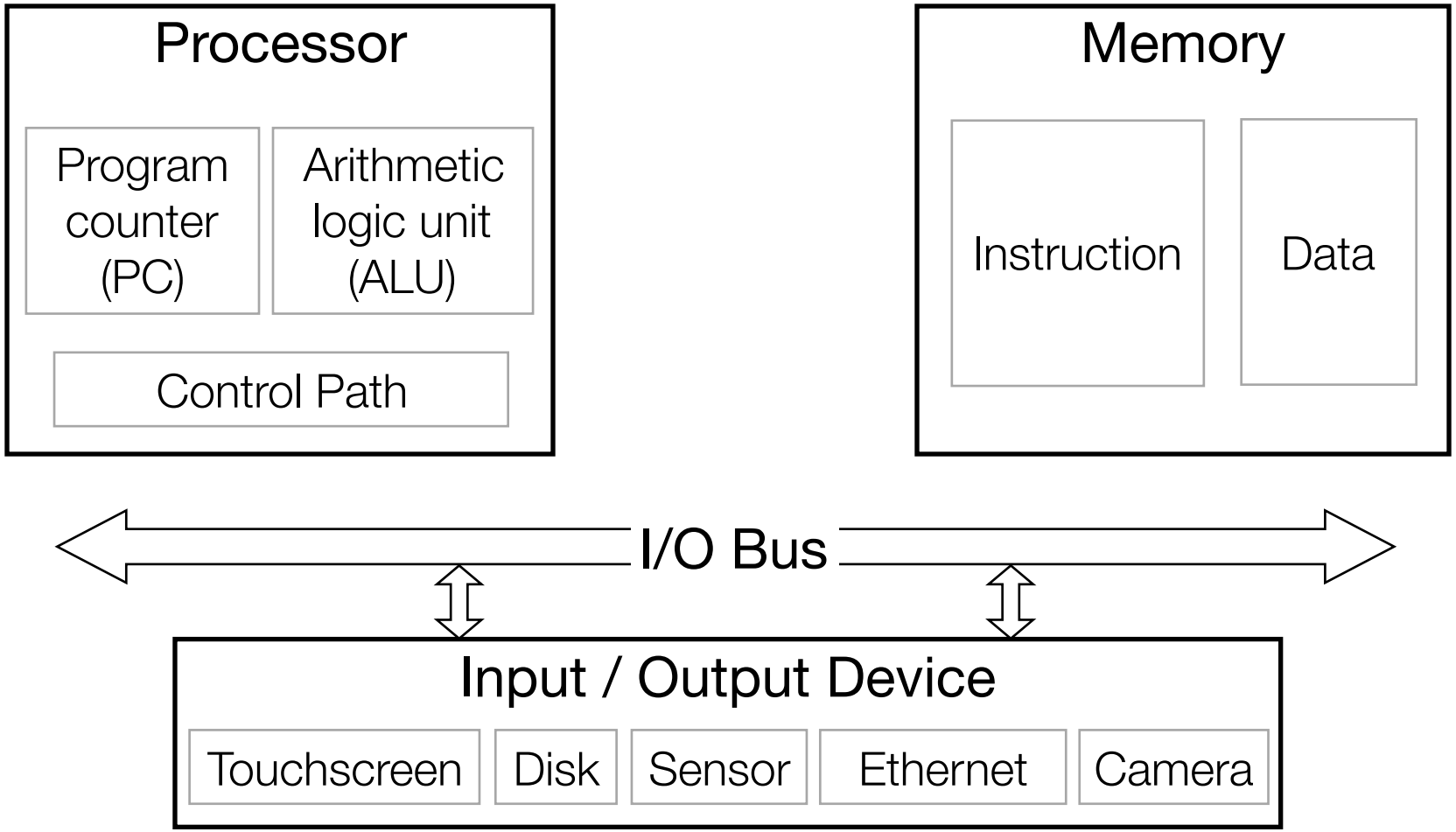

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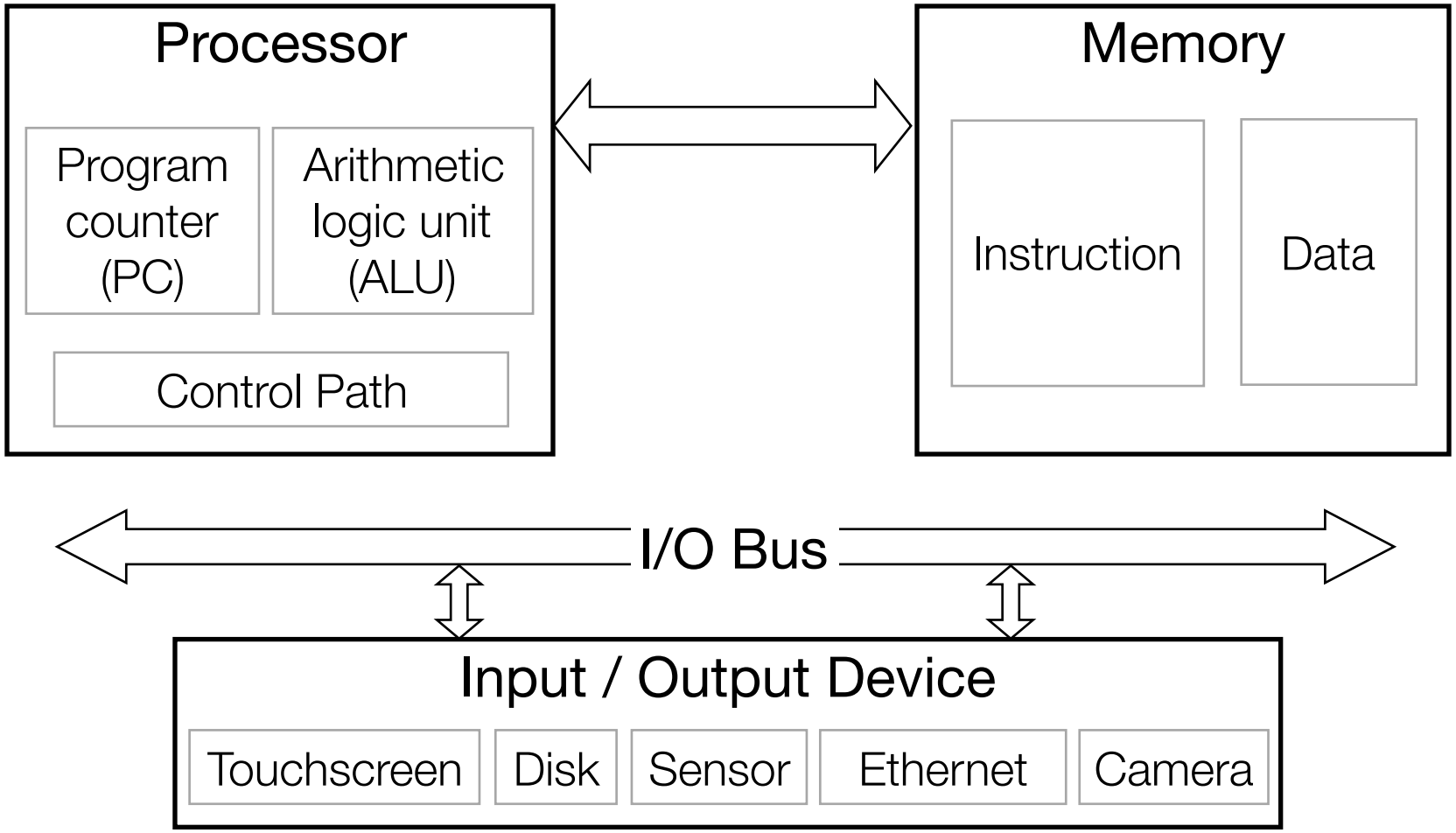

