The Plan: Lab 1 preview

Welcome to

CS 240:

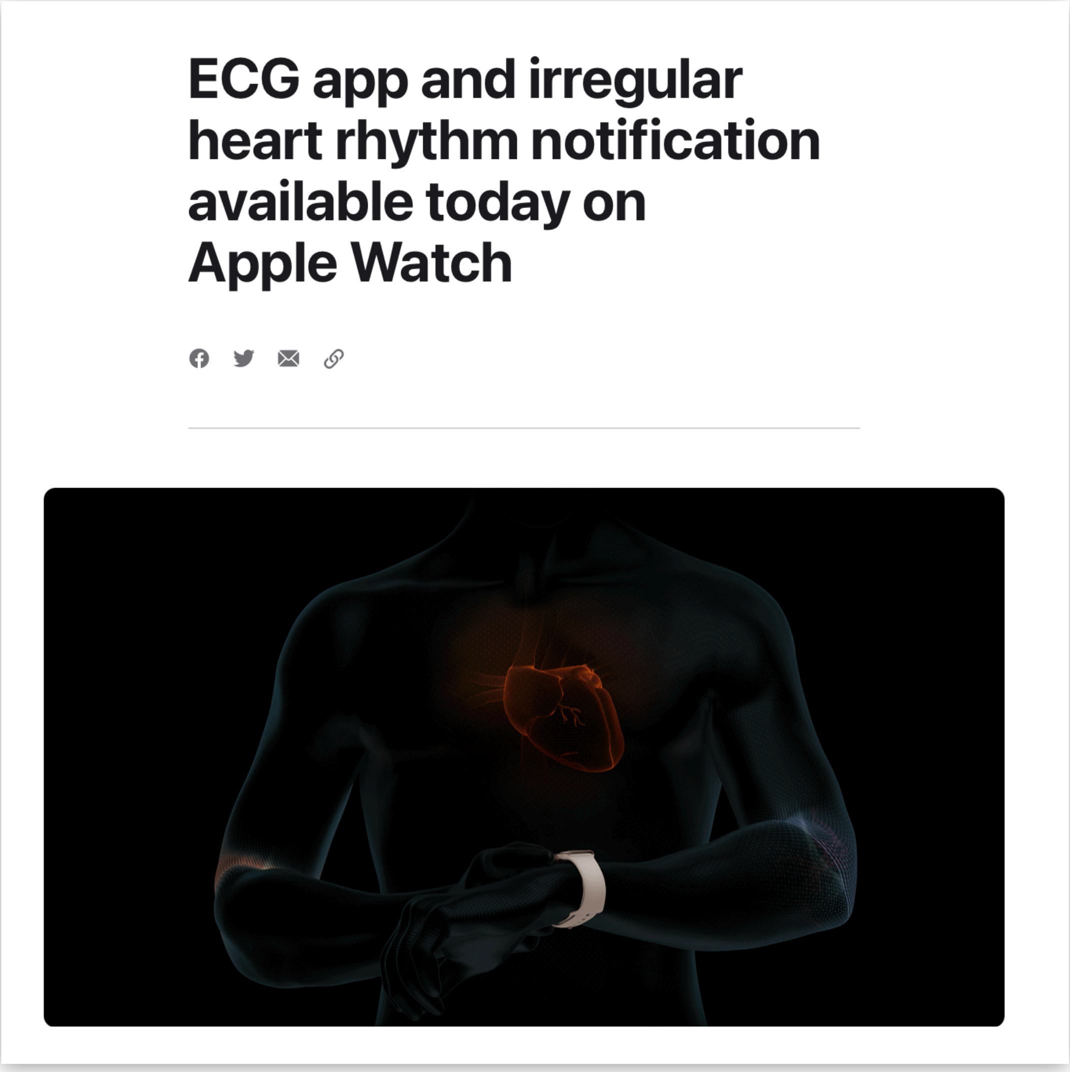
Foundations of

Computer Systems!

- Program, Application
- Programming Language
- Compiler/Interpreter
- Operating System
- Instruction Set Architecture
- Microarchitecture
- Digital Logic
- Devices (transistors, etc.)
- Solid-State Physics

Your lecture instructor: Alexa VanHattum

Note: you can call me "Alexa", "Prof. Alexa", or "Prof. VanHattum"



- New to Wellesley this semester!
- Research focus: programming languages & systems
  - I work with undergrad research assistants!

Before Wellesley:
- PhD in Computer Science at Cornell
- Software engineer for Apple health (heart monitoring)
  - THIS CLASS one of the most helpful across industry and research

Today's preview

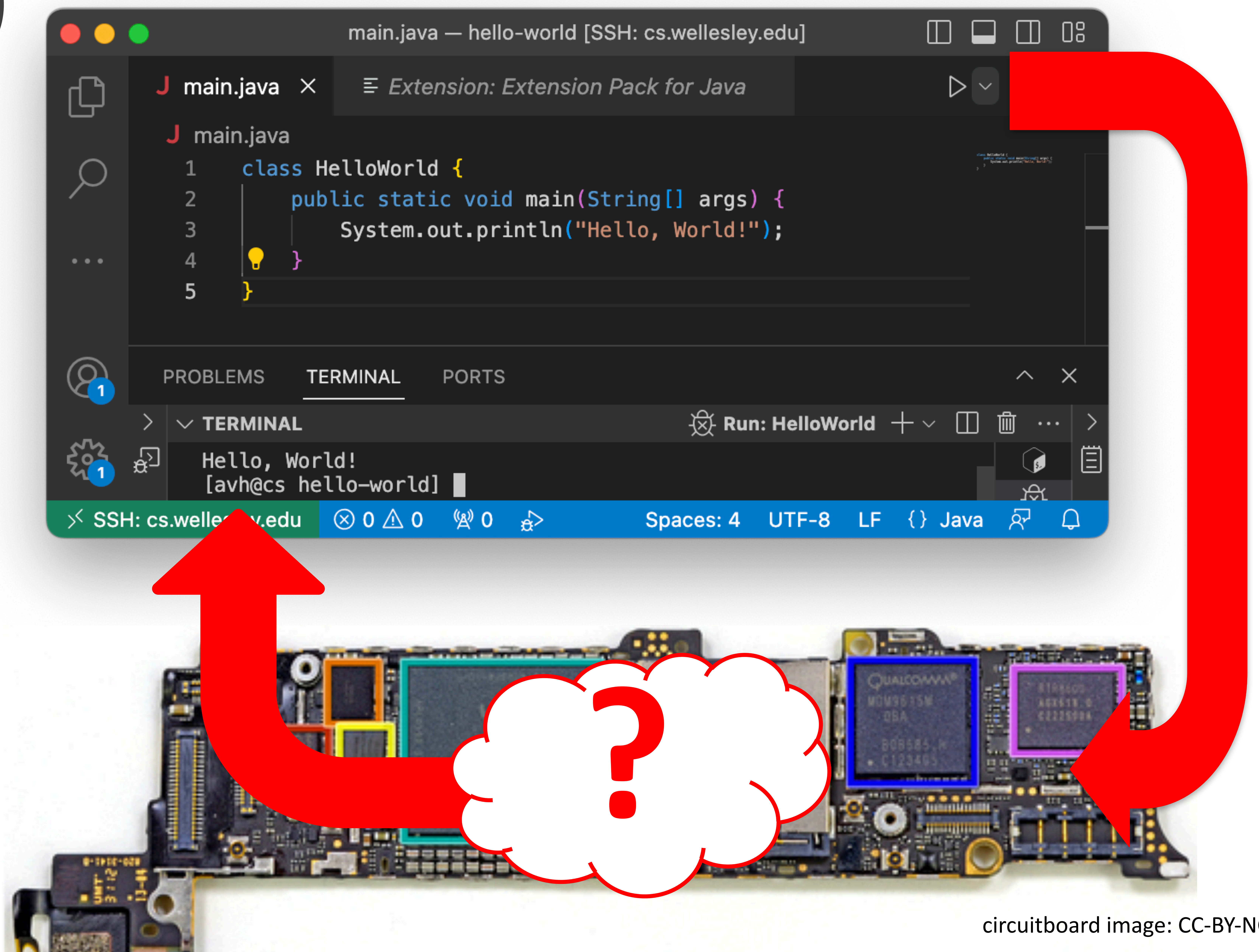
1. **What is CS 240?**
2. Why take CS 240? (in brief)
3. How does CS 240 work? (in brief)

