CS 240
Foundations of Computer Systems

WELLESLEY

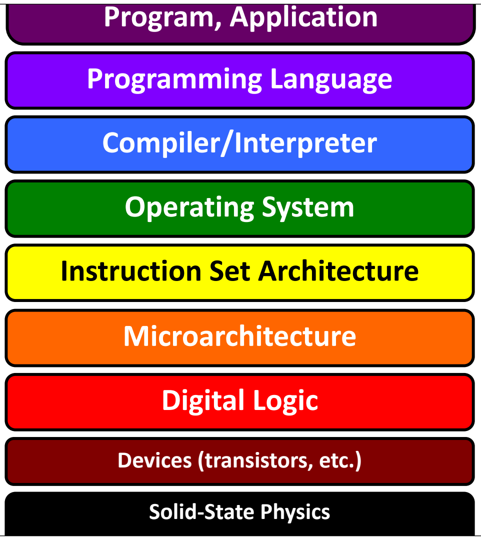
The Plan: Lab 1 preview

Welcome to

CS 240:

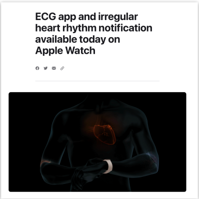
Foundations of

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"


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

- 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

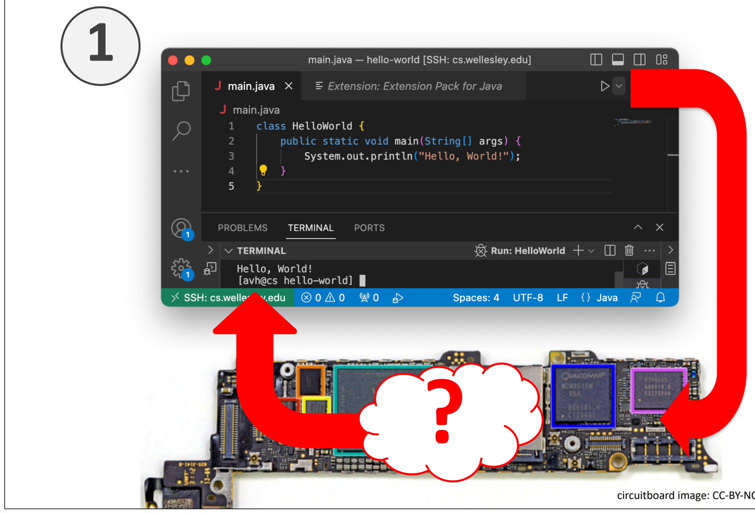
Today's preview

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?
- ...

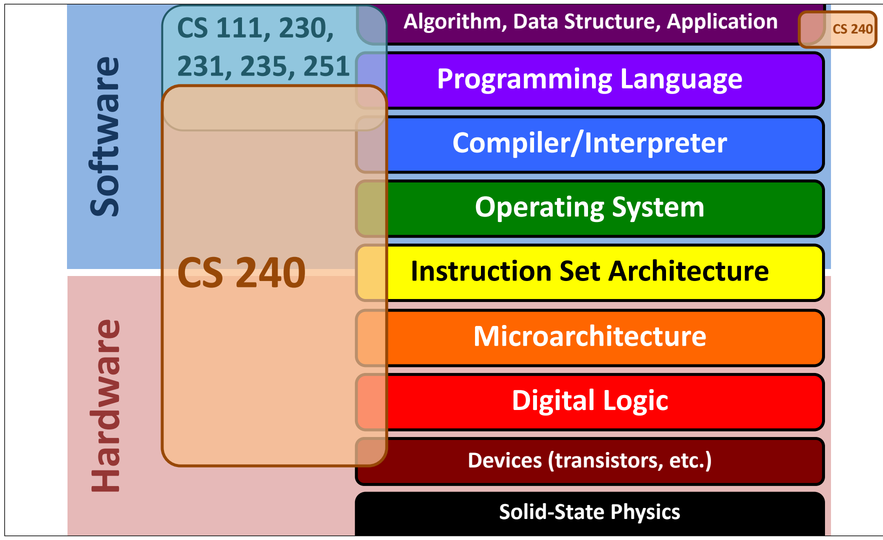
A BIG question is missing…



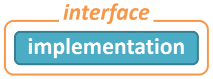
```java
class HelloWorld {
    public static void main(String[] args) {
        System.out.println("Hello, World!");
    }
}
```

