CS 240
Foundations of Computer Systems

WELLESLEY

The Plan: Lab 1 preview

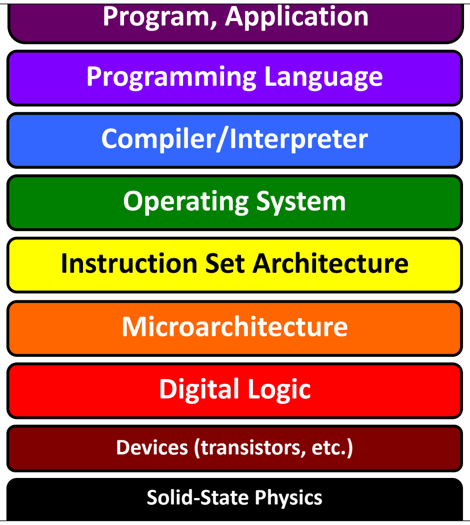
https://cs.wellesley.edu/~cs240/

Welcome to

CS 240:

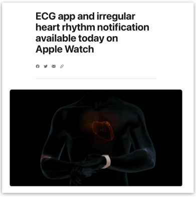
Foundations of

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"


ECG app and irregular heart rhythm notification available today on Apple Watch

- 3rd year at Wellesley
- 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

1 **What is CS 240?**

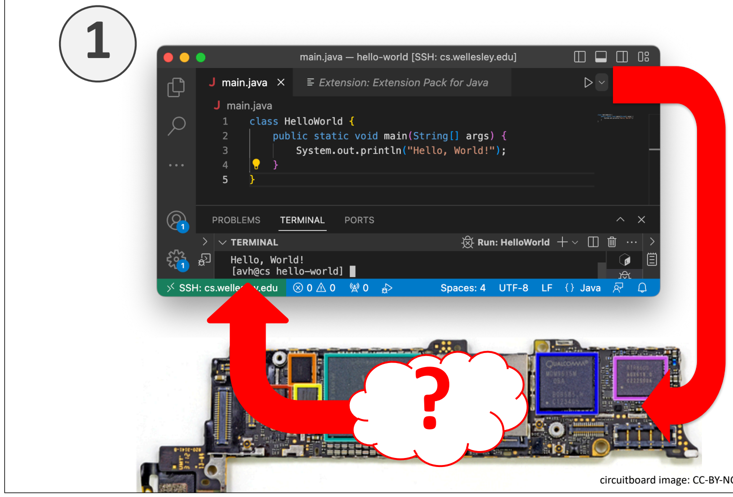
2 Why take CS 240? (in brief)

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?
- ...

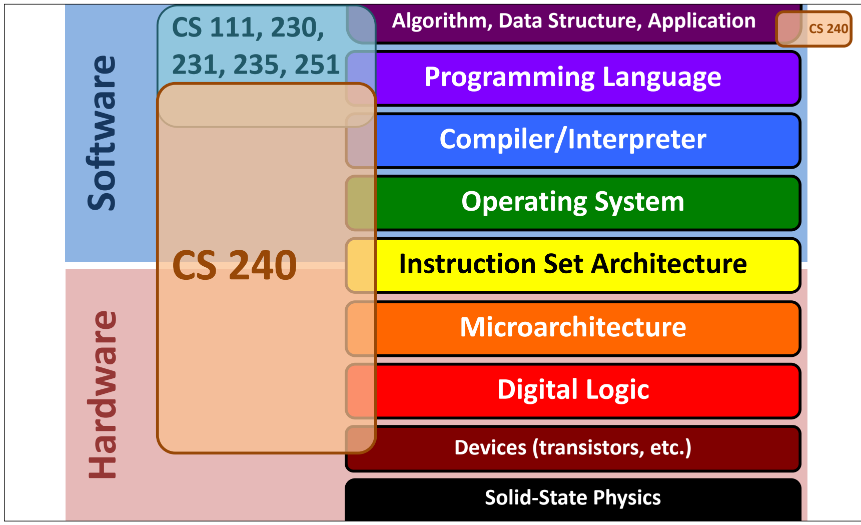
A BIG question is missing...



```java
class HelloWorld {
    public static void main(String[] args) {
        System.out.println("Hello, World!");
    }
}
```

```
Hello, World!
[avh@cs hello-world] 
```

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


Software

Hardware

CS 111, 230, 231, 235, 251

CS 240

Algorithm, Data Structure, Application

Programming Language

Compiler/Interpreter

Operating System

Instruction Set Architecture

Microarchitecture

Digital Logic

Devices (transistors, etc.)