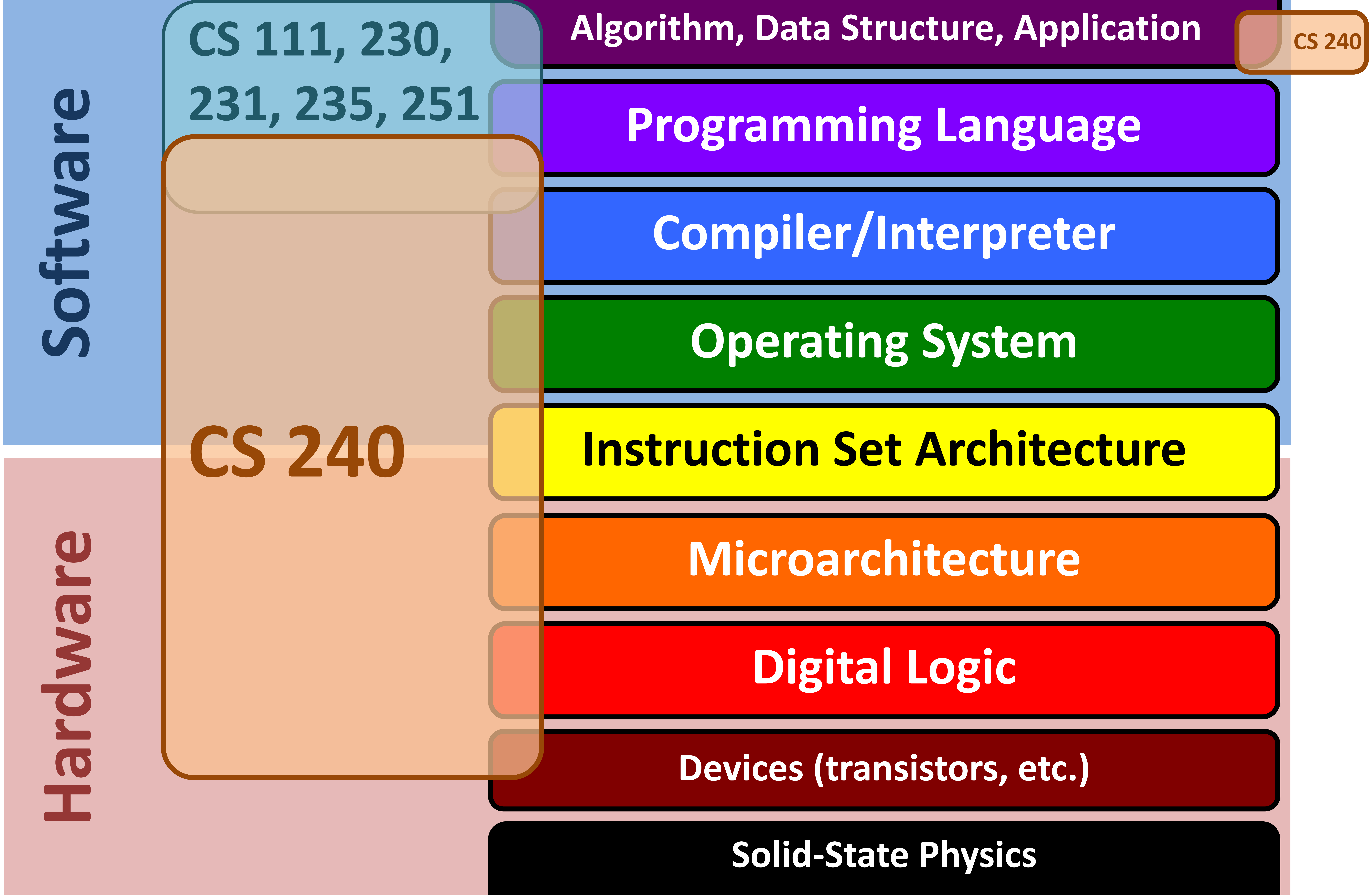
CS 111, 230, 231, 235, 251:

- How do you use programming to solve a problem?
- How do you structure a program?
- How do you know it is correct or efficient?
- How hard is it to solve a problem?
- How is computation expressed?
- What does a program mean?
- ...

A BIG question is missing…

1


main.java — hello-world [SSH: cs.wellesley.edu]
main.java
Extension: Extension Pack for Java
class HelloWorld {
public static void main(String[] args) {
System.out.println("Hello, World!");
}
}
PROBLEMS
TERMINAL
PORTS
Run: HelloWorld
Hello, World!
[avh@cs hello-world]
Spaces: 4
UTF-8
LF
Java
?


Software
Hardware
CS 111, 230,
231, 235, 251
CS 240
Algorithm, Data Structure, Application
CS 240
Programming Language
Compiler/Interpreter
Operating System
Instruction Set Architecture
Microarchitecture
Digital Logic
Devices (transistors, etc.)
Solid-State Physics

Big Idea:

Abstraction

interface

implementation

Layers manage complexity.

Algorithm, Data Structure, Application

Programming Language

Compiler/Interpreter

Operating System

Instruction Set Architecture

Microarchitecture

Digital Logic

Devices (transistors, etc.)

Solid-State Physics

Big Idea: Abstraction

with a few recurring subplots

Simple, general interfaces:

Hide complexity of efficient implementation.

Make higher-level systems easy to build.

Representation of data and programs — 0s and 1s, electricity

Translation of data and programs — compilers, assemblers, decoders

Control flow within/across programs — branches, procedures, operating system

Software

Desired computation
in a programming language

Abstraction!

