The Plan

Welcome to

CS 240:

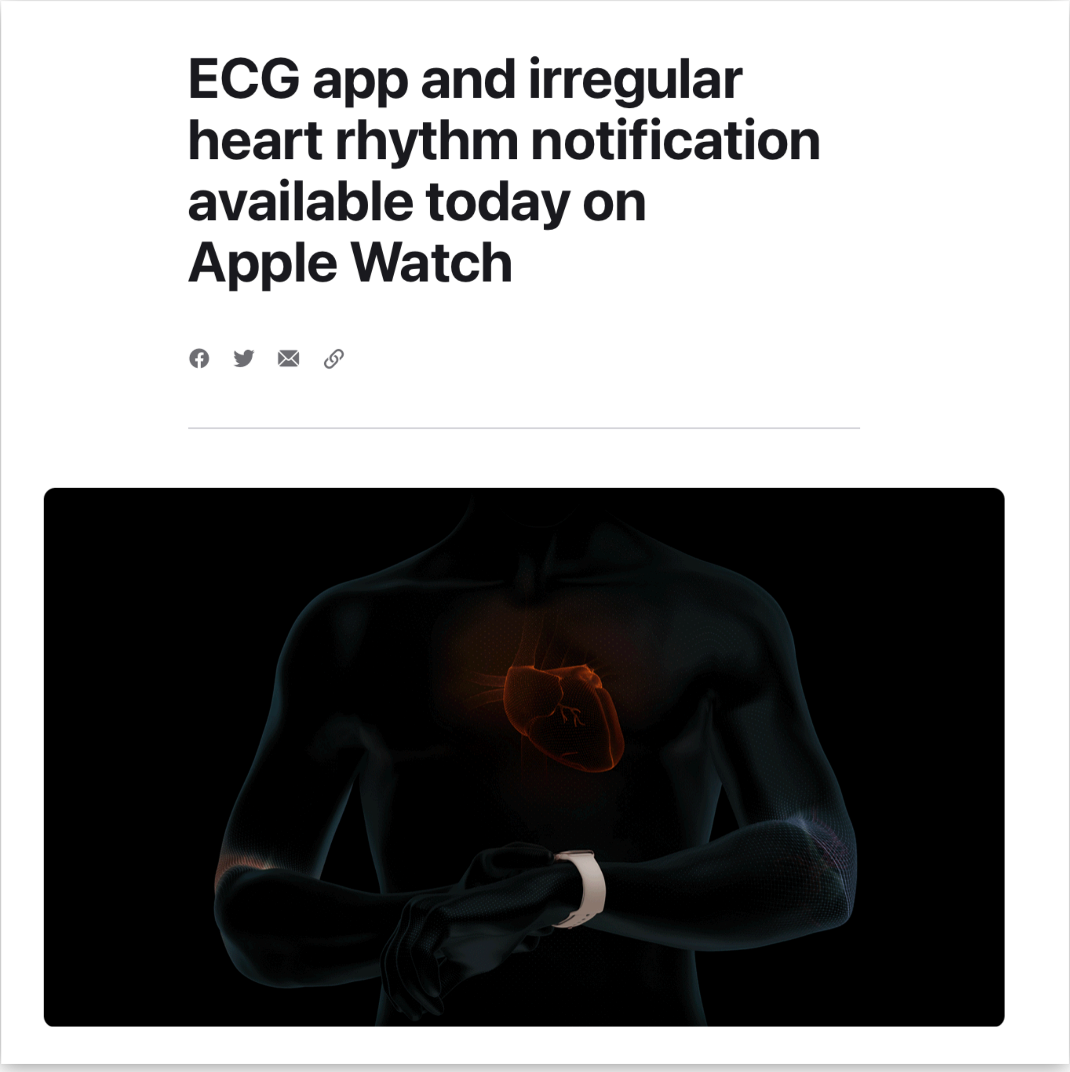
Foundations of

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 year!
- Research focus: programming languages & systems

