CS 240
Foundations of Computer Systems

WELLESLEY

The Plan

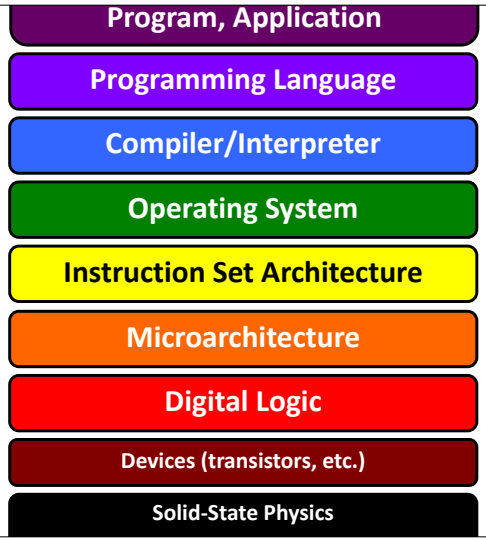
https://cs.wellesley.edu/~cs240/

Welcome to

CS 240:

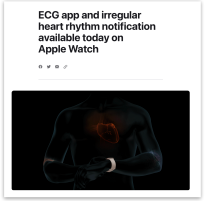
Foundations of

Computer Systems!



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

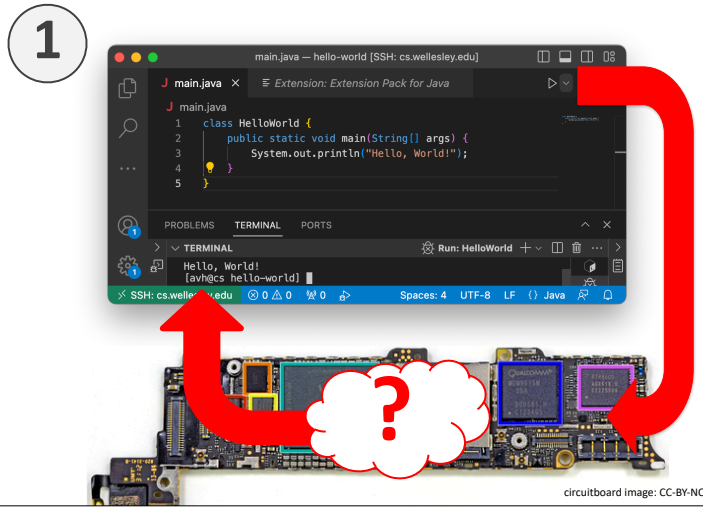
Today's preview

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

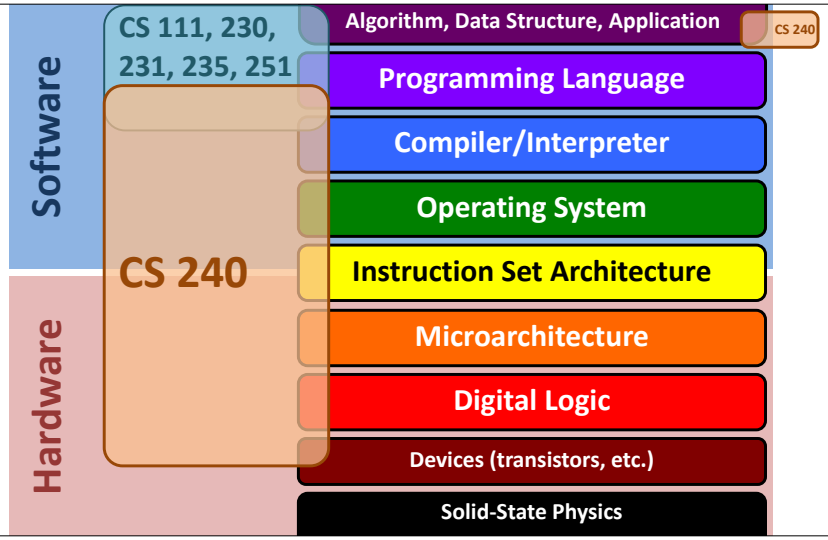
CS 111, 230, 231, 235, 251:

- 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…



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



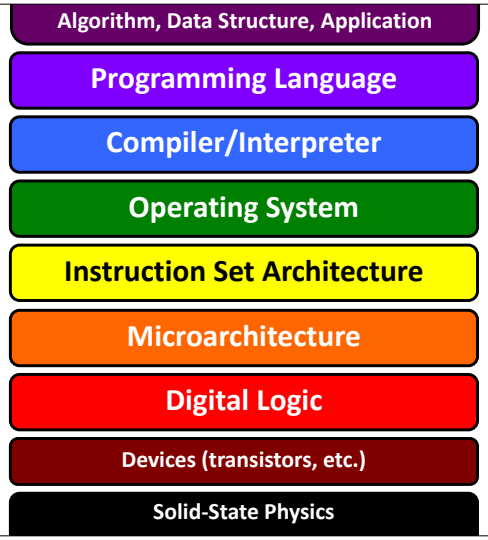
Big Idea:

Abstraction

interface

implementation

Layers manage complexity.