Hardware/Software Interface

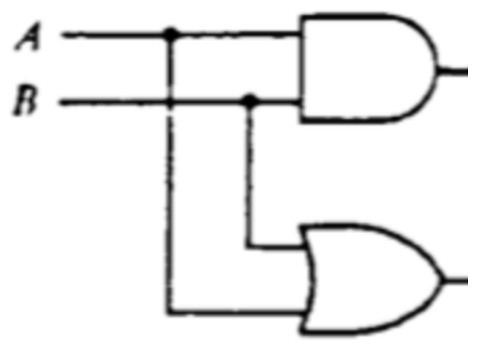
Hardware

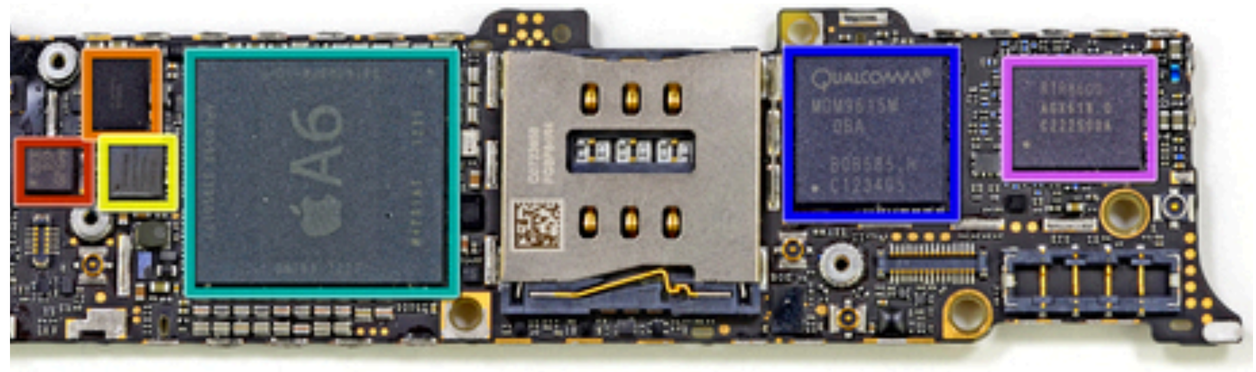
Physical implementation
with circuits and electricity.

CS 240 in 3 acts (4-5 weeks each)

1. Hardware *implementation*

From transistors to a simple computer





2. Hardware-software *interface*

From instruction set architecture to programming in C

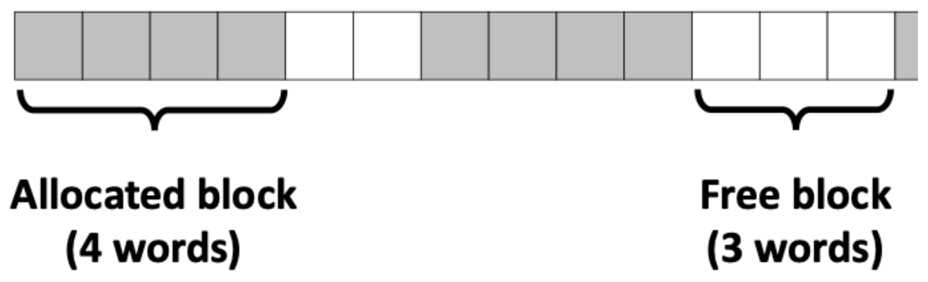
```
MOV x9, x10
ADD x12, x12, #1

*x = malloc(…);
```

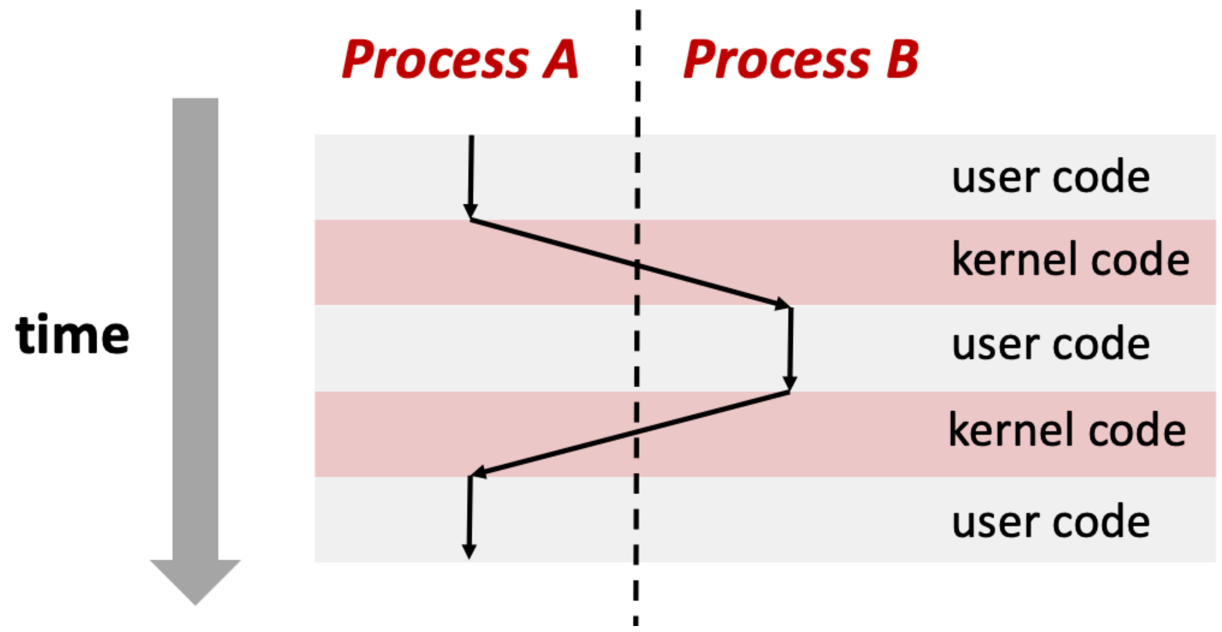
3. Abstraction for practical systems

Memory hierarchy

Operating system basics

Higher-level languages and tools





2

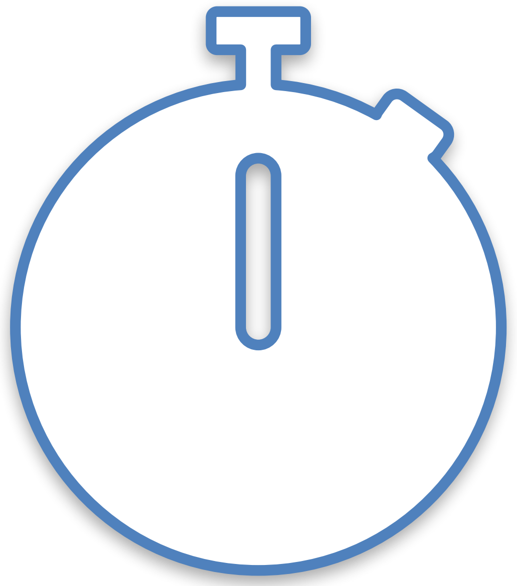
I just like to program.
Why study the implementation?