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

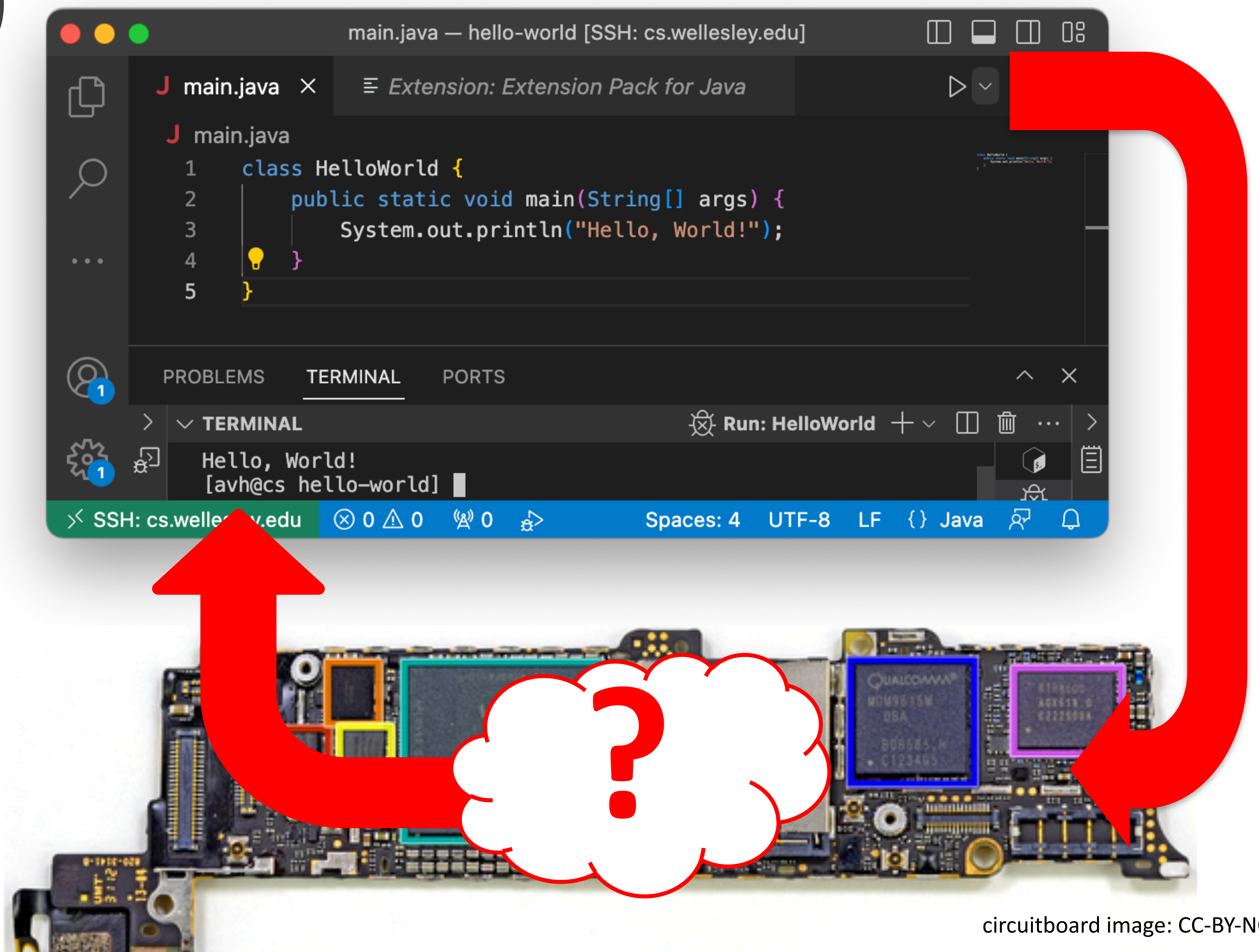
1. **What is CS 240?**
2. Why take CS 240? (in brief)
3. How does CS 240 work? (in brief)

CS 111, 230, 231, 235, 251:

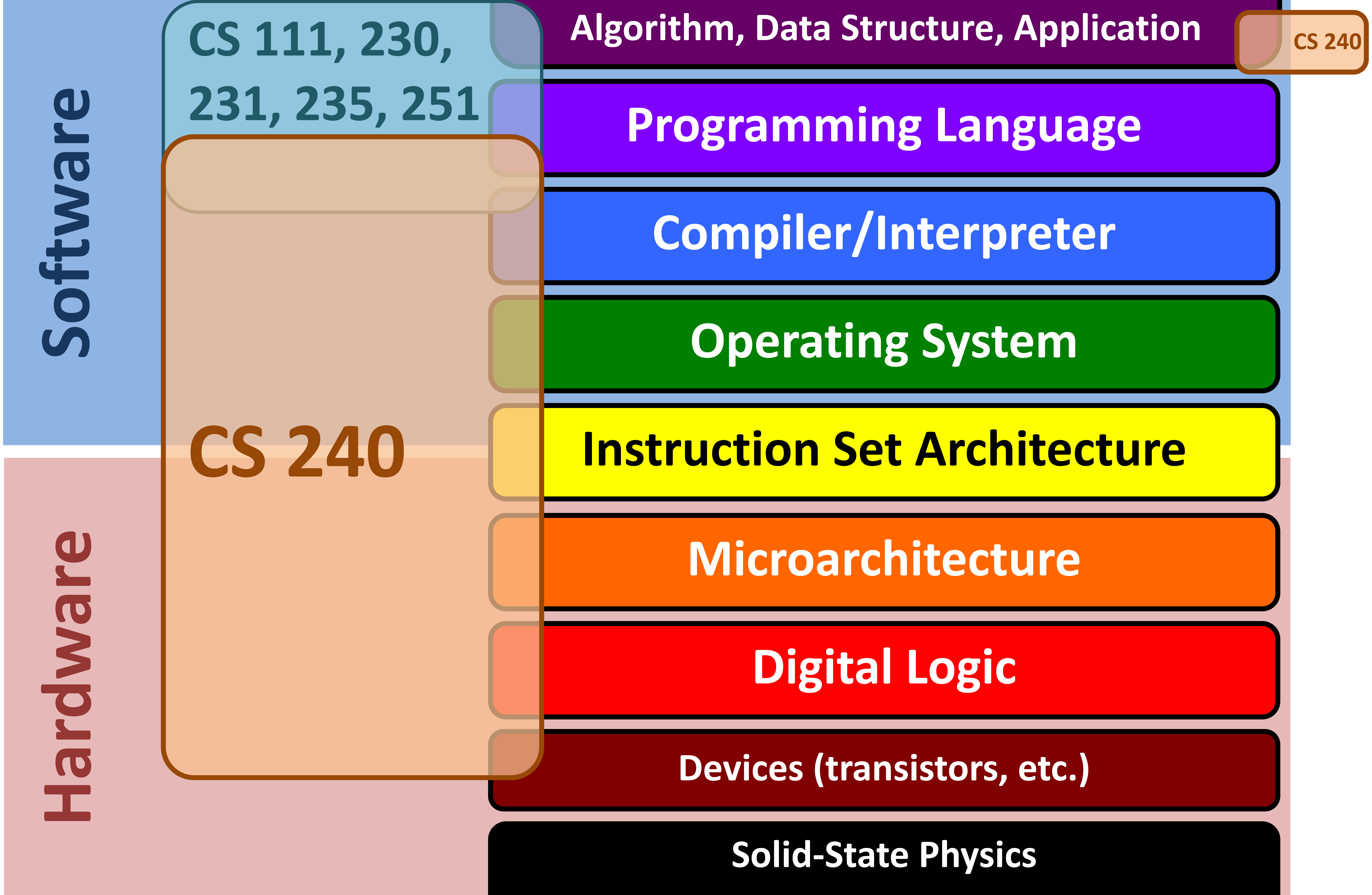
- How do you use programming to solve a problem?
- How do you structure a program?
- How do you know it is correct or efficient?
- How hard is it to solve a problem?
- How is computation expressed?
- What does a program mean?
- ...