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

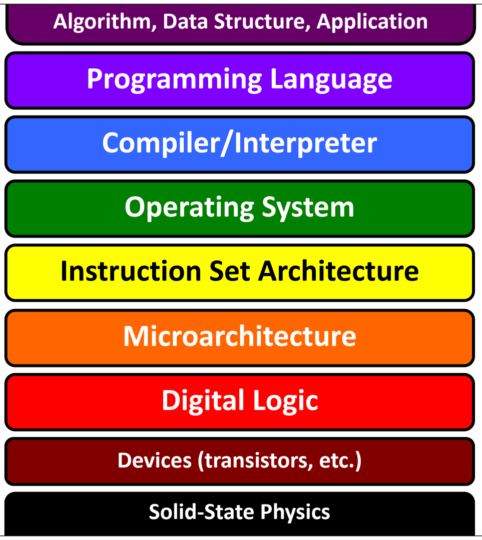
circuitboard image: CC-BY-NC-SA ifixit.com



Big Idea:
Abstraction



Layers manage complexity.



Big Idea: Abstraction

with a few recurring subplots

Simple, general interfaces:

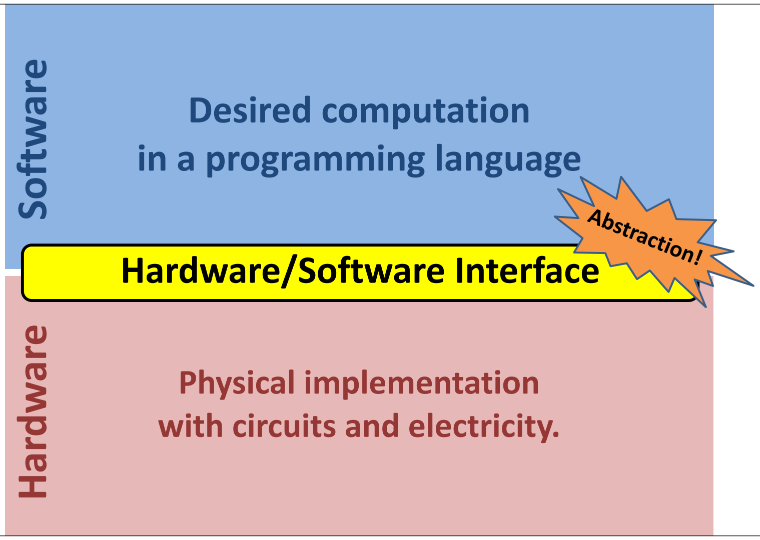
Hide complexity of efficient implementation.

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

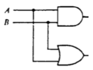
Hardware

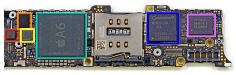
Physical implementation
with circuits and electricity.

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

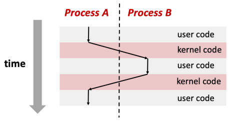
```
MOV x9, x10
ADD x12, x12, #1

*x = malloc(…);
```

3. **Abstraction for practical systems**

   Memory hierarchy

   Operating system basics

   Higher-level languages and tools



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

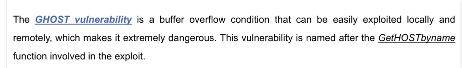
int ≠ integer
float ≠ real

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.

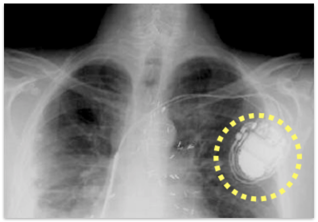
Cyber-Safe

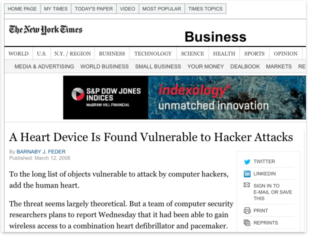
All computers are flawed -- and the fix will take years

by Selena Larson @selenalarson

January 26, 2018: 12:07 PM ET

Meltdown and Spectre





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!