2 *I just like to program. Why study the implementation?*

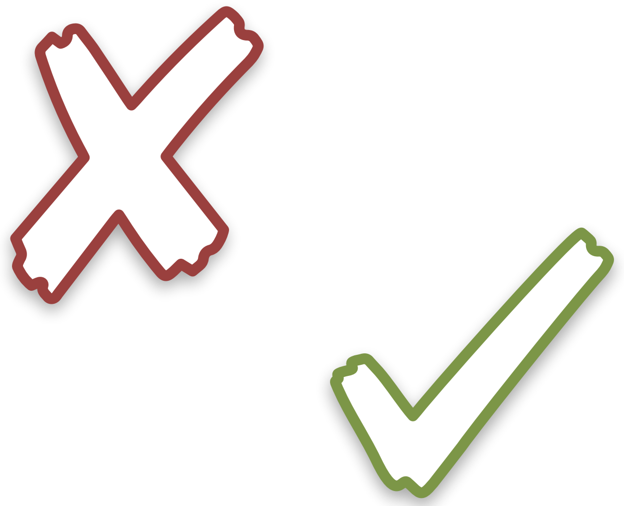
Most system abstractions "leak."

Implementation details affect your programs:

Their performance



Their correctness



Their security

Performance

x / 973 **x / 1024**

```
void copyji(int src[2048][2048],
            int dst[2048][2048])
{
  int i,j;
  for (j = 0; j < 2048; j++)
    for (i = 0; i < 2048; i++)
      dst[i][j] = src[i][j];
}
```

```
void copyij(int src[2048][2048],
            int dst[2048][2048])
{
  int i,j;
  for (i = 0; i < 2048; i++)
    for (j = 0; j < 2048; j++)
      dst[i][j] = src[i][j];
}
```

several times faster
due to hardware caches

Correctness

int ≠ integer
float ≠ real

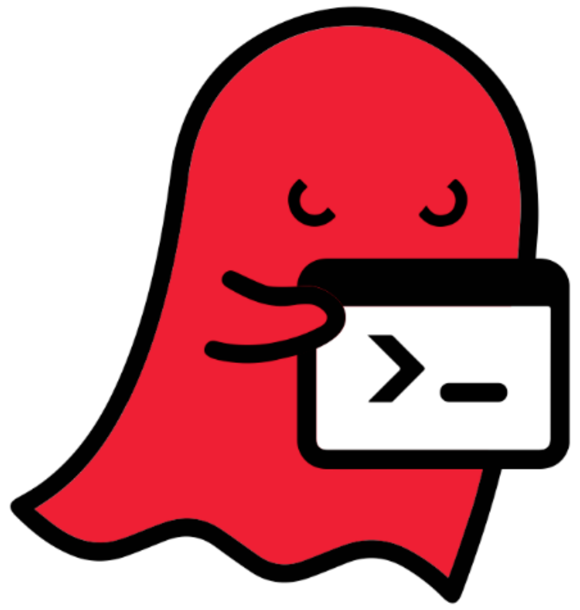
Exploded due to **cast** of 64-bit floating-point number to 16-bit signed number. **Overflow.**

Boeing 787, 2015

"... a **Model 787 airplane** … can lose all alternating current (AC) electrical power … caused by a **software counter** internal to the GCUs that will **overflow** after **248 days** of continuous power. We are issuing this AD to prevent loss of all AC electrical power, which could result in **loss of control of the airplane**."
--FAA, April 2015

Security

The ***GHOST vulnerability*** is a buffer overflow condition that can be easily exploited locally and remotely, which makes it extremely dangerous. This vulnerability is named after the *GetHOSTbyname* function involved in the exploit.



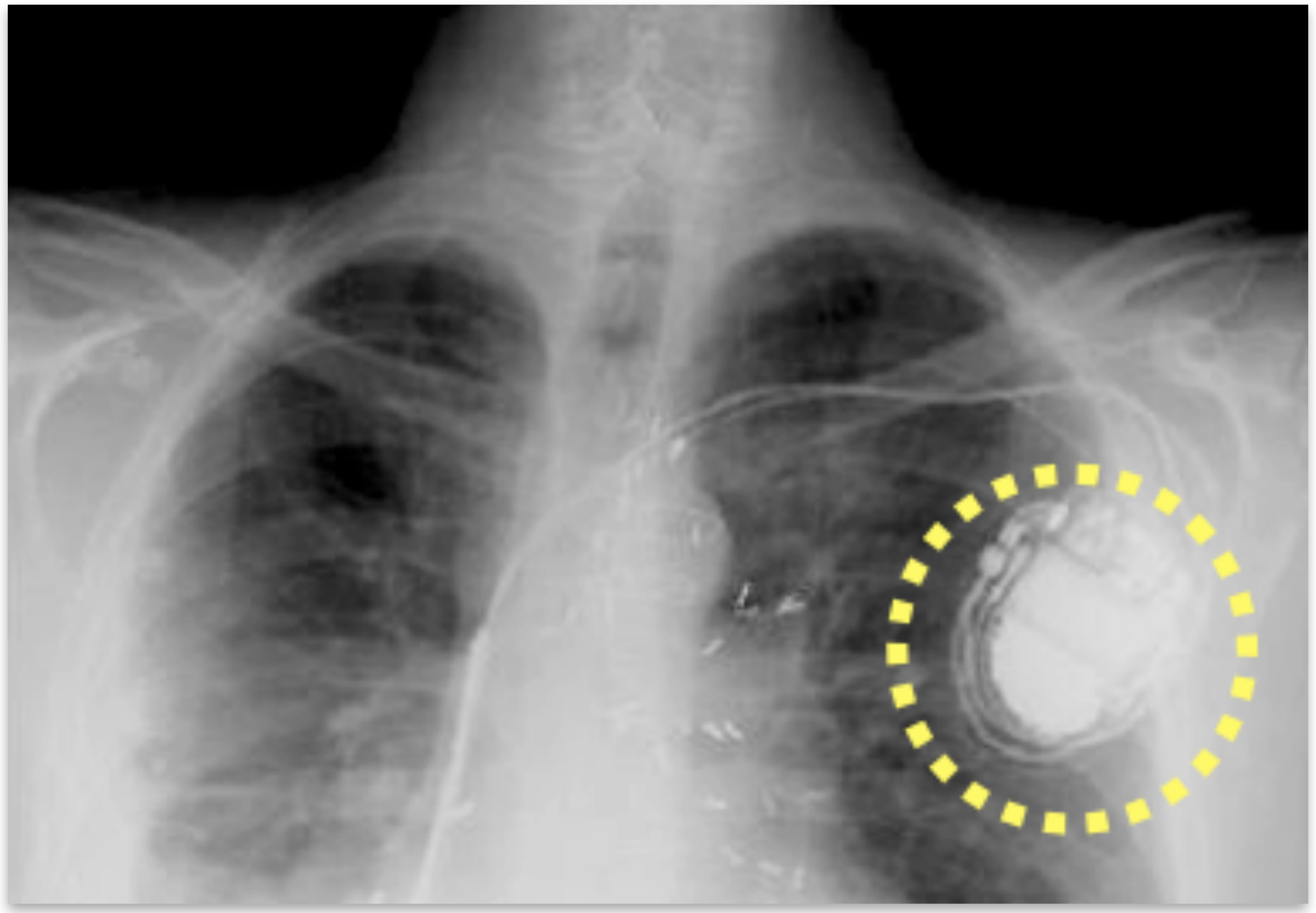
Cyber-Safe

All computers are flawed -- and the fix will take years

by Selena Larson @selenalarson

January 26, 2018: 12:07 PM ET

Meltdown and Spectre



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The New York Times **Business**