A BIG question is missing…

1



circuitboard image: CC-BY-NC-SA ifixit.com


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

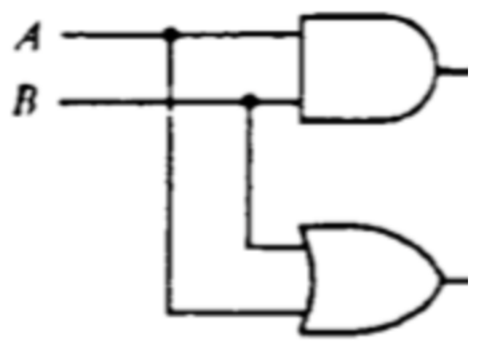
Hardware

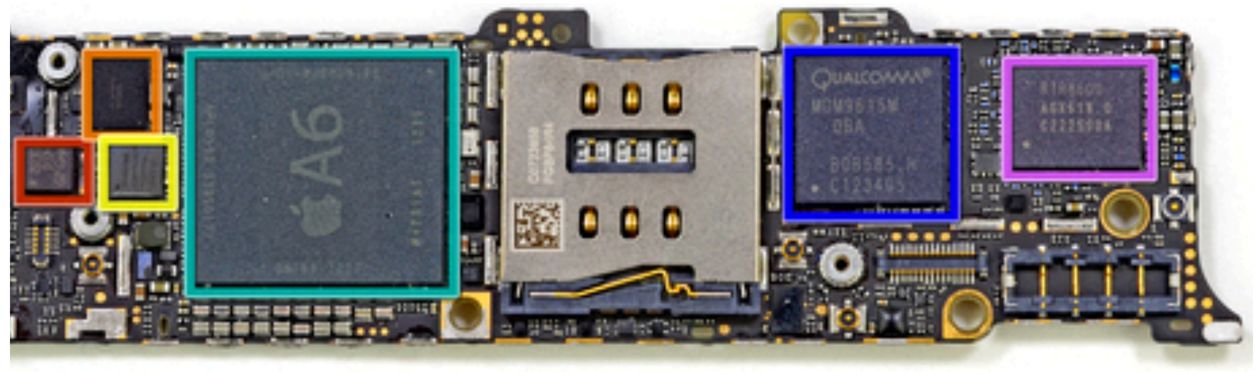
Physical implementation
with circuits and electricity.

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

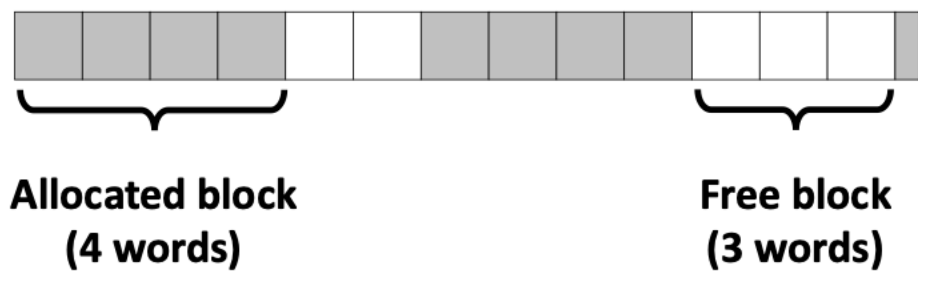
```
MOV x9, x10
ADD x12, x12, #1

*x = malloc(…);
```