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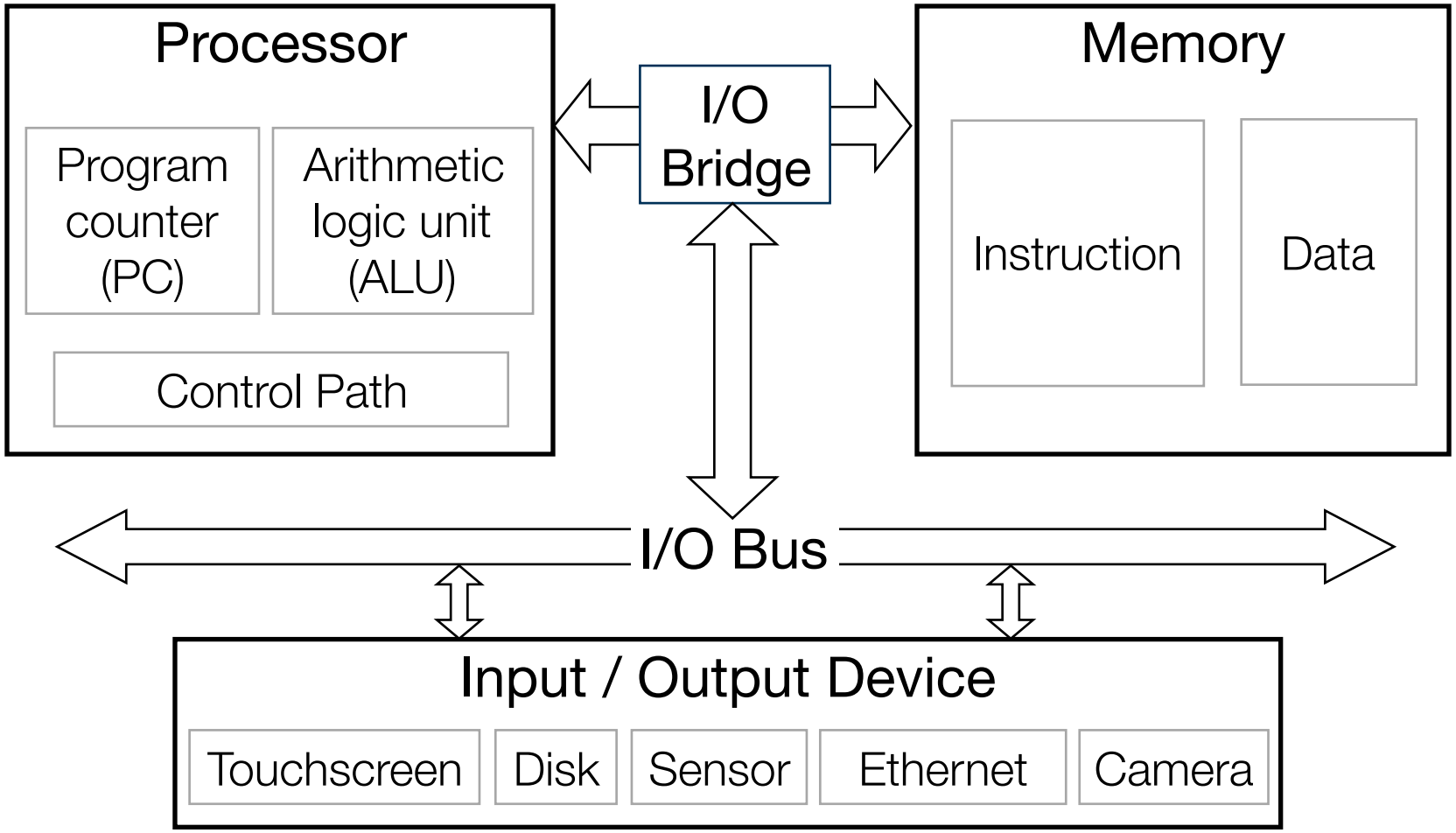