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*

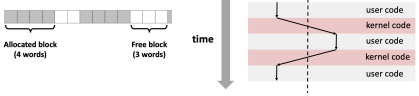
From instruction set architecture to programming in C

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

```
*x = malloc(...);
```

3. Abstraction for practical systems

Memory hierarchy
Operating system basics
Higher-level languages and tools



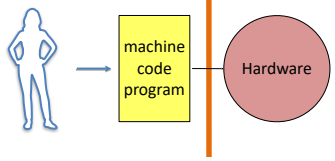
1940s | 1950s | 1960s | 1970s | 1980s | 1990s | 2000s | 2010s | 2020s

Machine Instructions

(adds two values and stores the result)

```
00000010100001010110010000010000
```

Instruction Set Architecture specification

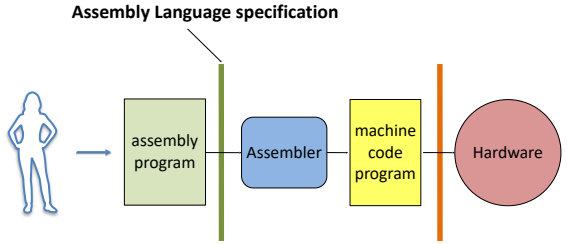


1940s | **1950s** | 1960s | 1970s | 1980s | 1990s | 2000s | 2010s | 2020s

Assemblers and Assembly Languages

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

→ `00000010100010101100100000010000`



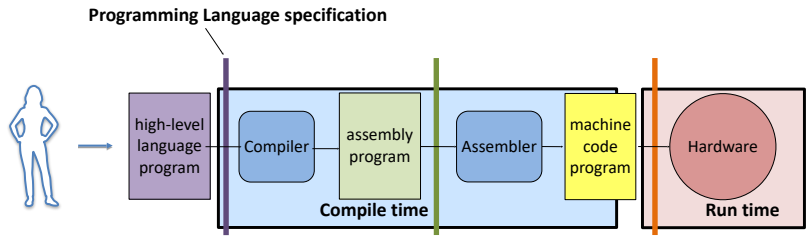
1940s | 1950s | **1960s** | 1970s | 1980s | 1990s | 2000s | 2010s | 2020s

Higher-Level Programming Languages

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

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

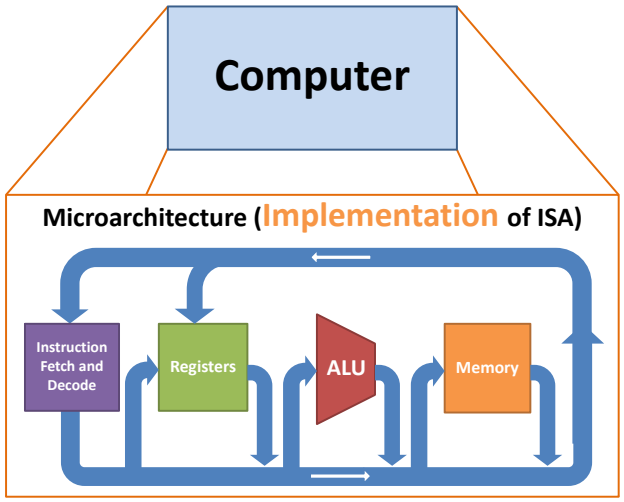
→ `00000010100010101100100000010000`



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

More and more layers…

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



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

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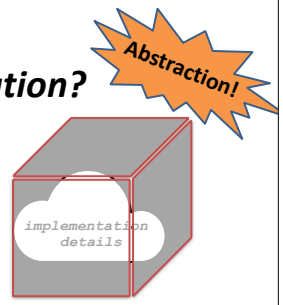

Most system abstractions "leak."

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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`x / 973` is faster 0%

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The same 0%

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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.

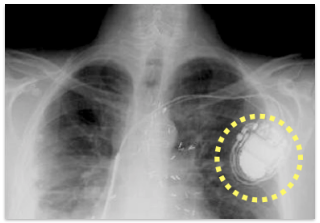
Cyber-Safe

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!

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3 Long but *necessary*!