Solid-State Physics

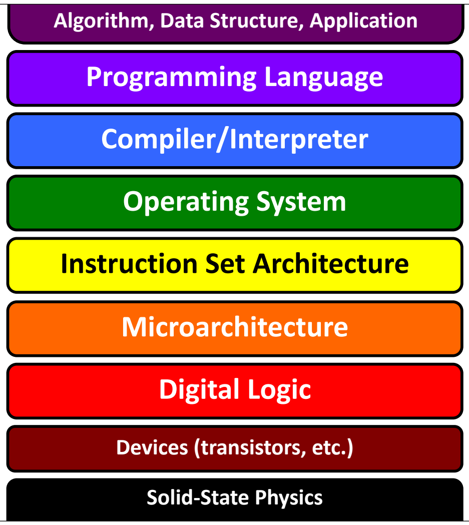
Big Idea:

Abstraction

interface

implementation

Layers manage complexity.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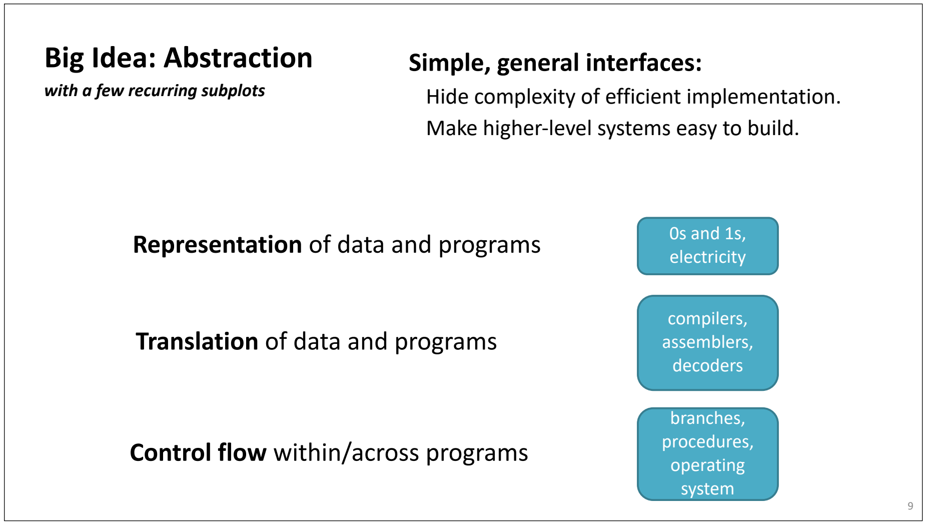


Big Idea: Abstraction

with a few recurring subplots

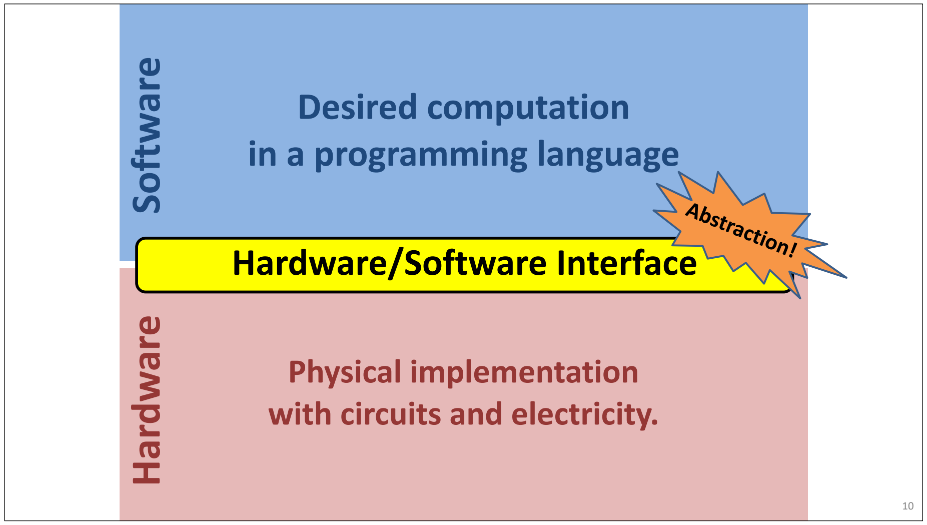
Simple, general interfaces:

Hide complexity of efficient implementation.
Make higher-level systems easy to build.