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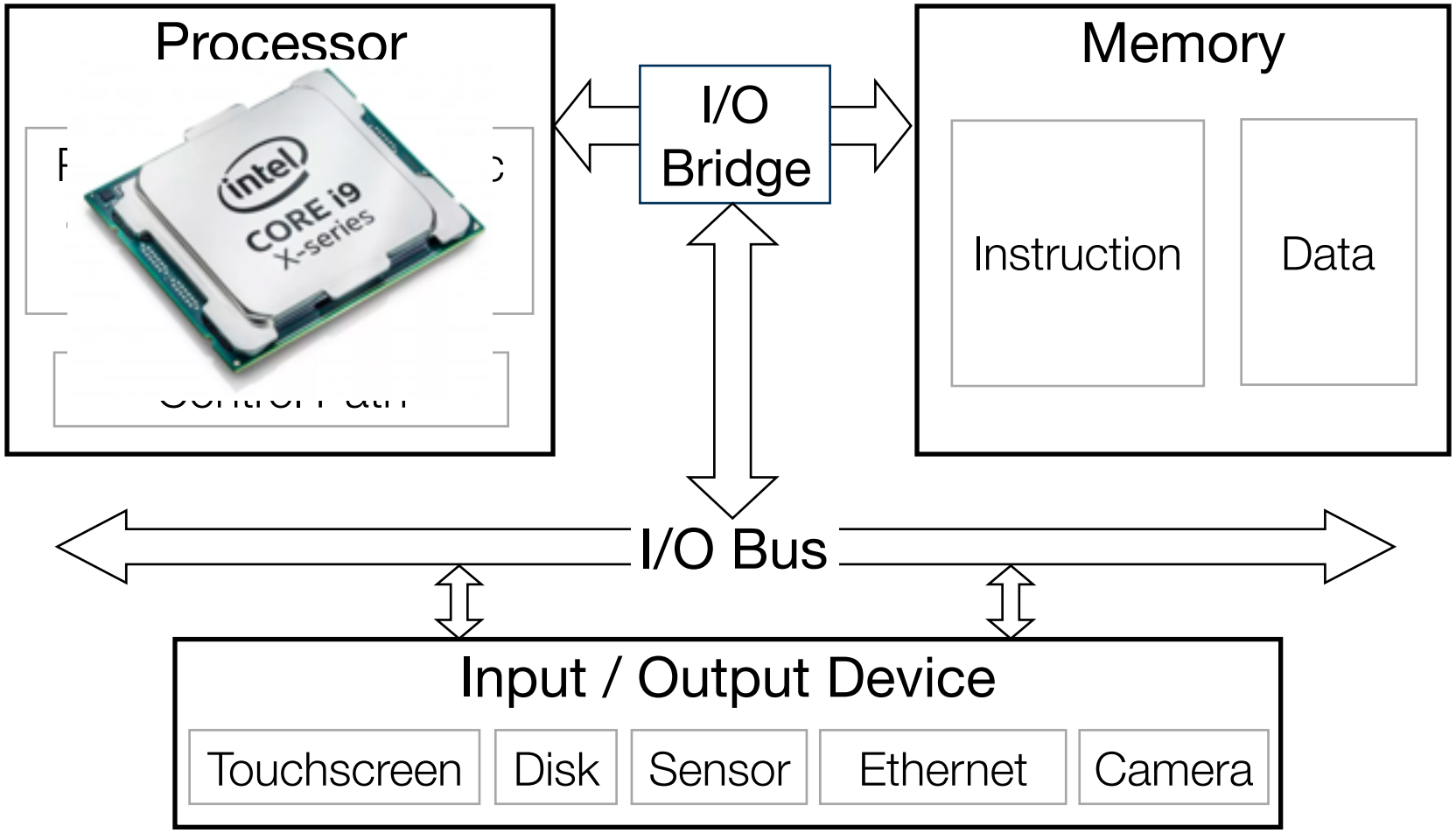

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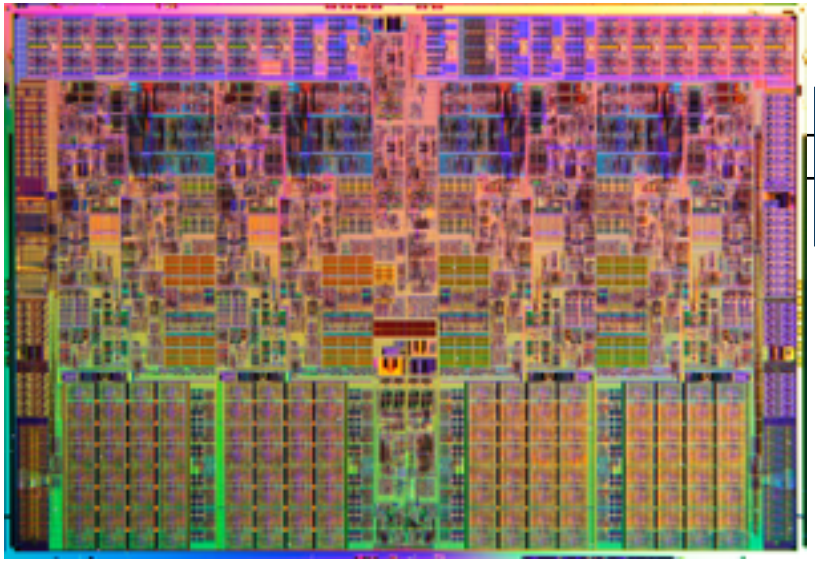

