

Computer Science History

15-110 – Monday 12/02

Learning Goals

Recognize five ideas that strongly influenced the field of computer science:

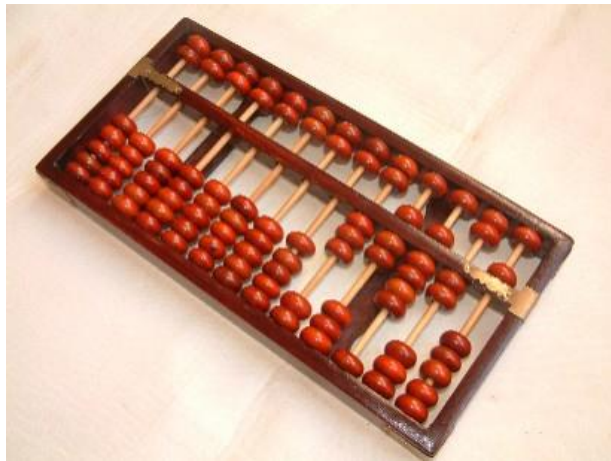
- How **binary theory** and **information theory** changed how we represent information
- How the concepts of **generalized computers** and **algorithms** were first formalized
- How the first true computers were built in terms of **hardware** and **software**
- How **personal computing** developed and was distributed into the world
- How the **internet** was developed, designed, and spread into the world

Binary Theory and Information Theory

Computer Science and Math

The foundation of the field of computer science lies in mathematics.

Many of the first 'computing devices' were built to do specific calculations on numbers.



Pictured above: an abacus, Leibniz's Calculating Machine, and Hollerith's tabulating machine

Number Bases in Math

To understand how math influenced computing, we need to go back to number systems.

Decimal number systems have been used across the world for a long time; for example, the abacus dates back to the 5th century BC.

A few cultures touched on the idea of a binary number system early on, but it was not formalized until the 17th century, by several mathematicians.

- Gottfried Leibniz, from the calculating machine shown before, was one of the people who studied it.

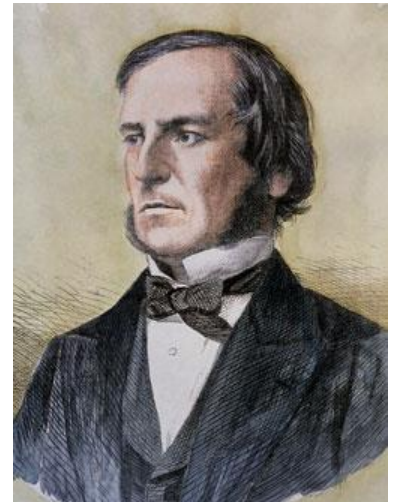
Boolean Algebra

In 1854, George Boole published "An Investigation of the Laws of Thought", which first introduced the idea of Boolean algebra and logic.

He recognized the useful properties of addition and multiplication on 0s and 1s, and introduced the 'and' and 'or' operations.

These properties later made it possible to design circuits.

Boolean values are named after him!



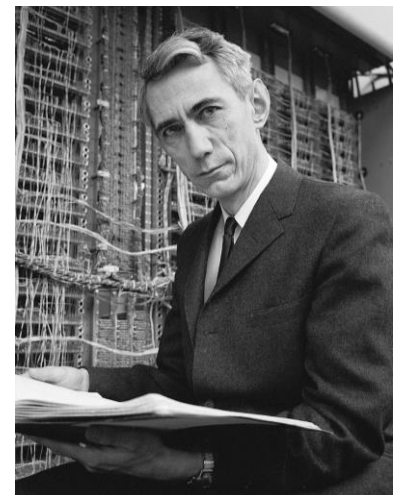
Information Theory

Much later on, in 1948, mathematics were used to directly model core ideas in the new field of computing by Claude Shannon.

He published "A Mathematical Theory of Communication", which introduced many of the core ideas of abstraction and encoding we use today.

Introduced concepts of encoding, compression, and the bit!

Considered the father of information theory.