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

3 Long but necessary!

The Plan

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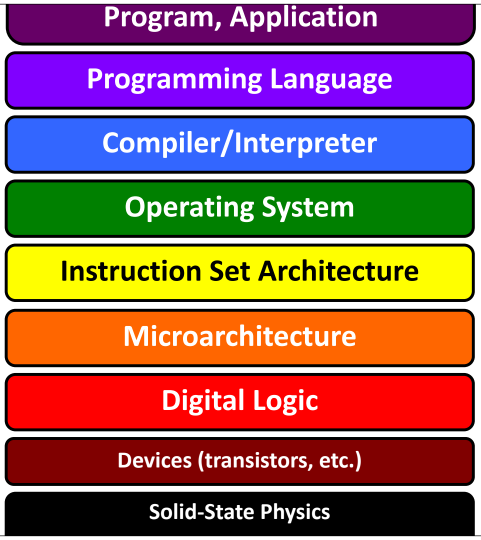


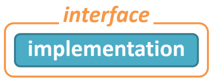
Today

1 **What is CS 240?**

2 How does CS 240 work?

3 Foundations of computer hardware

Big Idea:
Abstraction



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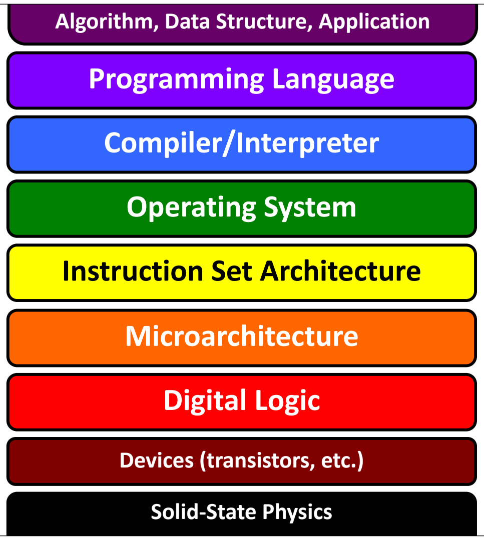

Big Idea: Abstraction

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

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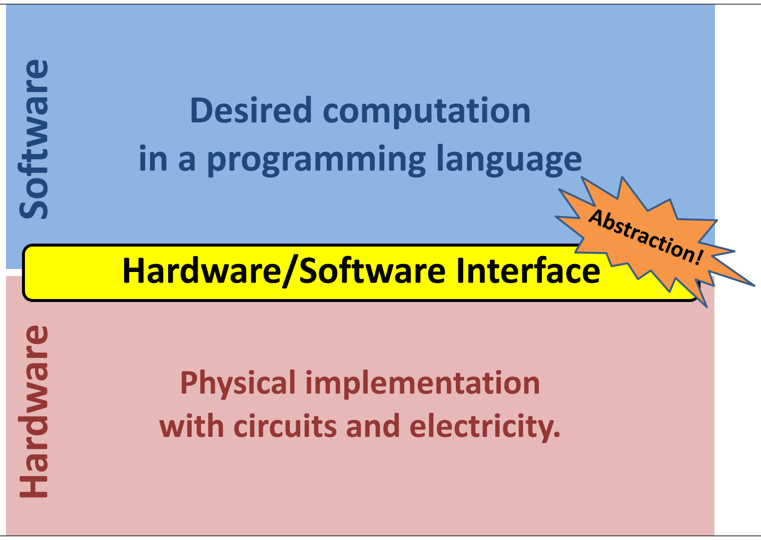
Control flow within/across programs — branches, procedures, operating system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Abstraction!
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Physical implementation
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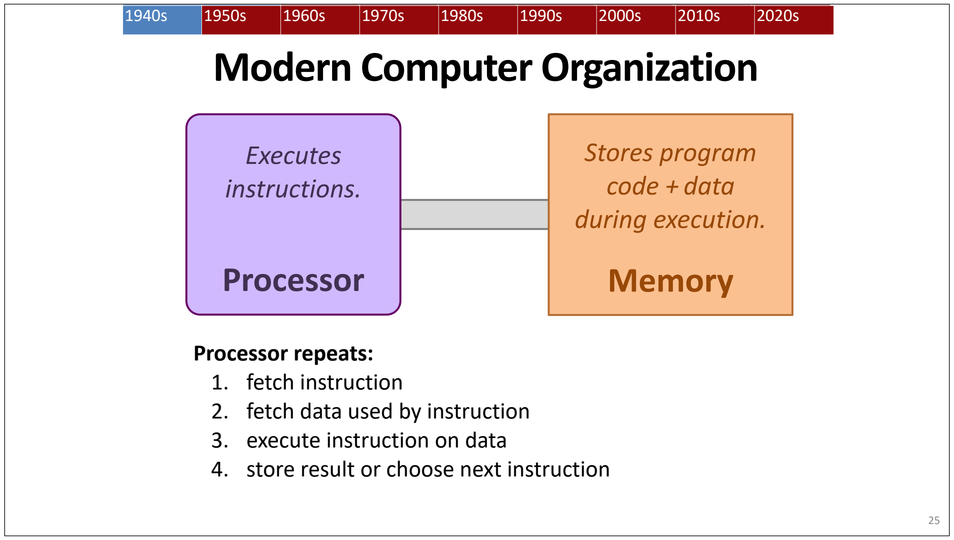