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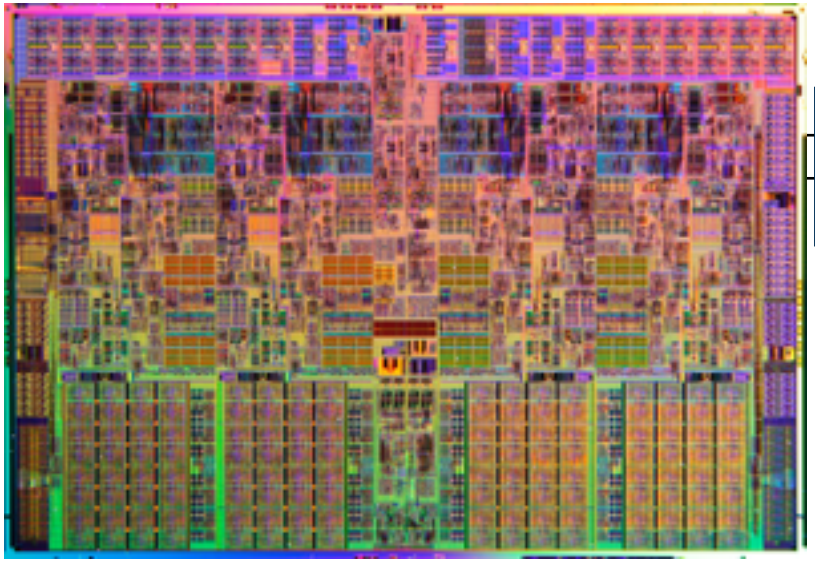
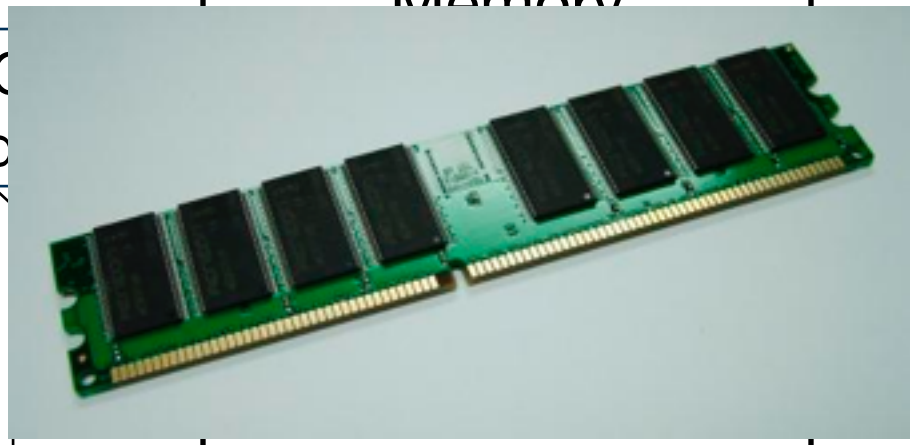


Memory

I/O Bridge



I/O Bus

Input / Output Device

Touchscreen | Disk | Sensor | Ethernet | Camera

Back to Layers of Transformation…

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

How does a modern computer execute that program?

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.

Instruction Set Architecture

Instruction Set Architecture

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

Assembly program: add.s

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movl    $1, -4(%rbp)
movl    $2, -8(%rbp)
movl    -4(%rbp), %eax
addl    -8(%rbp), %eax
…
callq   _printf
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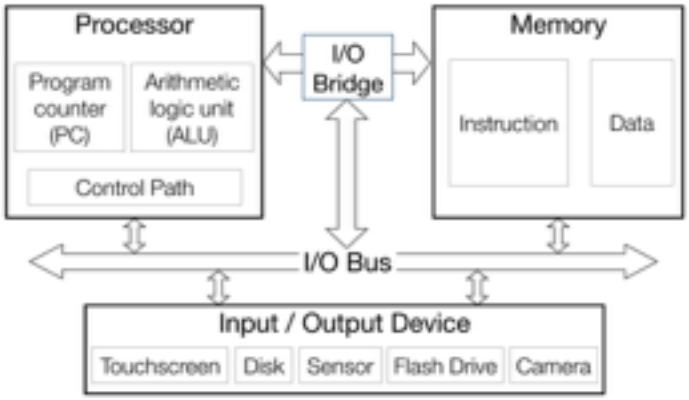

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- ISAs *abstract* away details of microarchitecture

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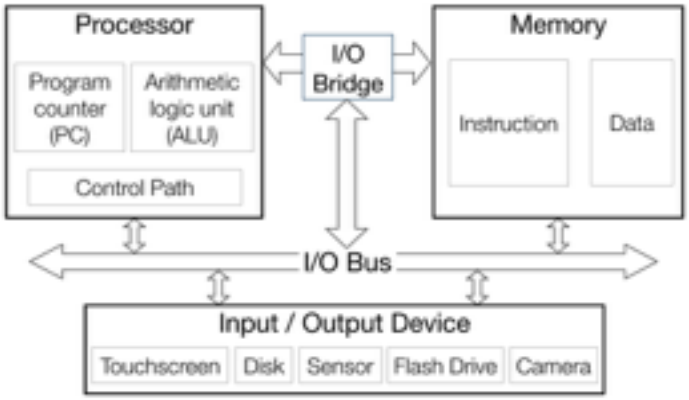