Main Takeaways

- The concepts of binary numbers and Boolean values were introduced well before computers
- The core ideas of abstraction in computer science (bits, and encoding) were introduced by Claude Shannon, in information theory

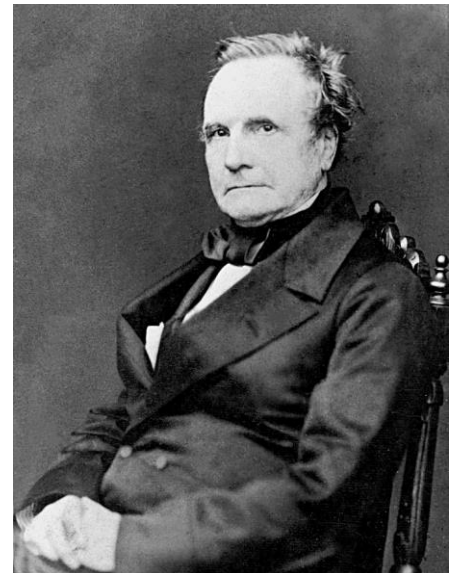
Generalized Computers and Algorithms

The Analytical Engine

In 1834-36, Charles Babbage designed the Analytical Engine.

Many philosophers built computing machines and automata for specific purposes, but the Analytical Engine was the first design for a **general** computing device.

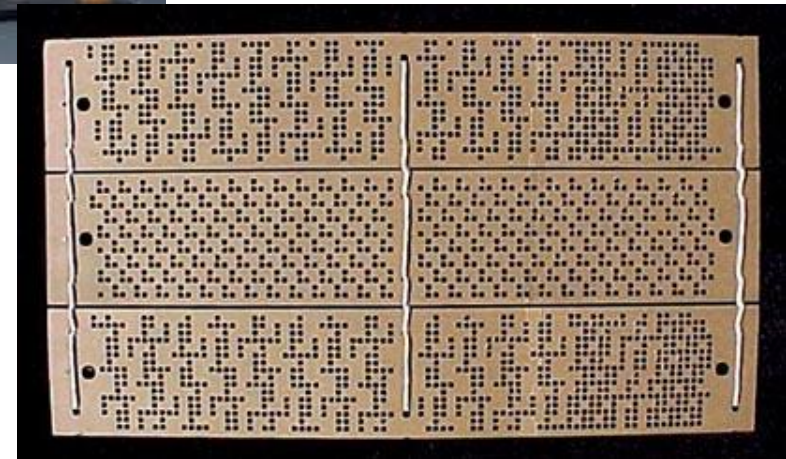
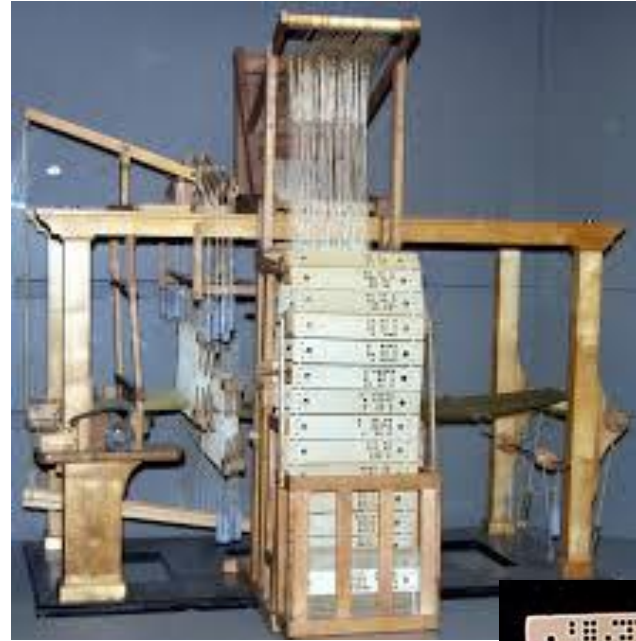
The goal: build a device capable of performing *any* mathematical operation. Babbage's design incorporated features such as sequential statements, branches, and looping- all core parts of programming today!