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MEDIA & ADVERTISING | WORLD BUSINESS | SMALL BUSINESS | YOUR MONEY | DEALBOOK | MARKETS | RE

A Heart Device Is Found Vulnerable to Hacker Attacks

By BARNABY J. FEDER
Published: March 12, 2008

To the long list of objects vulnerable to attack by computer hackers, add the human heart.

The threat seems largely theoretical. But a team of computer security researchers plans to report Wednesday that it had been able to gain wireless access to a combination heart defibrillator and pacemaker.

TWITTER
LINKEDIN
SIGN IN TO E-MAIL OR SAVE THIS
PRINT
REPRINTS

Why take CS 240?

Learn *how* computers execute programs.
Deepen your appreciation of **abstraction.**
Learn enduring **system design principles**.
Improve your **critical thinking** skills.

Become a **better programmer**:

- Think rigorously about execution models.
- Identify limits and impacts of abstractions and representations.
- Learn to use software development tools.

Foundations for:

- Compilers, security, computer architecture, operating systems, …

Have fun and feel accomplished!

https://cs.wellesley.edu/~cs240/

3 Long but necessary!

The Plan

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- Operating System
- Instruction Set Architecture
- Microarchitecture
- Digital Logic
- Devices (transistors, etc.)
- Solid-State Physics

Today

1. **What is CS 240?**
2. How does CS 240 work?
3. Foundations of computer hardware

Big Idea:

Abstraction

interface

implementation

Layers manage complexity.

- Algorithm, Data Structure, Application
- Programming Language
- Compiler/Interpreter
- Operating System
- Instruction Set Architecture
- Microarchitecture
- Digital Logic
- Devices (transistors, etc.)
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Big Idea: Abstraction

with a few recurring subplots

Simple, general interfaces:

Hide complexity of efficient implementation.

Make higher-level systems easy to build.

But they are not perfect.

Representation of data and programs

0s and 1s, electricity

Translation of data and programs

compilers, assemblers, decoders

Control flow within/across programs

branches, procedures, operating system

Software

Desired computation
in a programming language

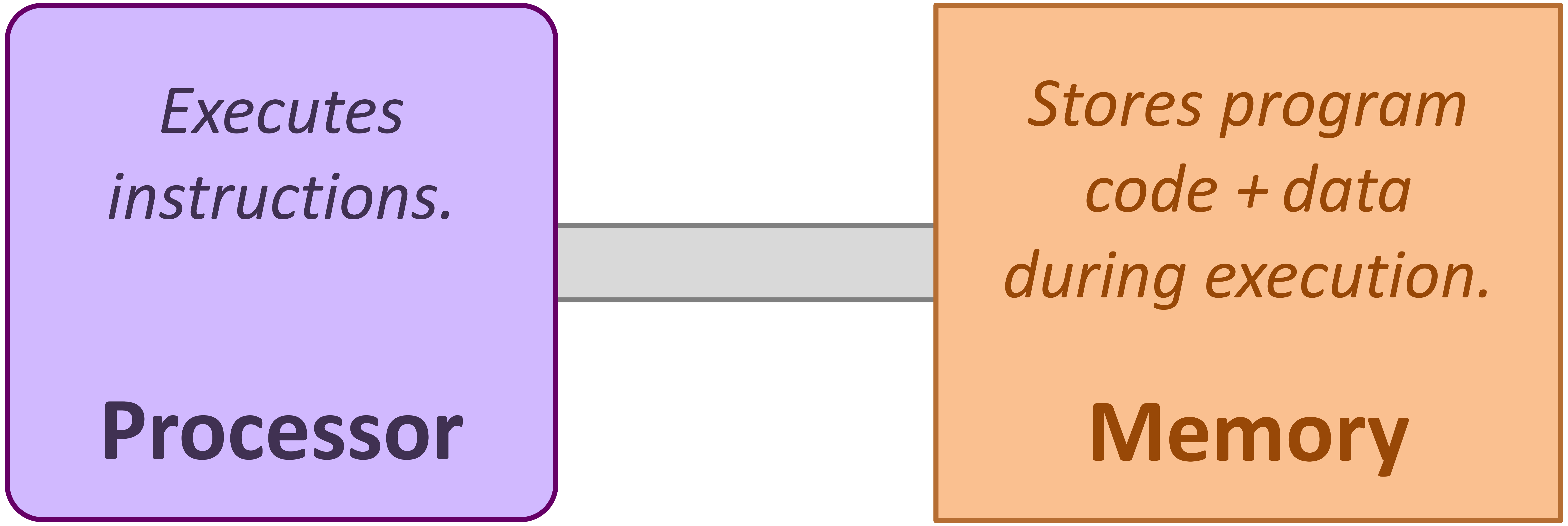
Abstraction!

Hardware/Software Interface

Hardware

Physical implementation
with circuits and electricity.