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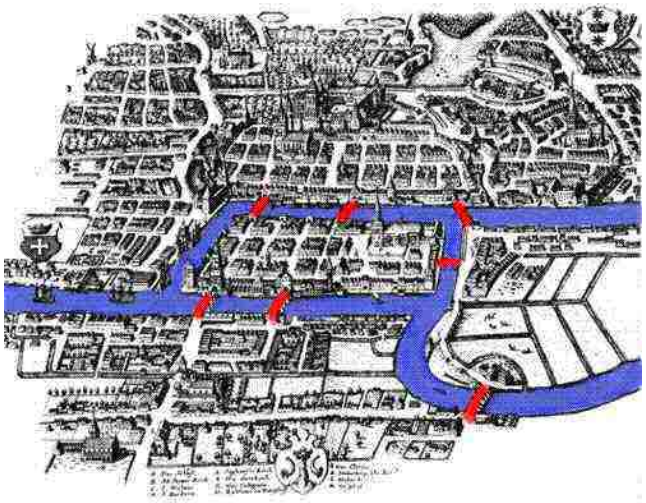
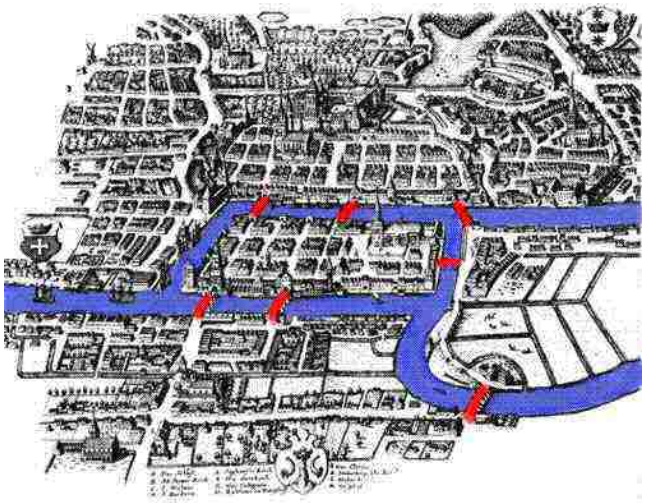
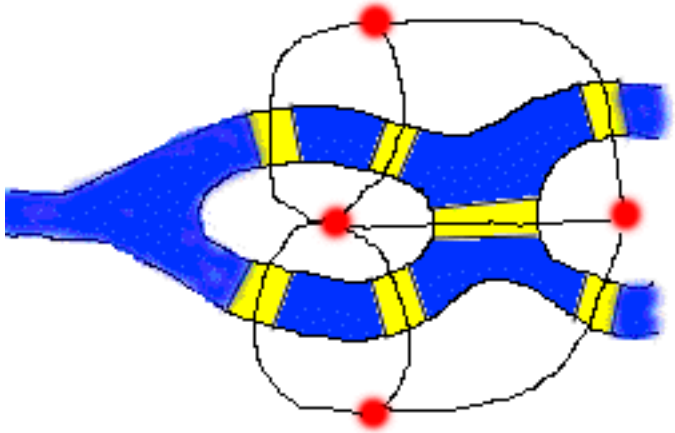


Abstraction

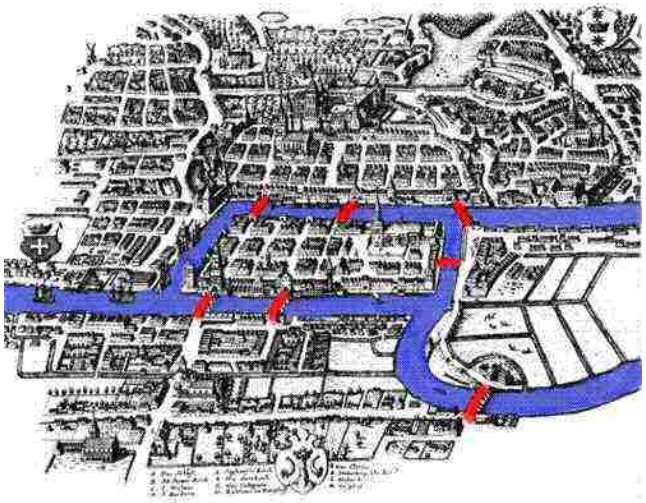
- Think of car versus engine, transmission, brakes, …
- Bridges of Konigsberg
  - Is there a walk that crosses each bridge exactly once?
- Solution by Euler
  - Key insight: connectivity between land masses is what is important, not the actual distances or the orientations of the bridges

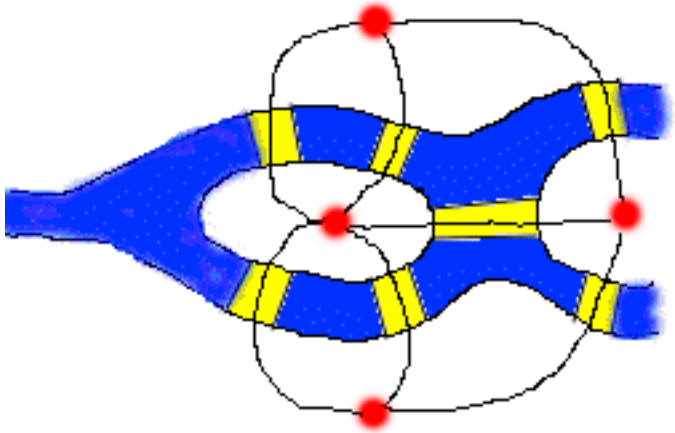




Abstraction

- Create an abstraction
  - One node for each land mass
  - Edge between two nodes if there is a bridge connecting the two land masses
- Graph has nodes of odd degree, so there is no walk with desired property.
- Led to field we now call topology.