Punched Cards and Jacquard's Loom

The Analytical Engine could be programmed using 'punched cards', a technology that had been developed to provide instructions for weaving on a mechanical loom in 1805 by Joseph-Marie Jacquard.

These cards could provide input for different weave patterns, to easily produce complex results. Babbage envisioned using them to provide instructions for a program.



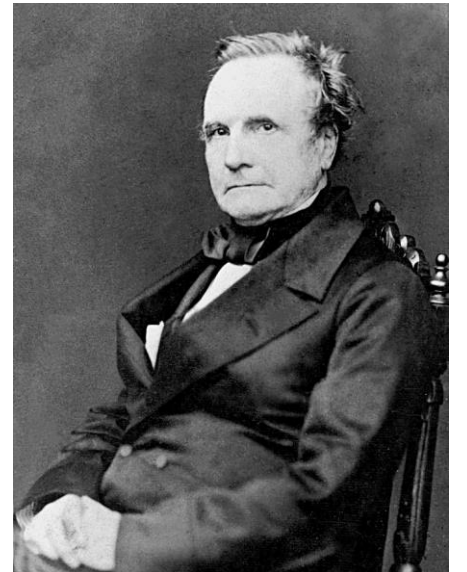
The Analytical Engine

Unfortunately, Babbage was never able to build his Analytical Engine.

He did build an earlier machine- the Difference Engine- which could compute polynomial functions automatically. Looking at this device can show what kind of technology was available at the time.

Here's a demo of a replica Difference Engine:

<https://www.youtube.com/watch?v=be1EM3gQkAY>



The First Program

In 1843, one of Babbage's correspondent's, Ada Lovelace, was hired to translate lecture notes on the Analytical Engine from French to English.

She added extensive notes to this paper with her own thoughts. One of these notes contained an example that showed how the Analytical Engine could be used to calculate Bernoulli numbers.

This was the first program to be written for a computer, so Lovelace is considered the first programmer.



Diagram for the computation by the Engine of the Numbers of Bernoulli. See Note G. (page 722 *et seq.*)

[illegible]

Computational Thinking

Ada Lovelace is also credited as being the first person to realize that computers could be used for more than just math. One of her notes read:

"[The Analytical Engine] **might act upon other things besides number**, were objects found whose mutual fundamental relations could be expressed by those of the abstract science of operations, and which should be also susceptible of adaptations to the action of the operating notation and mechanism of the engine...

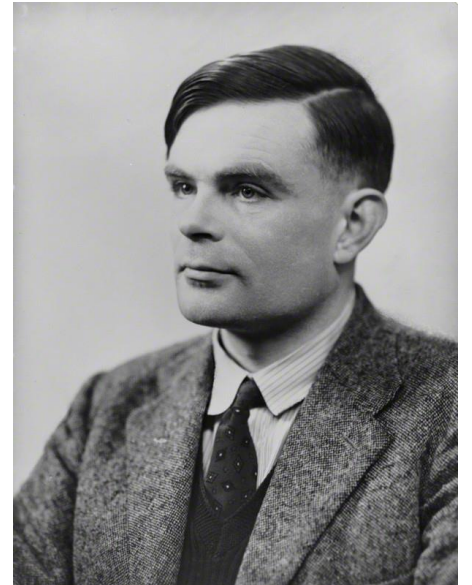
Supposing, for instance, that the fundamental relations of **pitched sounds in the science of harmony and of musical composition** were susceptible of such expression and adaptations, **the engine might compose elaborate and scientific pieces of music** of any degree of complexity or extent."



A General Model of Computers

Fast forward to 1936. In the same period of time, two people- Alonzo Church and Alan Turing – developed a general model to describe what we now call computers. This is now referred to as the Church-Turing Thesis. We'll focus on Turing's model for now.

Turing invented the concept of a 'Turing Machine', which has certain specific properties. It is widely acknowledged today that all general computers can be reduced down to the idea of a Turing Machine.