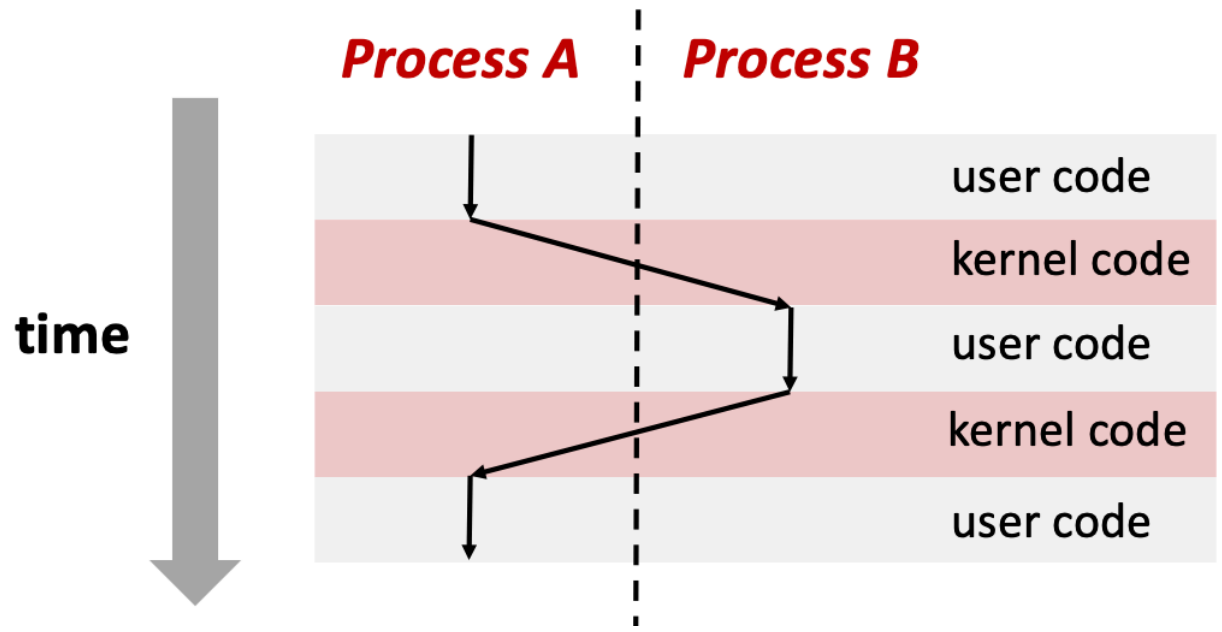
3. Abstraction for practical systems

Memory hierarchy

Operating system basics

Higher-level languages and tools