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- The act or process of leaving out of consideration one or more properties of a complex object so as to focus on others
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  - ISA also leaves our *how long* an “ADD” instruction takes

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  - ISA also leaves our *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 coffee-cup
  - Bad ISAs don’t tell you the hardware can do multiplication

Every Layer in CS is an Abstraction

Problem	Who scores the highest on the exam?
Algorithm	Quicksort
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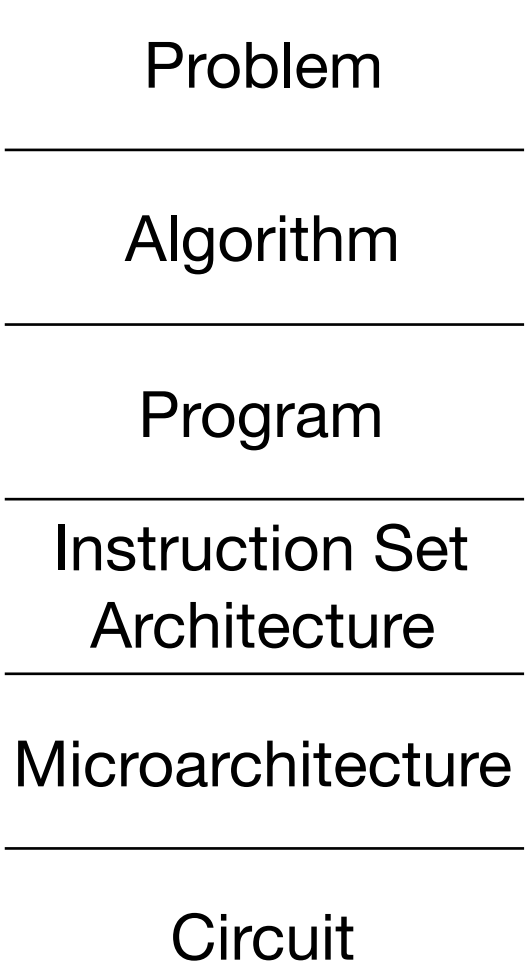
- Depend on which layer you want to live at, you have different views of the computer



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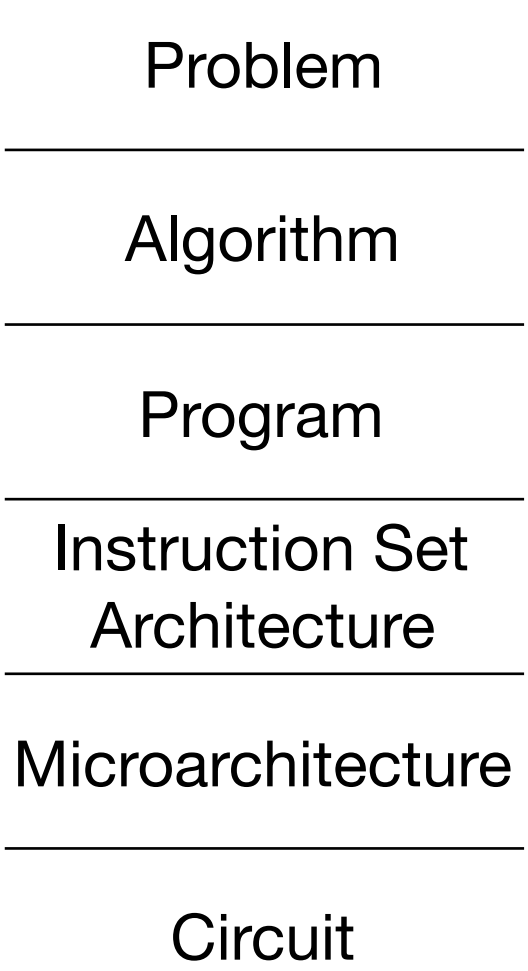
- This course expands your layers of abstractions



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- 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 (UC Berkeley, https://riscv.org/)

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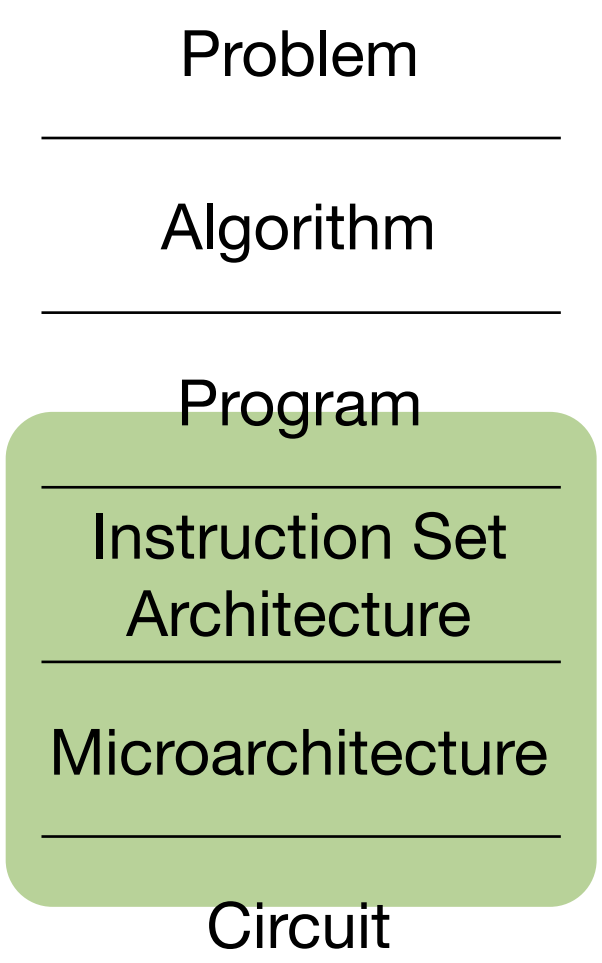
  - Think opportunities, not overhead