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

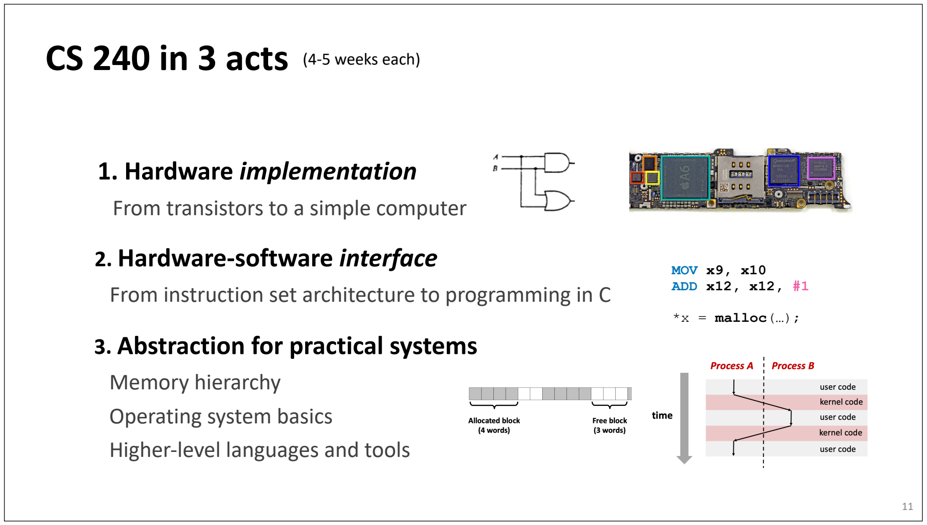
Desired computation
in a programming language