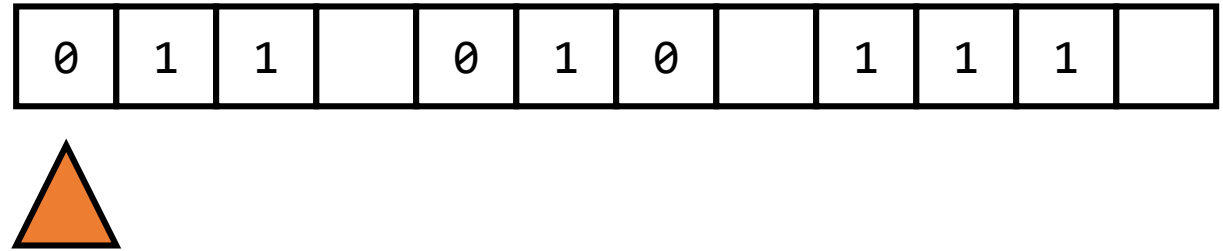


Turing Machines

A Turing machine can be thought of as a long piece of tape combined with a device.

The tape is divided into cells. Each cell can be blank, or can have a symbol written in it.

The device can move to any cell on the tape. It can read the current symbol in the cell, erase the current value, or write a new value.

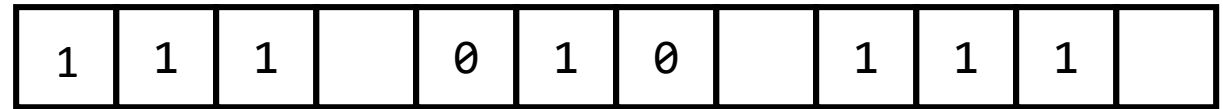


Turing Machines

The **state** of a Turing Machine is the current position of the device, combined with the current value in the cell it points to.

The machine can make decisions about what to do next based on the state.

This perfectly models our computers today!



State [0]:

 If 0:

 Set to 1

 Move to State [4]

 If 1:

 Move to State [1]

 If blank:

 End process

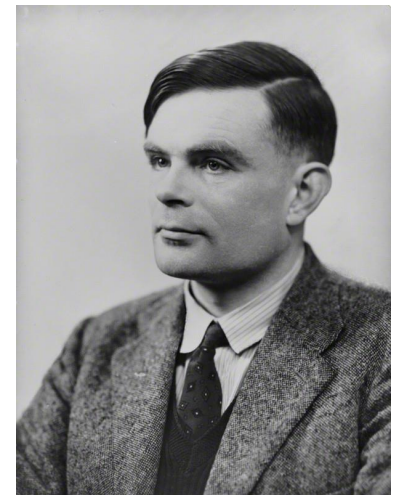
Limits of Computation

In the same paper, Alan Turing proved that there are some algorithms a Turing Machine (computer) can never do.



Earlier (in 1930), Kurt Gödel proved the Incompleteness Theorem, which showed that every formal system will have some expressions it cannot represent.

Turing demonstrated this in computing with the Halting problem. This used a proof by contradiction to show that it's impossible to write a program that determines whether another program will ever halt (stop).



Main Takeaways

- The first design for a general computing device was the Analytical Engine, and was invented by Charles Babbage in the 19th century.
- The first program was written shortly afterwards by Ada Lovelace, and aimed to calculate Bernoulli numbers on the Analytical Engine.
- The most general definition of a computer was defined by Alan Turing, using the concept of a Turing Machine.

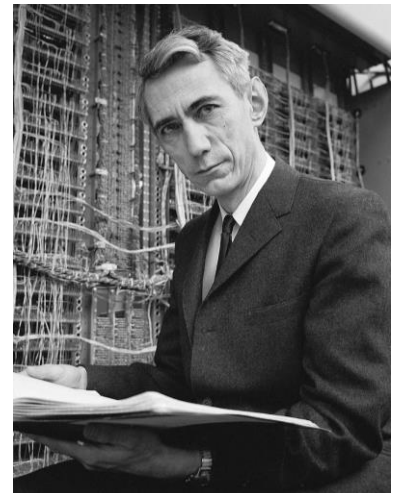
Original Hardware and Software

From Booleans to Circuits

In 1937, Claude Shannon published his Master's Thesis, "A Symbolic Analysis of Relay and Switching Circuits". This was the first time Boolean logic was translated into physical format with electronics.