The Role of a Computer System Designer



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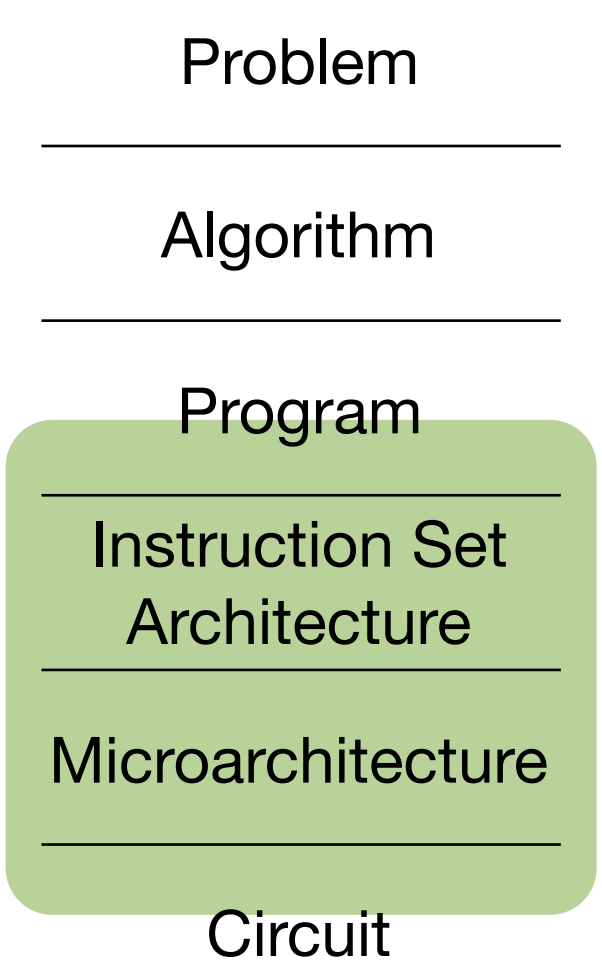

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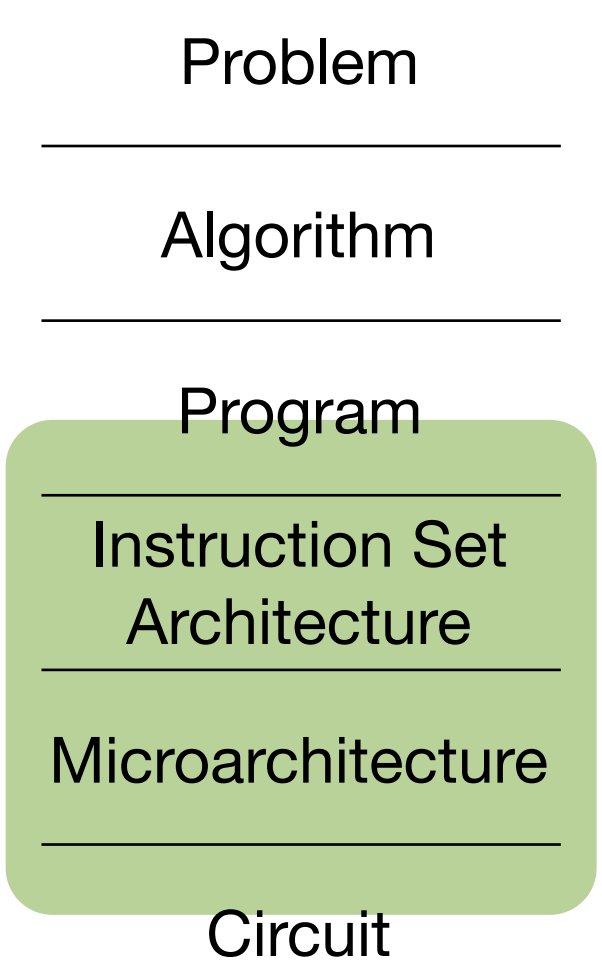

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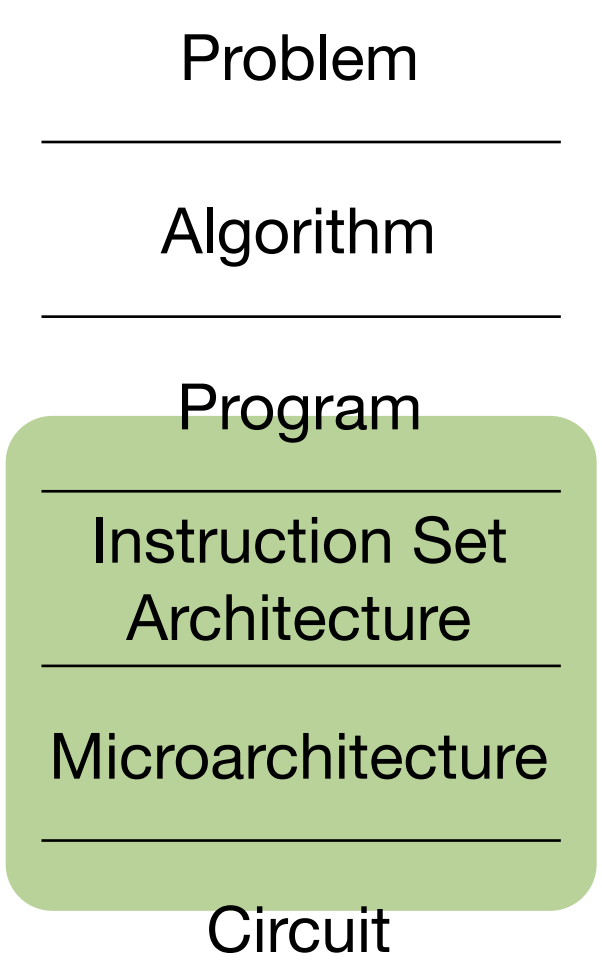