1940s 1950s 1960s 1970s 1980s 1990s 2000s 2010s 2020s

Modern Computer Organization

Executes instructions.

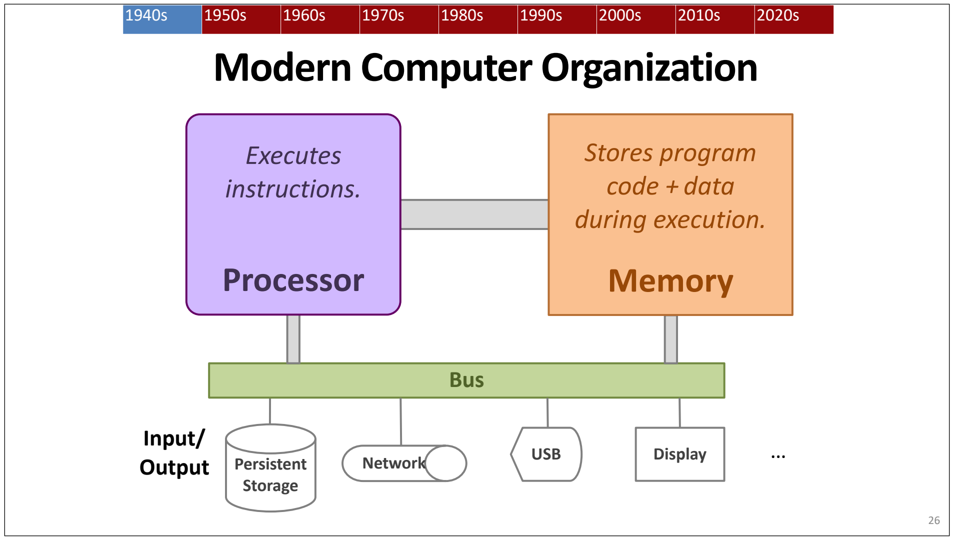
Processor

Stores program code + data during execution.

Memory

Processor repeats:

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



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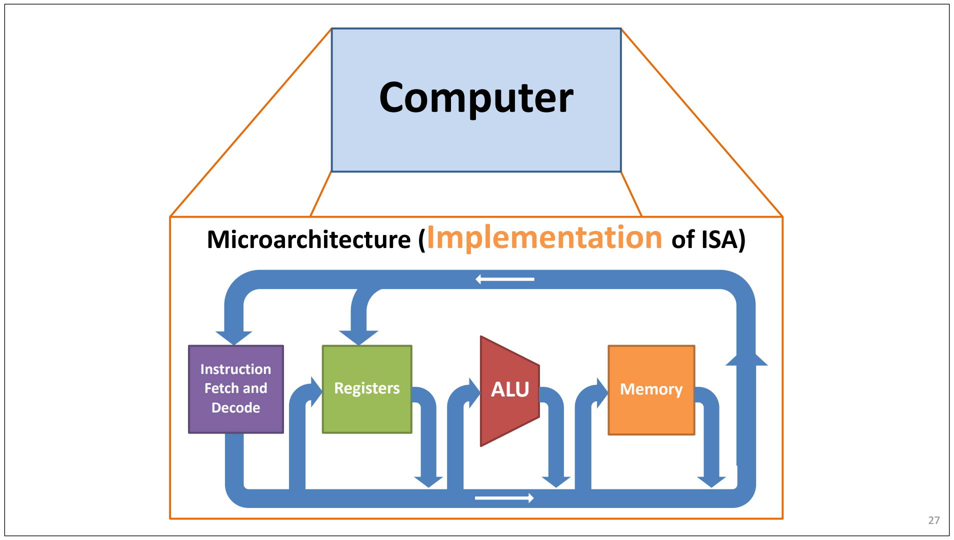
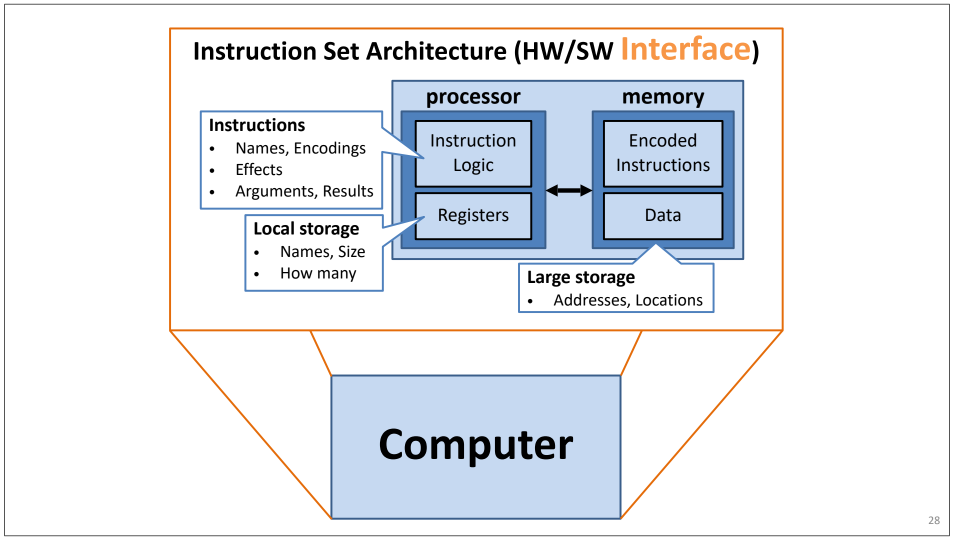


Microarchitecture (Implementation of ISA)



Instruction Set Architecture (HW/SW Interface)

Instructions
- Names, Encodings
- Effects
- Arguments, Results

Local storage
- Names, Size
- How many

Large storage
- Addresses, Locations

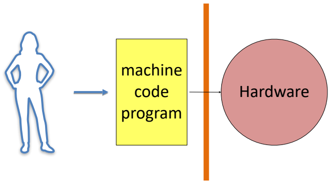
1940s **1950s** 1960s 1970s 1980s 1990s 2000s 2010s 2020s

Machine Instructions

(adds two values and stores the result)

```
00000010100010101100100000010000
```

Instruction Set Architecture specification



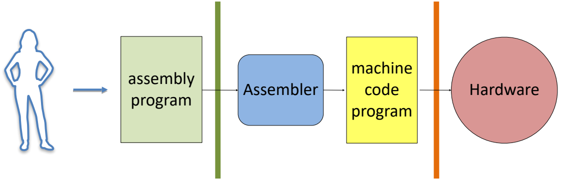
1940s **1950s** 1960s 1970s 1980s 1990s 2000s 2010s 2020s

Assemblers and Assembly Languages

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

```
00000010100010101100100000010000
```

Assembly Language specification



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

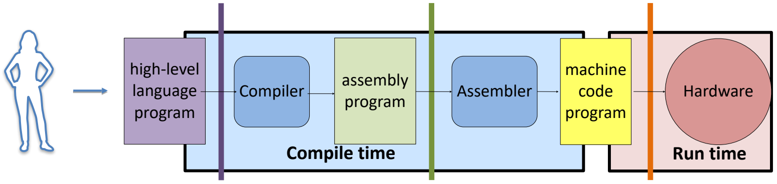
Higher-Level Programming Languages

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

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

```
00000010100010101100100000010000
```

Programming Language specification



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

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

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

More and more layers…

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

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

3 Long but necessary!