This work became the foundation of circuit design, and made it possible to design the computers we know today.

He also invented the full adder as an example in his paper!



Computing Devices in World War II

Shortly after this electronic breakthrough, World War II began. This meant that computing was used to try to gain an advantage in wartime efforts.

Computing played the most powerful role in code-breaking, as Allied forces attempted to decipher German messages.

We'll take a brief dive into work done in Great Britain, at Bletchley Park, which led to the first programmable computer.

The Enigma Machine

The German forces used a device called the Enigma Machine to encrypt communications. This encryption was done using a type of substitution cipher with a **shared key**. German officers were given key lists ahead of time, and would set a new key every day.

The Allied forces were able to re-construct the physical device. However, they had to check all possible keys by hand every day, which took too long to be useful.



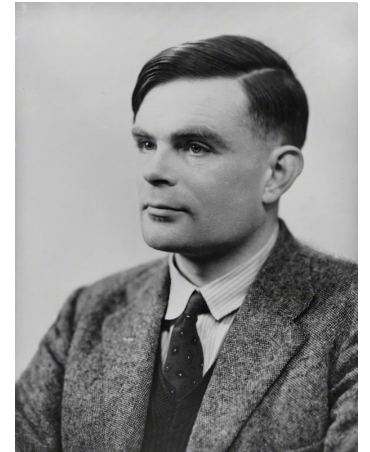
This lasted until someone noticed a pattern in German messages – they always sent a weather report at 6am each day. The common words in this report made it easier to check possible keys **computationally**.

The Bombe

The original deciphering machine, the Bomba, was designed by Marian Rejewski in 1938. Due to improvements in the Enigma and a lack of funds, the idea was passed to Britain.



In 1939, Alan Turing worked with a team to develop the Bombe, which checked all possible settings to see if they could find one that matched the expected words.



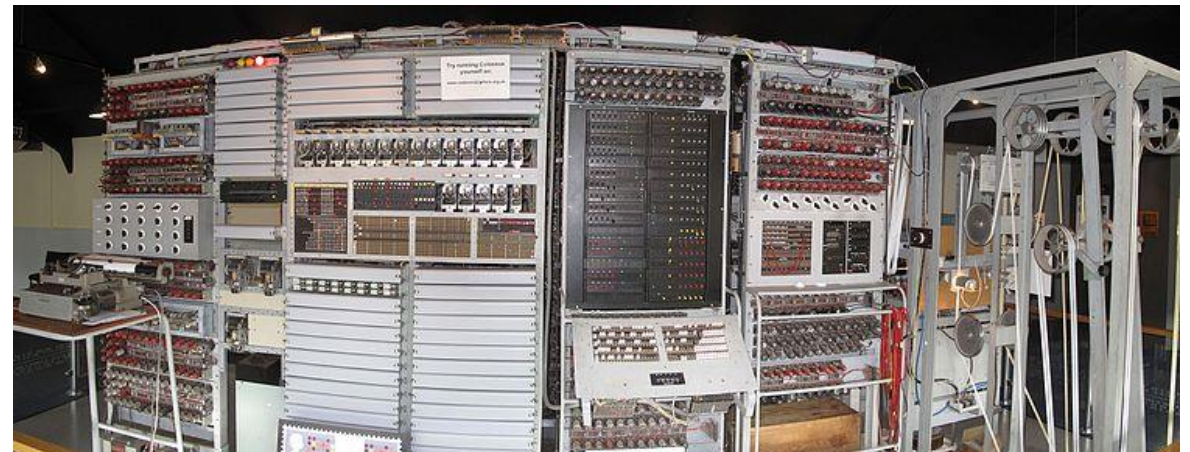
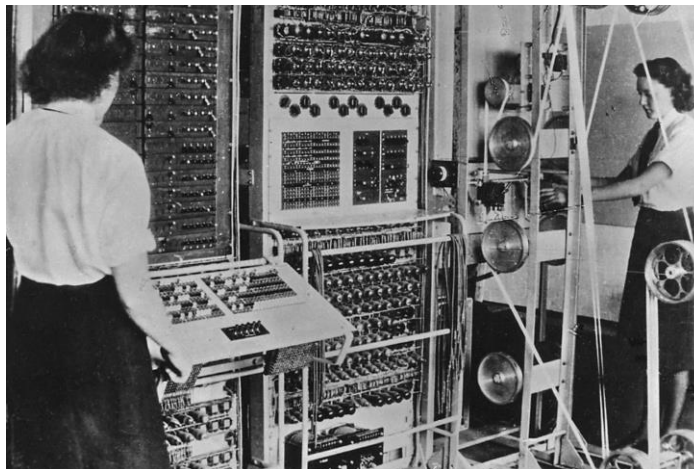
This process was dramatized in the movie The Imitation Game.