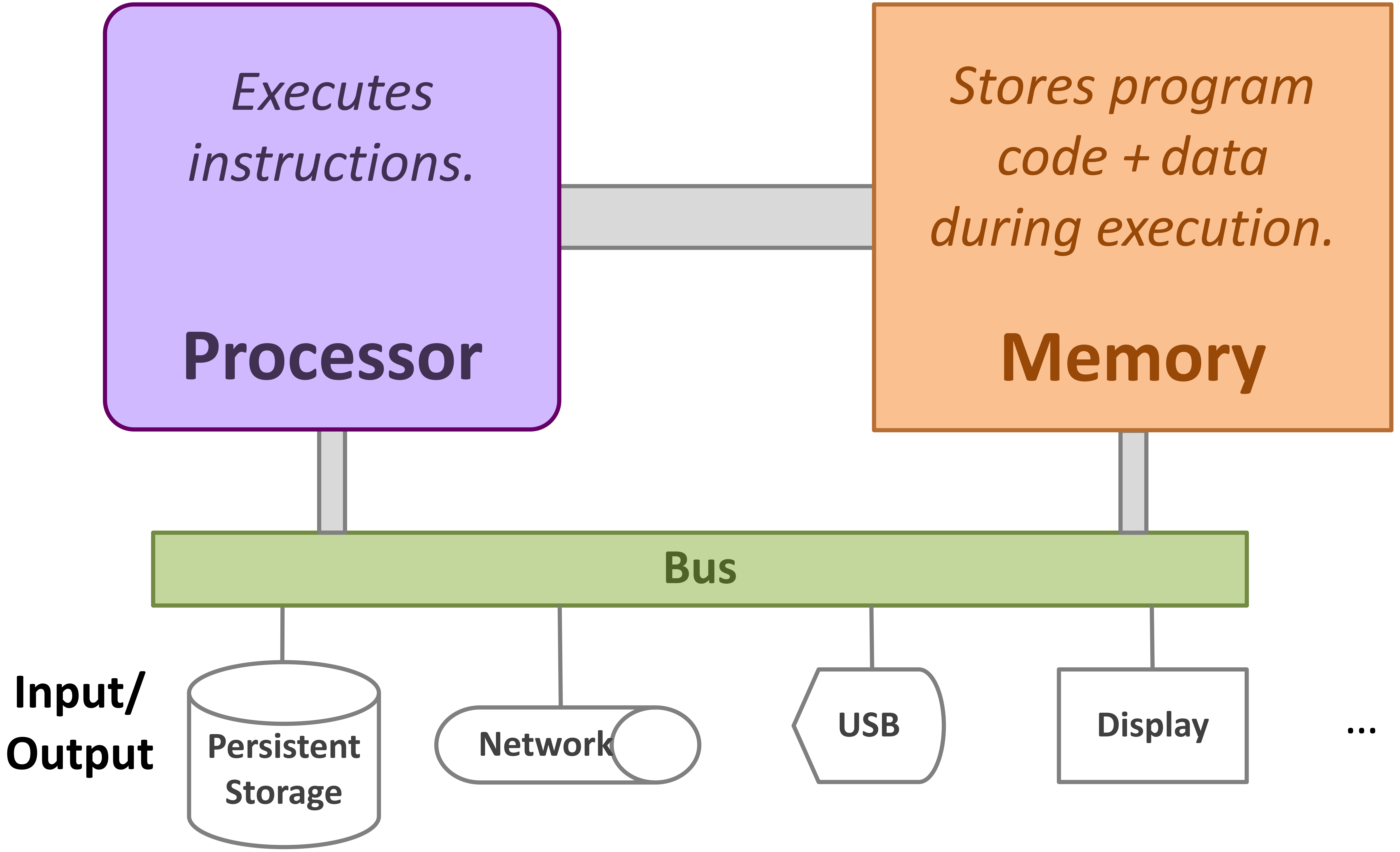
Modern Computer Organization

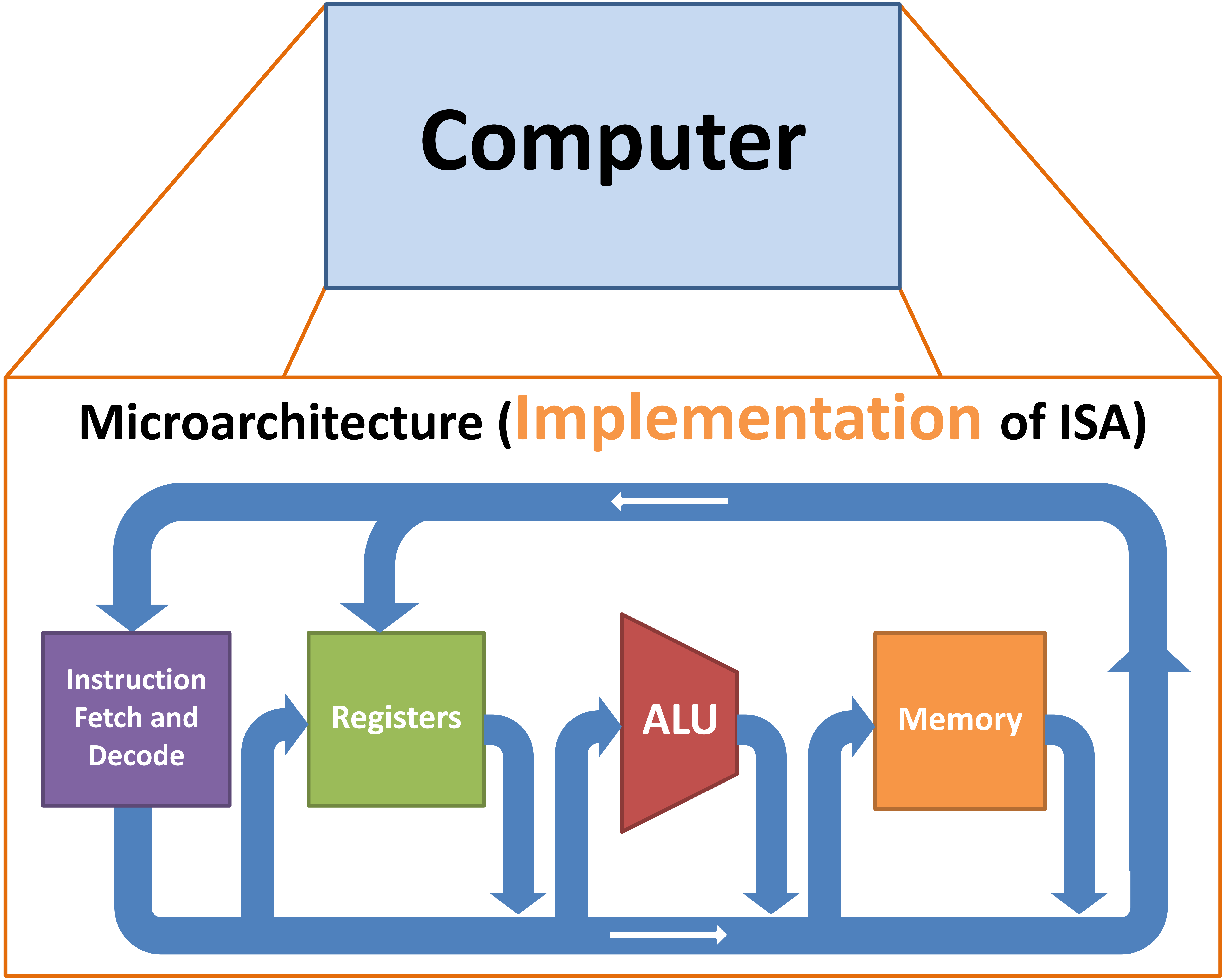


Processor repeats:

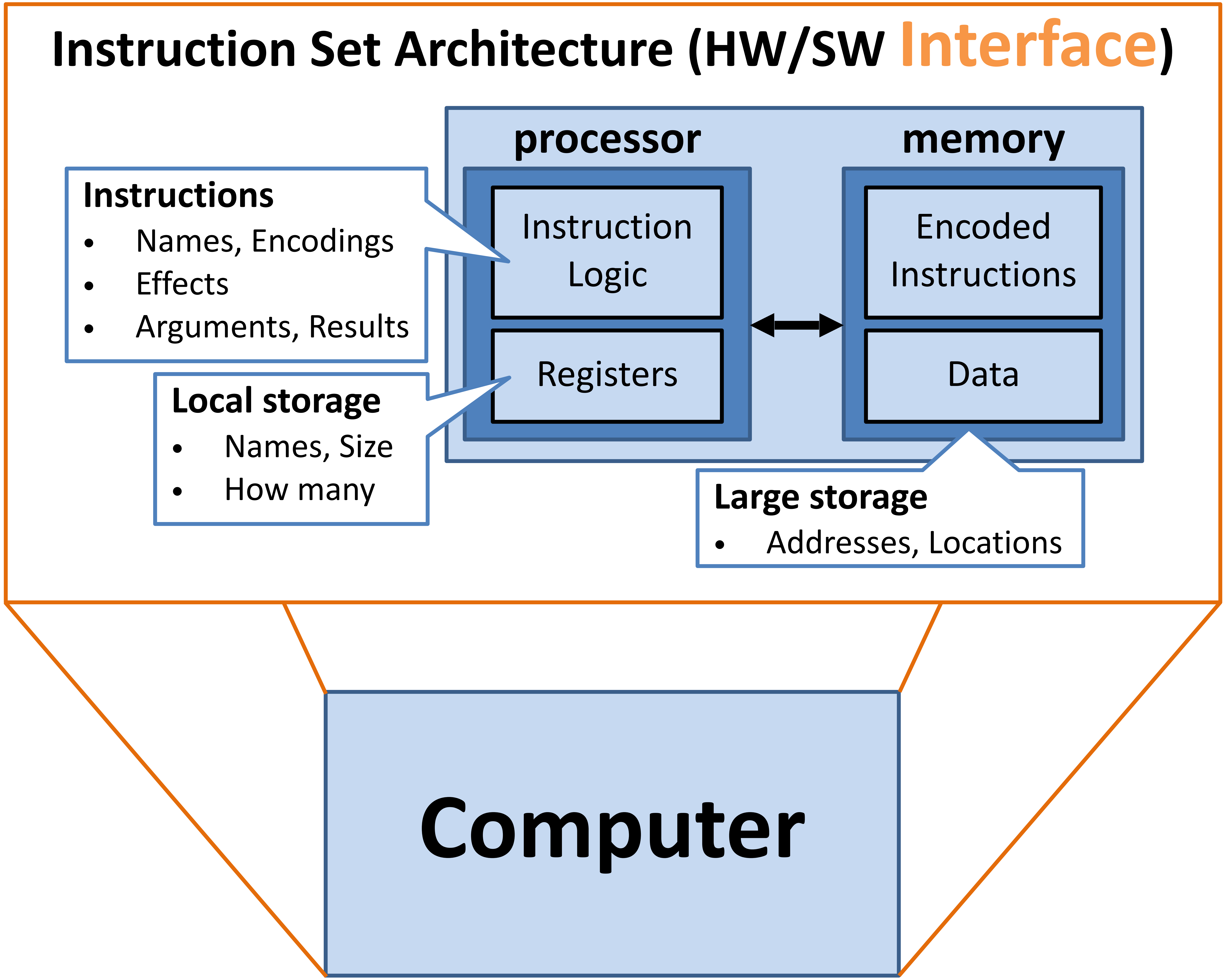
1. fetch instruction
2. fetch data used by instruction
3. execute instruction on data
4. store result or choose next instruction

Modern Computer Organization





Computer
Microarchitecture (Implementation of ISA)
Instruction Fetch and Decode
Registers
ALU
Memory

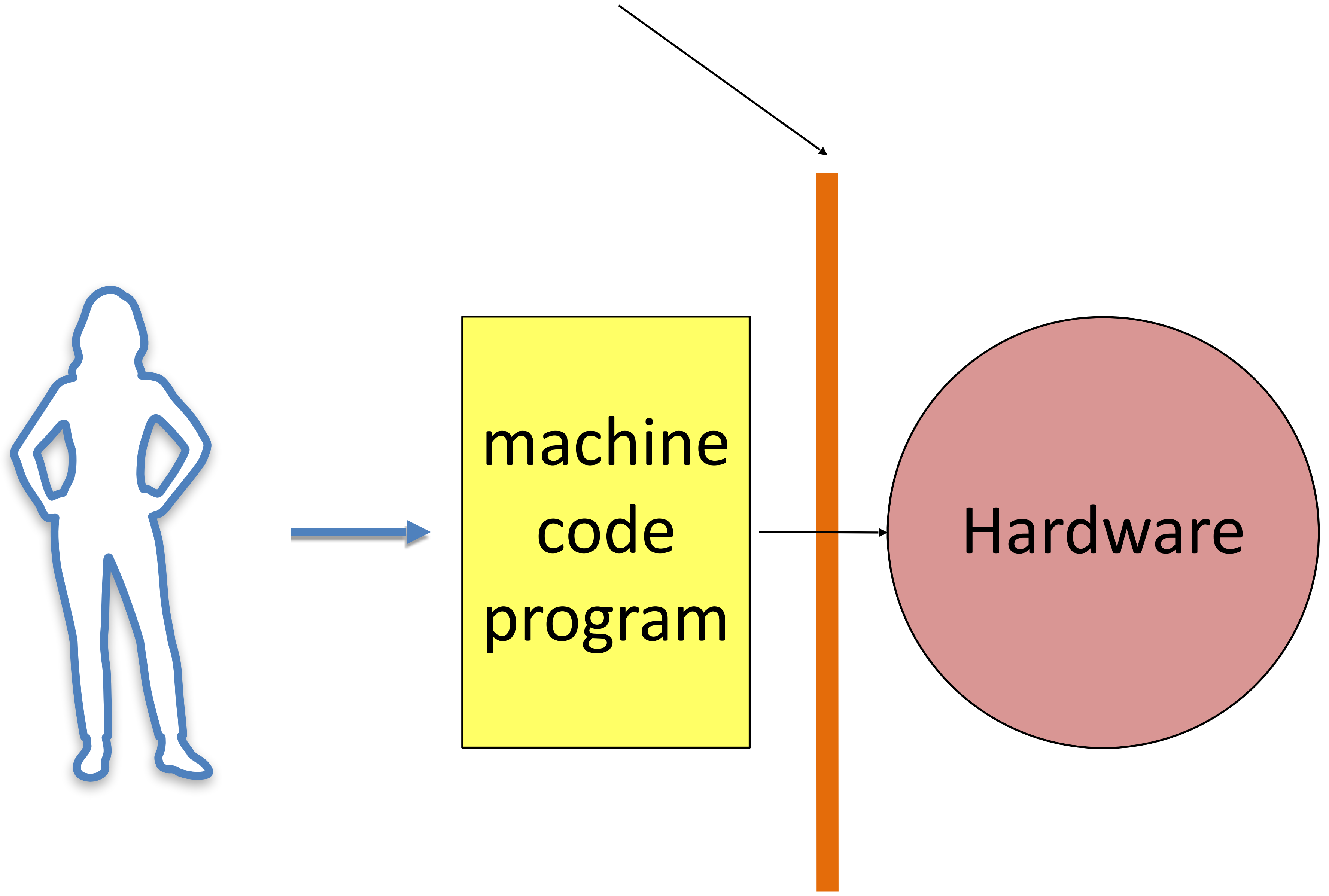

Instruction Set Architecture (HW/SW Interface)
processor
memory
Instructions
• Names, Encodings
• Effects
• Arguments, Results
Instruction Logic
Registers
Encoded Instructions
Data
Local storage
• Names, Size
• How many
Large storage
• Addresses, Locations
Computer