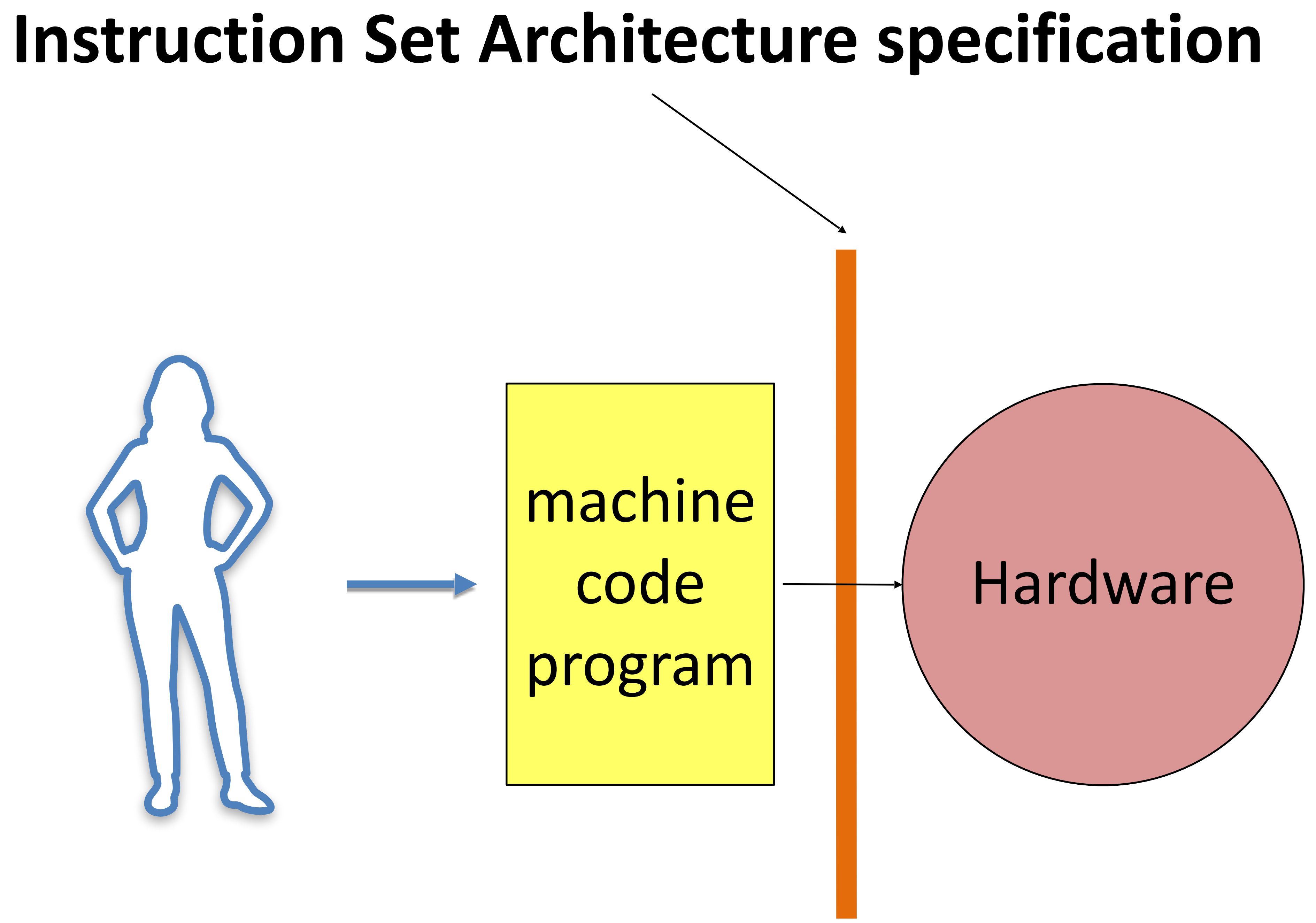




Machine Instructions

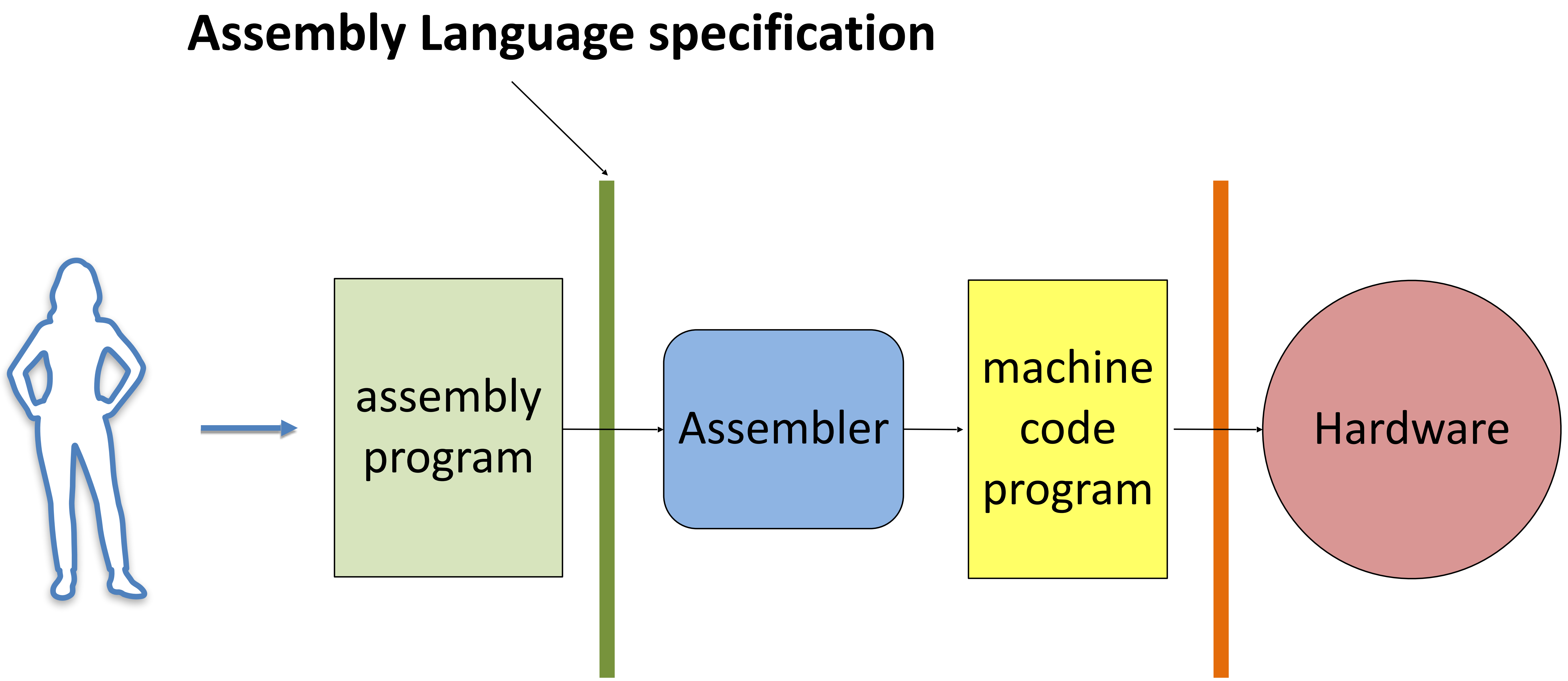
(adds two values and stores the result)