<https://www.youtube.com/watch?v=zZuqLLdx2YQ&feature=youtu.be&t=15>

The Colossus

Later in the war, German forces started using a new encryption system for high-security messages. The Lorenz cipher proved much harder to crack, as the Allied forces had no information about the machine used to produce them.

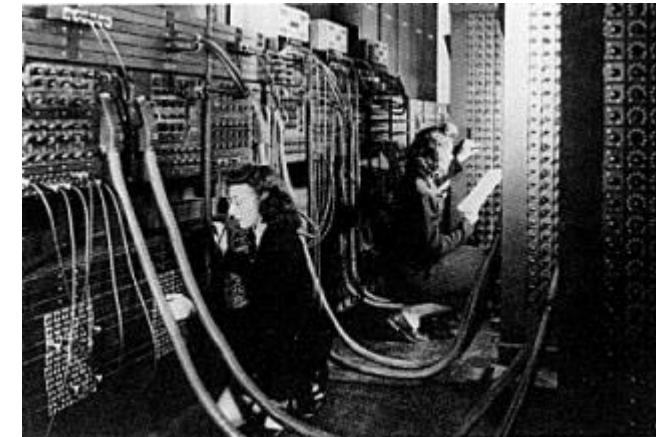
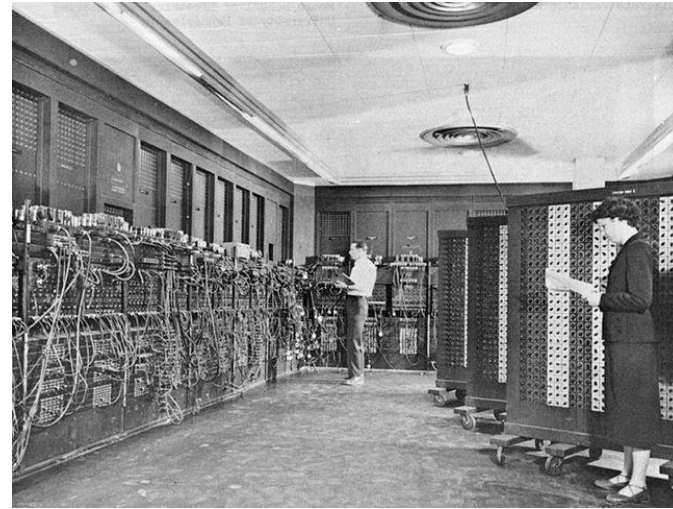
From 1943-1945, Tommy Flowers led a team to design the Colossus, which was used to break Lorenz ciphers. This is widely considered to be the first electronic **programmable** computer. However, it could only be programmed for cipher-breaking, not general tasks.



The First Modern Computer

In 1945, after the war ended, companies and research groups started work on designing computers for corporate and military use.