Machine Instructions

(adds two values and stores the result)

00000010100010101100100000010000

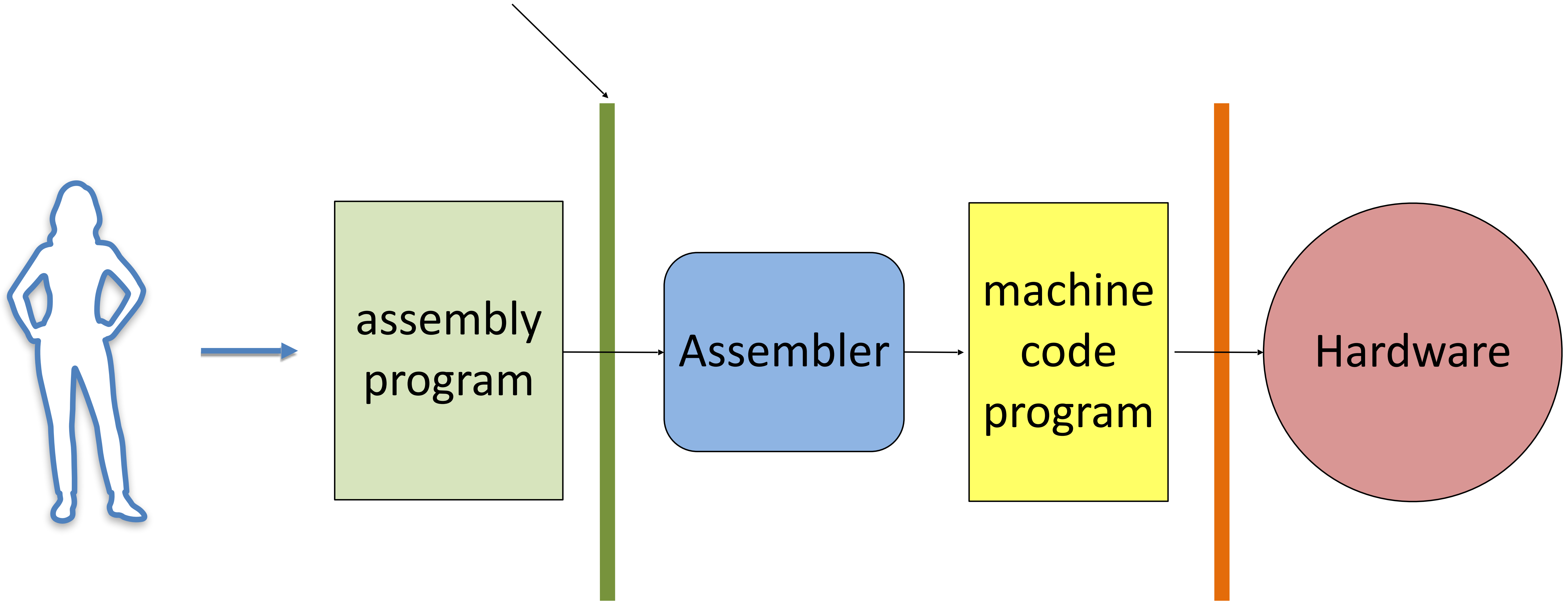
Instruction Set Architecture specification



Assemblers and Assembly Languages

`addl %eax, %ecx` → `00000010100010101100100000010000`

Assembly Language specification



1940s	**1950s**	**1960s**	1970s	1980s	1990s	2000s	2010s	2020s

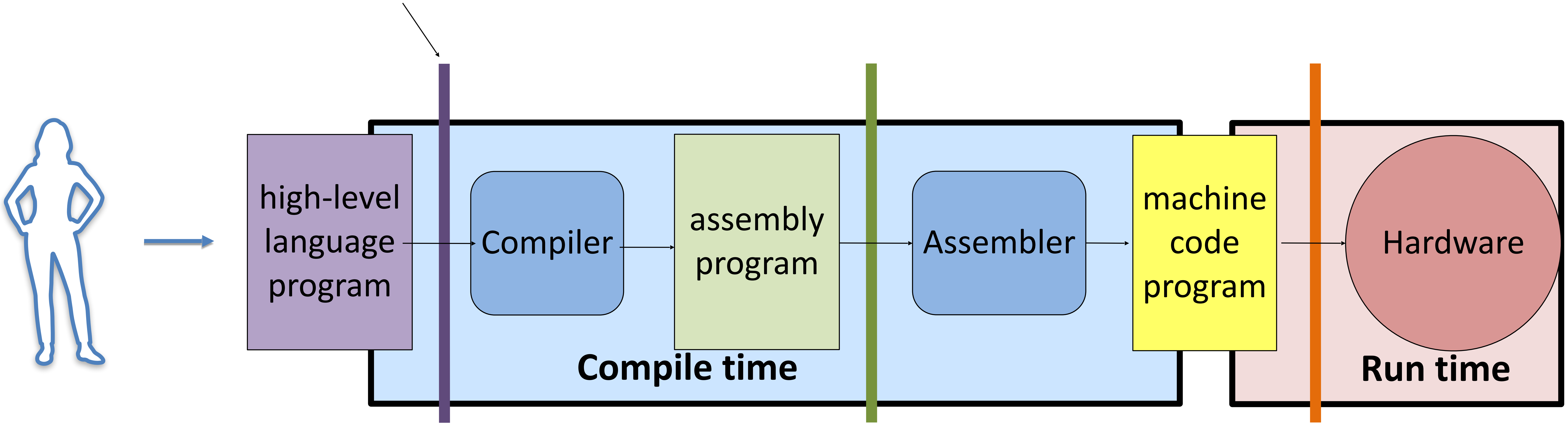
Higher-Level Programming Languages

```
x = x + y;
```

```
addl %eax, %ecx
```

```
00000010100010101100100000010000
```

Programming Language specification



A-0: first compiler, by Grace Hopper

Early 1950s

Maybe closer to

assembler/linker/loader

Later: B-0 → FLOW-MATIC

→ COBOL, late 50s

Jean Sammet also involved

- headed first sci comp group at Sperry in the '50s
- Later first female president of ACM
- Mount Holyoke alum, class of 1948

More and more layers…

- Operating systems
- Virtual machines
- Hypervisors
- Web browsers
- …

https://cs.wellesley.edu/~cs240/

3 Long but necessary!