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(…);
```

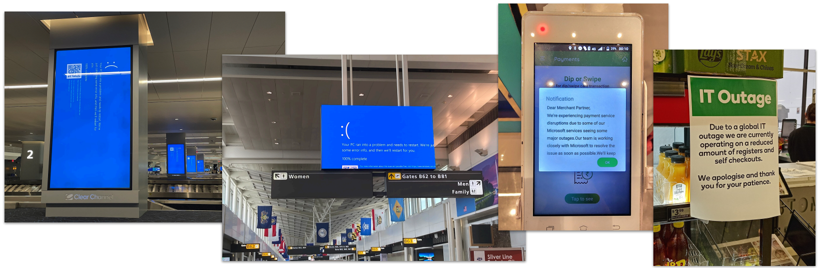
3. Abstraction for practical systems

Memory hierarchy
Operating system basics
Higher-level languages and tools

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

Does anyone remember what was noteworthy about July 19, 2024?

…was anyone trying to travel by plane around then?


IT Outage
Due to a global IT outage we are currently operating on a reduced amount of registers and self checkouts.
We apologise and thank you for your patience.

What happened?

invalid memory access in C *code running in OS kernel* *insufficient testing & validation*

unchecked array length *limitations of processor multithreading*

… all CS240 topics!

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

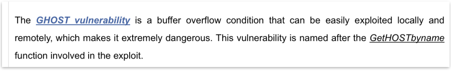
int ≠ integer
float ≠ real

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

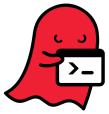
Boeing 787, 2015

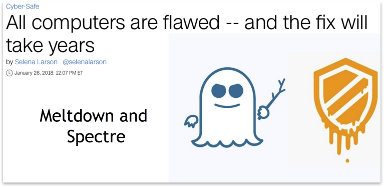
"… a **Model 787 airplane** … can lose all alternating current (AC) electrical power … caused by a **software counter** internal to the GCUs that will **overflow** after **248 days** of continuous power. We are issuing this AD to prevent loss of all AC electrical power, which could result in **loss of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





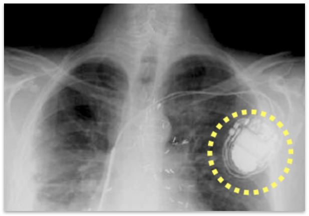
Cyber-Safe

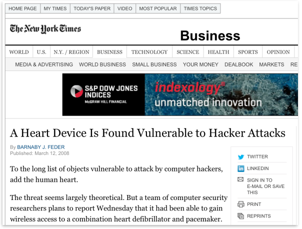
All computers are flawed -- and the fix will take years

by Selena Larson @selenalarson

January 26, 2018: 12:07 PM ET

Meltdown and Spectre





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.

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!

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3 Long but *necessary*!

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The Plan

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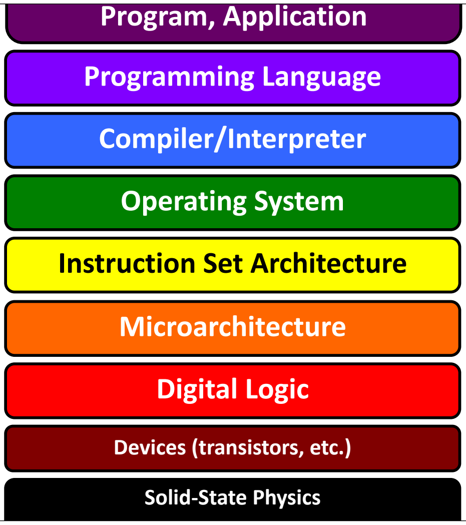


What's a topic you are excited to learn more about in CS240?

Nobody has responded yet.

Hang tight! Responses are coming in.

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

Today

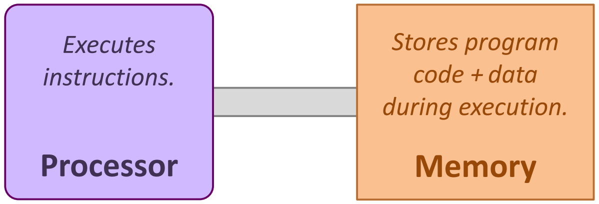
1 **What is CS 240?**

2 How does CS 240 work?

3 Foundations of computer hardware

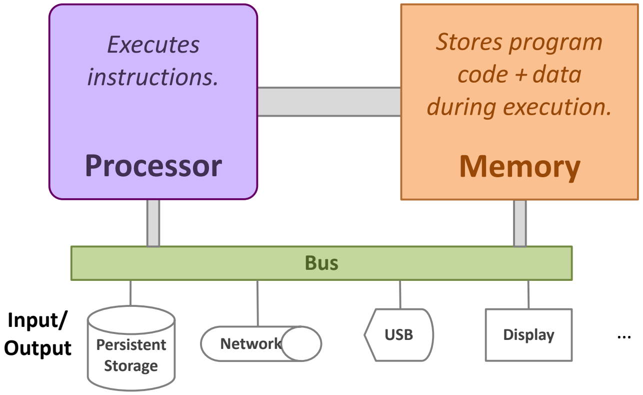
1940s 1950s 1960s 1970s 1980s 1990s 2000s 2010s 2020s

Modern Computer Organization



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

Modern Computer Organization



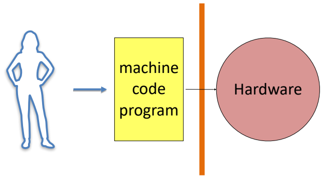
1940s 1950s 1960s 1970s 1980s 1990s 2000s 2010s 2020s

Machine Instructions

(adds two values and stores the result)

00000010100010101100100000010000

Instruction Set Architecture specification



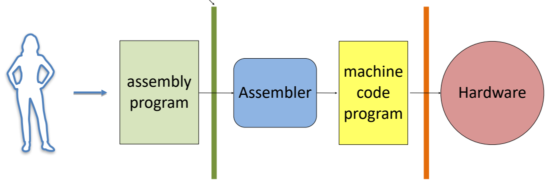
1940s 1950s 1960s 1970s 1980s 1990s 2000s 2010s 2020s

Assemblers and Assembly Languages

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

00000010100010101100100000010000

Assembly Language specification



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

A-0: first compiler, by Grace Hopper

Early 1950s

Maybe closer toassembler/linker/loader

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

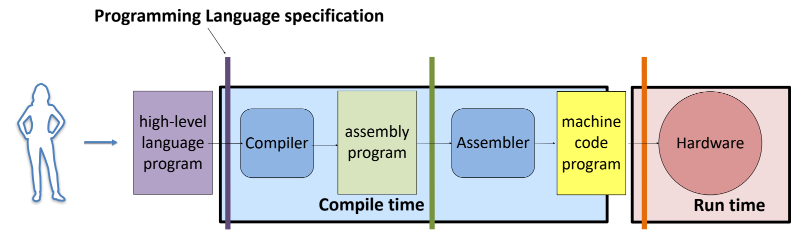
1940s | **1950s** | **1960s** | 1970s | 1980s | 1990s | 2000s | 2010s | 2020s

Higher-Level Programming Languages

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

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

```
00000010100010101100100000010000
```



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

3 Long but *necessary*!