00000010100010101100100000010000



Assemblers and Assembly Languages

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

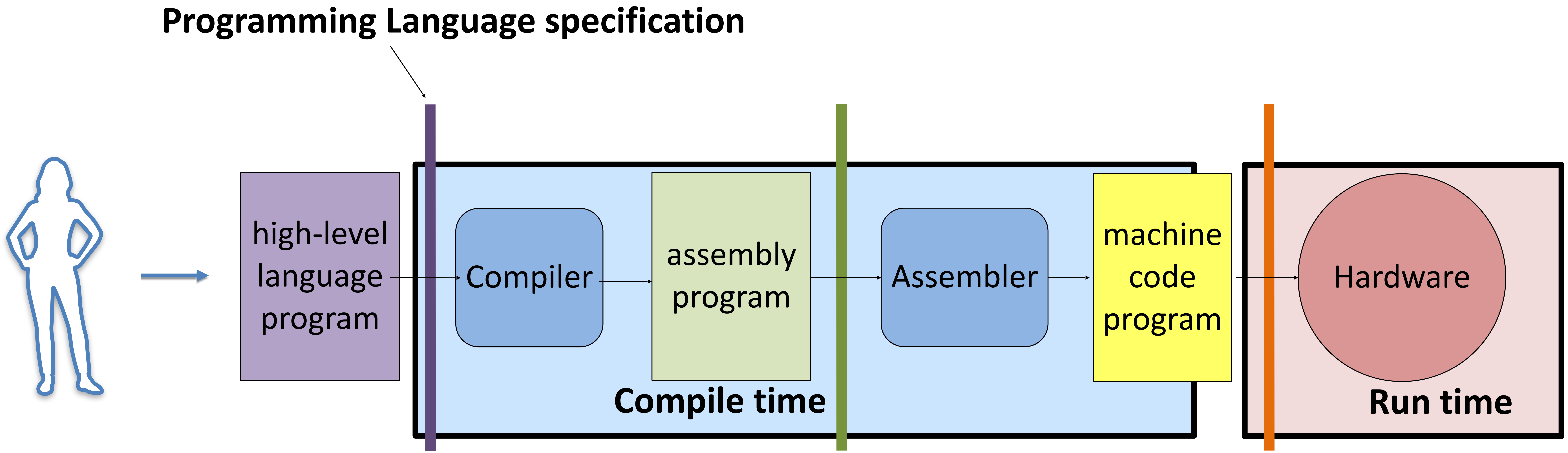


Higher-Level Programming Languages

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

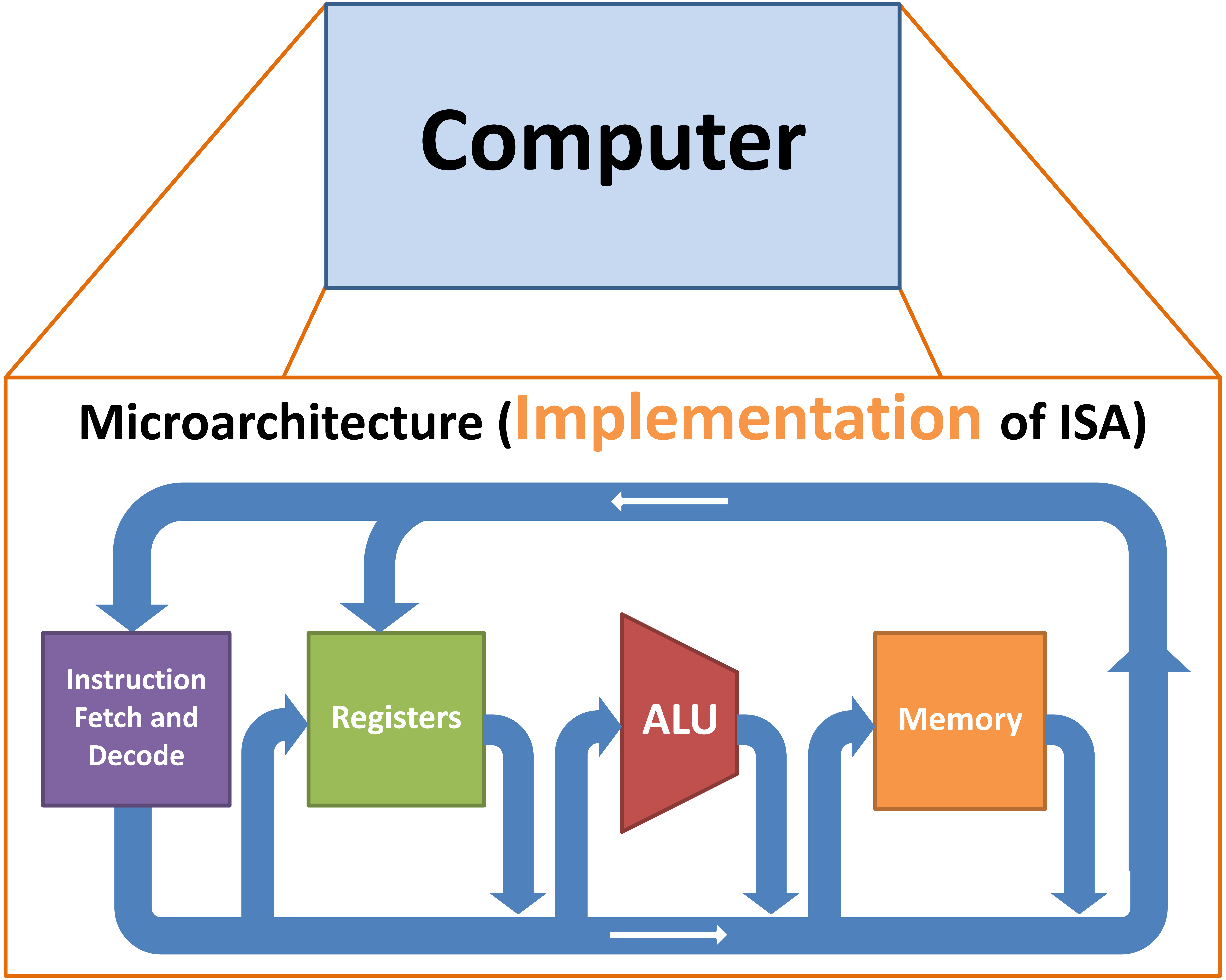
```
addl %eax, %ecx
```

```
00000010100010101100100000010000
```