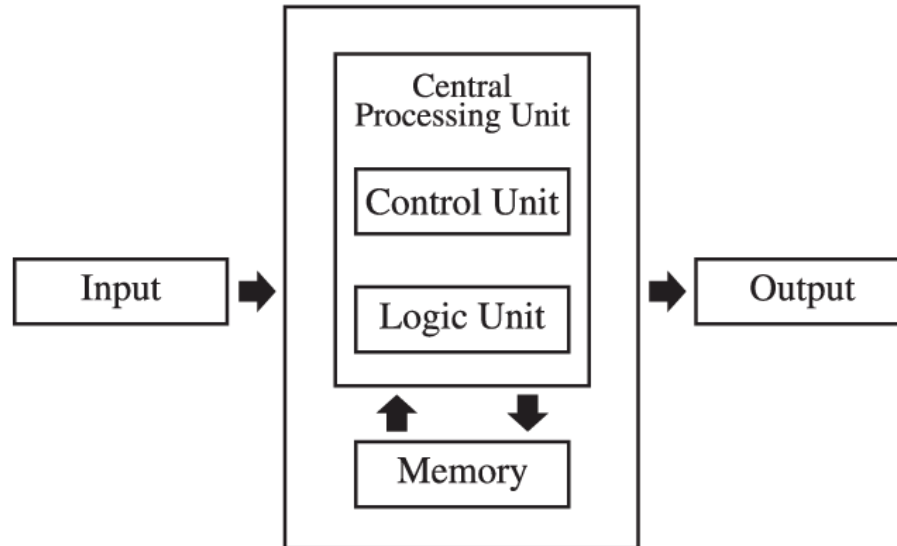
John Mauchly and J. Presper Eckert designed the ENIAC (Electronic Numerical Integrator and Computer), the first electronic general-purpose computer. This machine was programmable and had input and output in the form of punch cards. It influenced many machines that came after it.



Software Architecture

At the same time, still in 1945, the software architecture of computers that we use today was designed.

John von Neumann introduced the von Neumann architecture, which organized the CPU, memory, and input/output. This also introduced the idea of representing machine code by running instructions sequentially until a conditional jump is reached.



Programming Languages

Up until this point, machines ran on punch-card or typed code that was machine-specific and not very readable.

In 1952, Grace Hopper invented a compiler, which could take statements written in strictly formatted English and translate them into computer-readable code.

She also was part of a team that designed COBOL, one of the first plain-language programming languages.



Main Takeaways

- WWII led to the design and implementation of programmable computers
- The ENIAC was the first general programmable computer
- The von Neumann architecture was a breakthrough software architecture that we still use today
- The compiler led to programs becoming easier to write

Personal Computing

Corporate to Personal

Originally, computers were only used for corporate or government purposes. Individuals did not own computers, because they were far too large and difficult to interact with.

This changed due to two events: invention of technology that made computers smaller, and invention of interaction modalities that made computers easier to work with.

The Transistor

In 1947, John Bardeen, William Shockley and Walter Brattain at AT&T Bell Labs designed the transistor. This device could be used to switch electric signals.