The Role of a Computer System Designer

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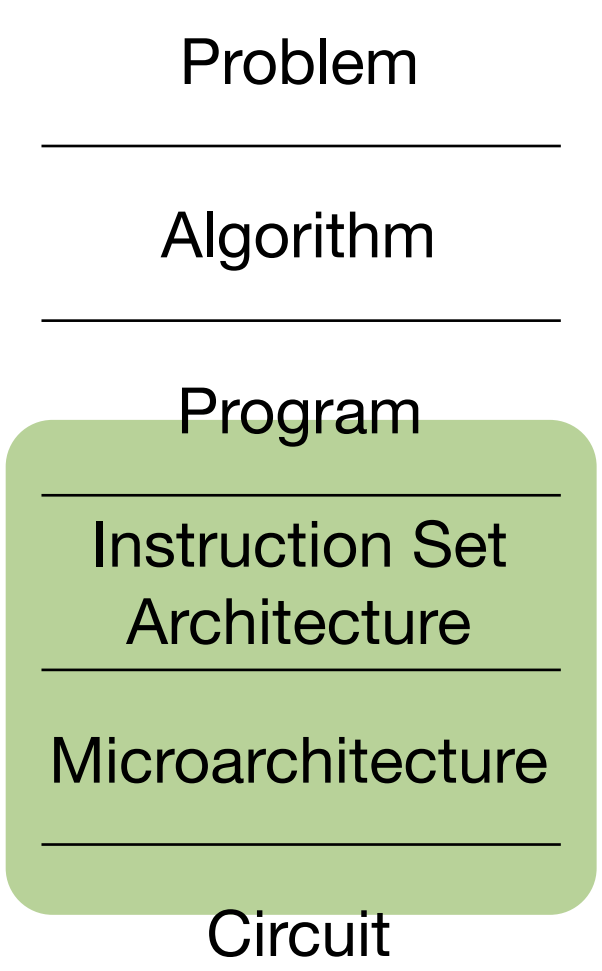
- Look Forward (Listen to dreamers and predict the future)



Why This Course Matters to You

- It's just a lot of fun. You get to look up and down, forward and backward.

- Without understanding Computer Systems you may write grossly inefficient code and have no idea why (this could easily cost you a job OR, in contrast, if you know why - get you a promotion).

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Questions?

Who Are We?

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- Myself: Yuhao Zhu
  - WH 3501, yzhu@rochester.edu
  - Office hours TBD (soon) or by appointment
  - Got a good education
  - Got some industry experience
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- **Coming to office hours does NOT mean you are weak!**

What Do I Expect From You?

- ***Learn the material***
- ***Do the work***
- If you're going to come to class, come on time
    - I do not take attendance and you will not be graded on it
    - However, all of the top students from previous years regularly attended class
- Big believer in communicating
    - Probably the most important thing to know
    - Speak up, ask questions, participate in class
- You can eat, but please by quiet
- There will be a minimum standard to pass the class
- This class will definitely be tough

What Should You Expect From Me?

- *Think of me as your tutor*
  - Be your guide in inducing you to explore concepts
  - Create situations and post problems that set the scene for your exploration
  - Answer your questions

- Not spend lecture reading the textbook to you with slightly different words

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?
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All The Way Back to Medieval Times..

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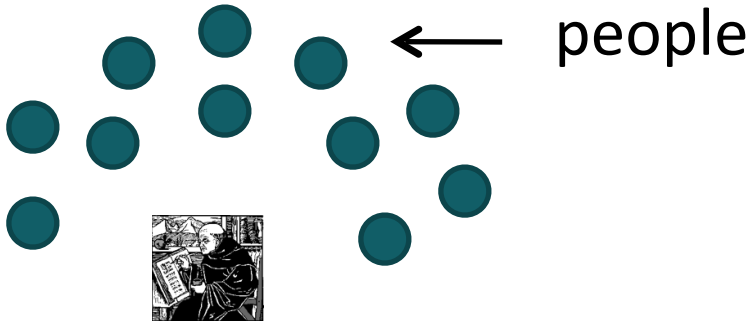
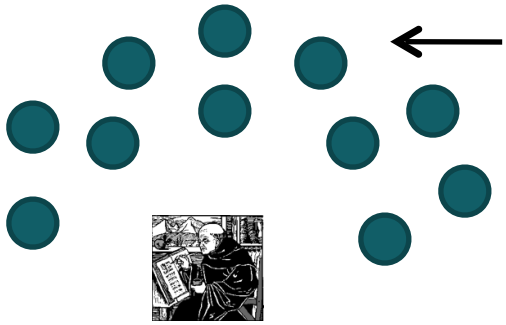


All The Way Back to Medieval Times..

Lecture Halls



people

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

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- To learn, you must do the work with your own muscle (brain)!

How Will You Be Evaluated?

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- Programming Assignments: 54%
  - 6 assignments, 9% each
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- Observations:
  - Programming assignments have the most weight because that's where you really learn and will benefit the most
  - Final is almost twice as important as the midterm because we care about what you know in the end
  - All three parts are important. You can't pass the class while focusing only on one part.

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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 assembler.
- We only accept ANSI-C that can be compiled by the default GCC on the CSUG Linux boxes

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- No collaboration on exams

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.

Where to Find Stuff

Lab 0 (get CSUG account)
Sign up for blackboard

- http://cs.rochester.edu/courses/252/spring2018/
  - General info
  - Programming assignments details
  - Various course materials
  - Opportunities and “ads”
- Blackboard for ***all*** communication
  - Only place for all announcements (e.g., when an assignment is out)
  - Only place for digitized Q&A
  - Except personal issues
  - Don’t waste time: **check/search previous posts before posting**
- CSUG machines for programming assignments submissions