More and more layers…

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

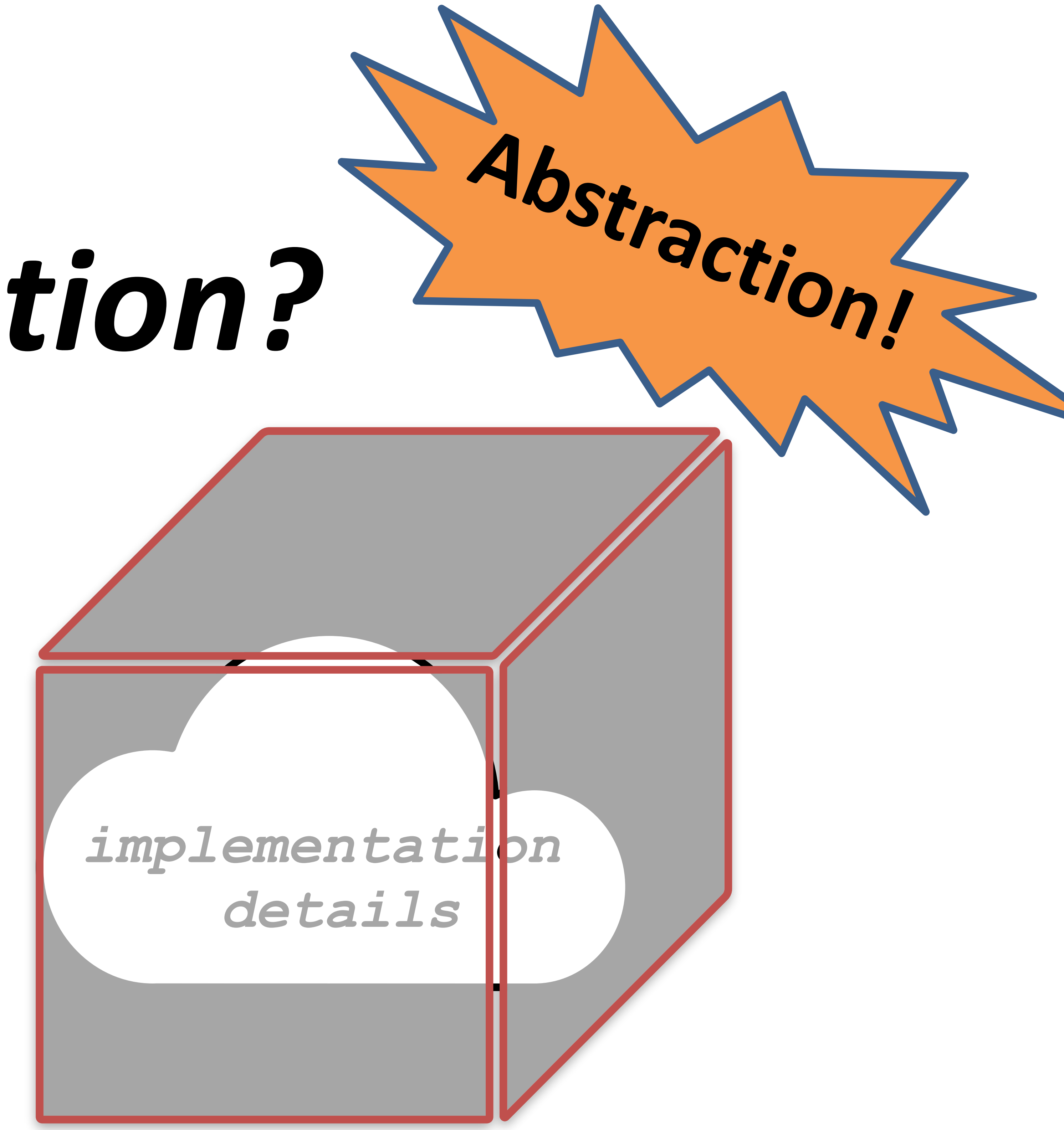

Computer
Microarchitecture (Implementation of ISA)
Instruction Fetch and Decode
Registers
ALU
Memory

2

I just like to program.
Why study the implementation?

2

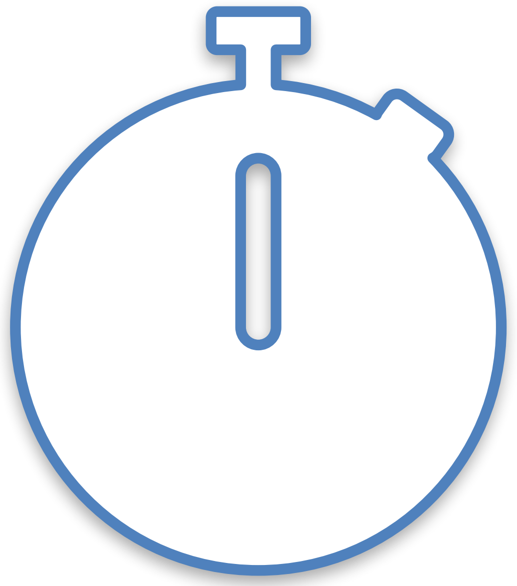
I just like to program.
Why study the implementation?



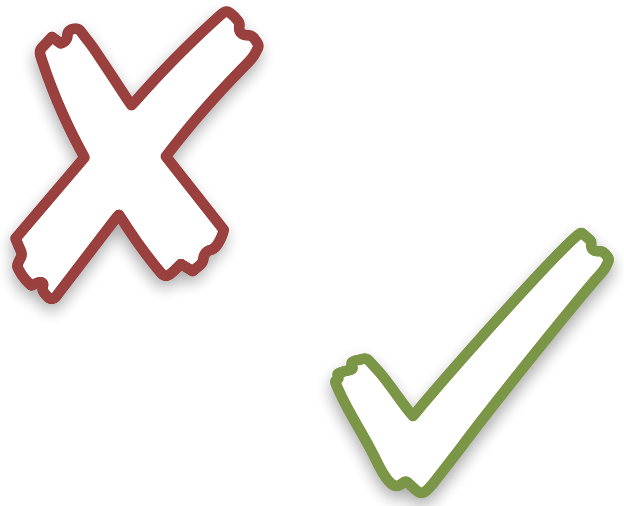
Most system abstractions "leak."

Implementation details affect your programs:

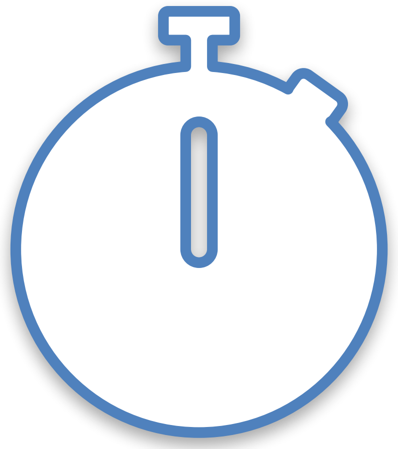
Their performance



Their correctness



Their security

Performance 

x / 973 **x / 1024**

Which of these code snippets is faster? `x / 973` or `x / 1024`

`x / 973` is faster

`x / 1024` is faster

The same

Start the presentation to see live content. For screen share software, share the entire screen. Get help at **pollev.com/app**

Which of these code snippets is faster? `x / 973` or `x / 1024`

`x / 973` is faster — 0%

`x / 1024` is faster — 0%

The same — 0%

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Which of these code snippets is faster? `x / 973` or `x / 1024`

`x / 973` is faster

0%

`x / 1024` is faster

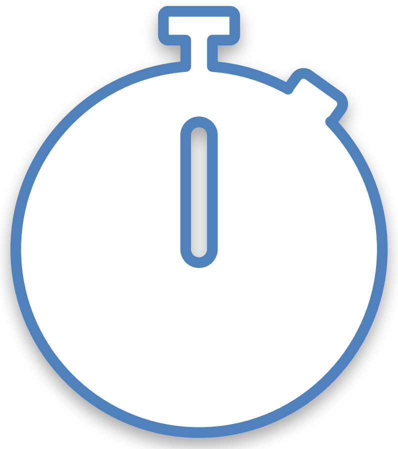
0%

The same

0%

Start the presentation to see live content. For screen share software, share the entire screen. Get help at **pollev.com/app**

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

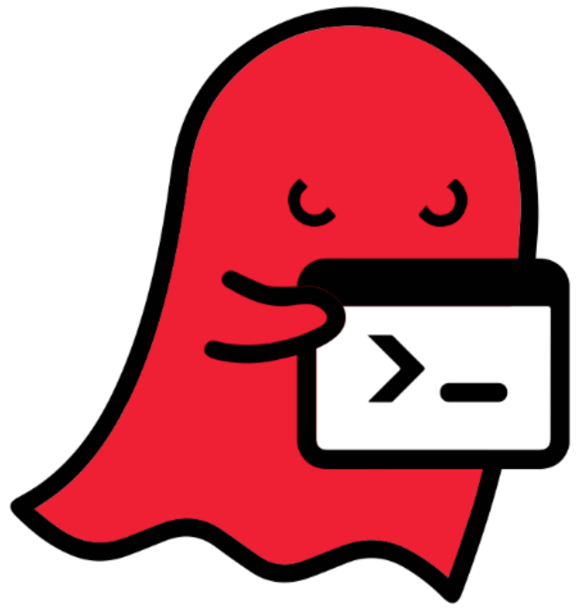
Exploded due to **cast** of 64-bit floating-point number to 16-bit signed number. **Overflow.**

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.



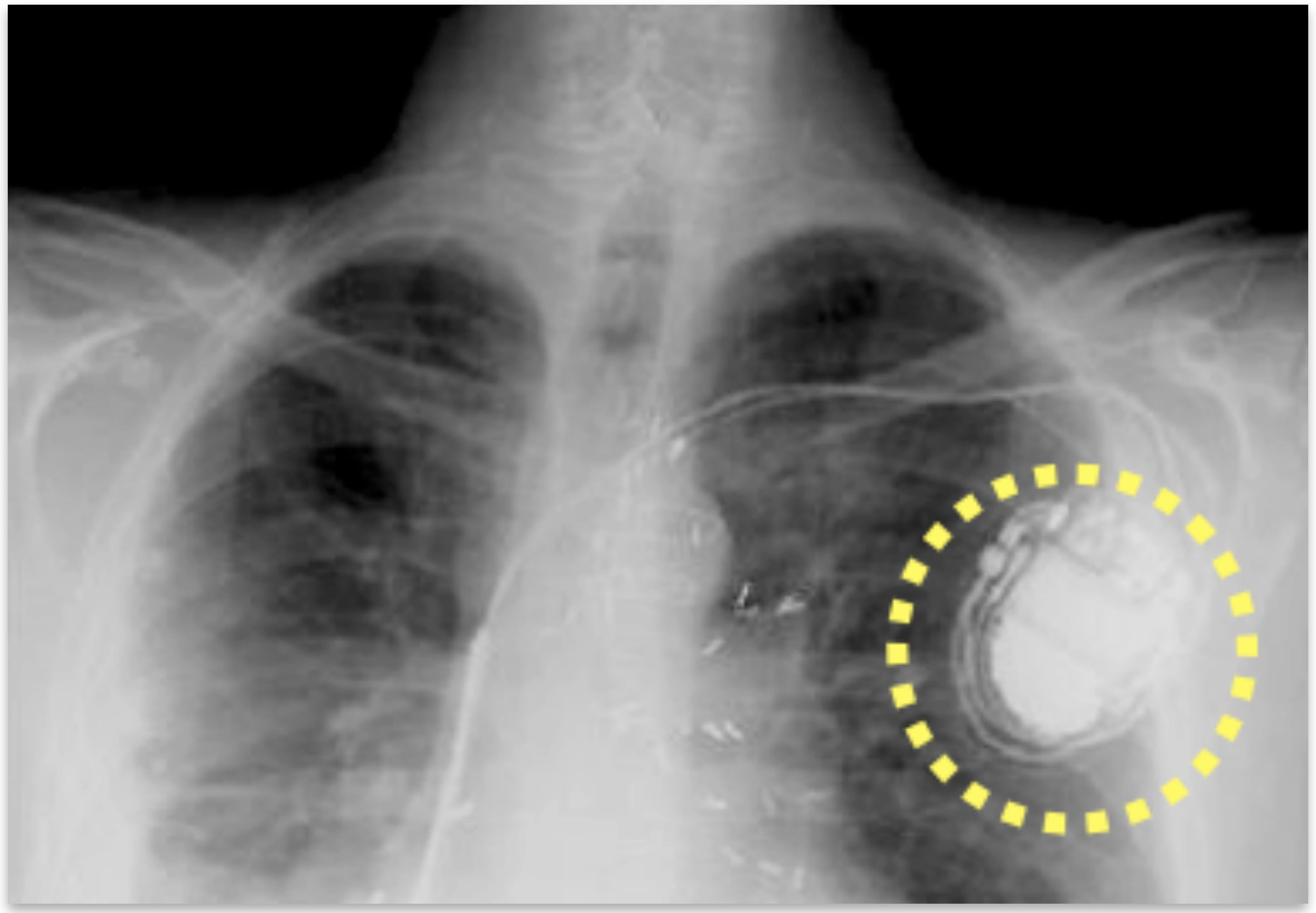
Cyber-Safe

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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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.

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REPRINTS

Why take CS 240?

Learn *how* computers execute programs.

Deepen your appreciation of **abstraction.**

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*!