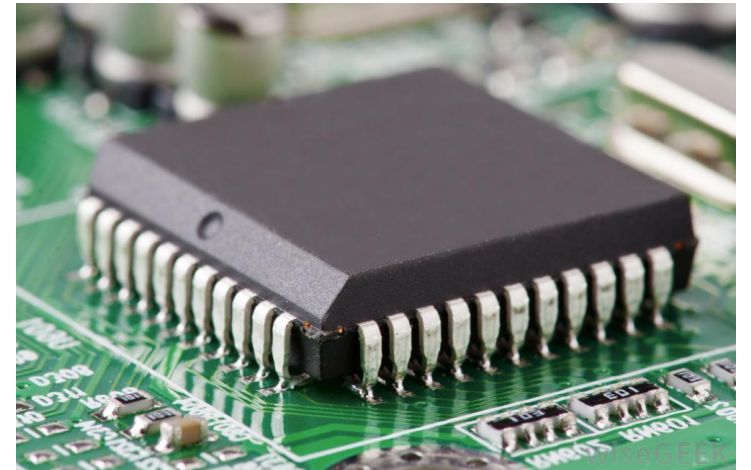
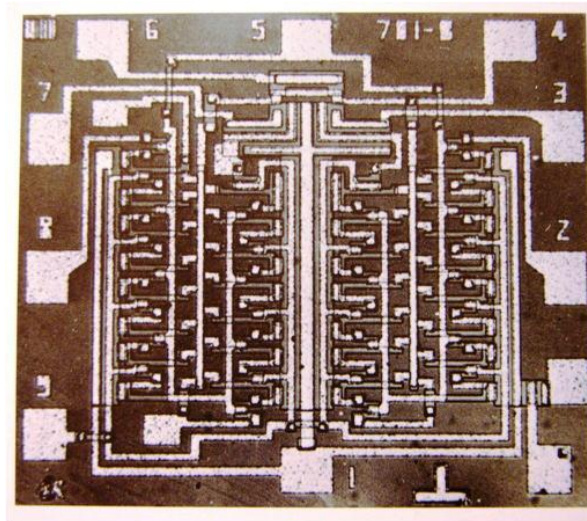
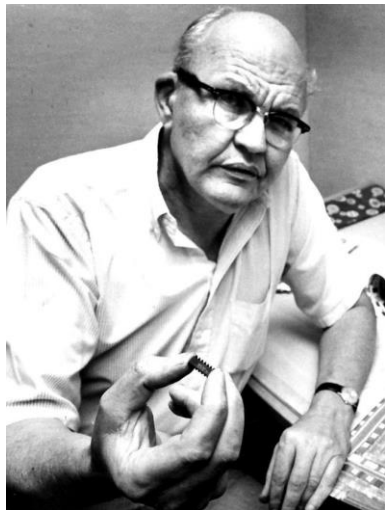
Previously, computers had to use vacuum tubes, which were very large. The invention of the transistor made it possible to make computers smaller.



The Integrated Circuit

In 1958, Jack Kilby invented the Integrated Circuit (IC). This is a small electronic device (or 'chip') that can contain a large number of circuits and is easy to produce. It was possible to make this because of the invention of the transistor.

The IC again made it possible to make computers much smaller, as more electronics could be fit onto a smaller surface.

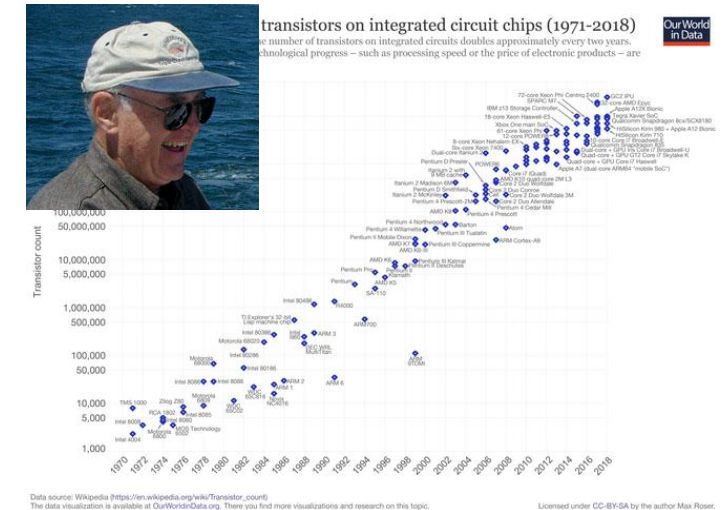


Moore's Law and The Microprocessor

In 1965, Gordon Moore introduced the business model known as Moore's Law, which states that the number of transistors on an IC will double every two years.

By 1971, this led to the invention of the microprocessor at Intel. A microprocessor is a whole processor that can fit onto a single chip.

This breakthrough made it possible to put chips in many new devices, like calculators and clocks!

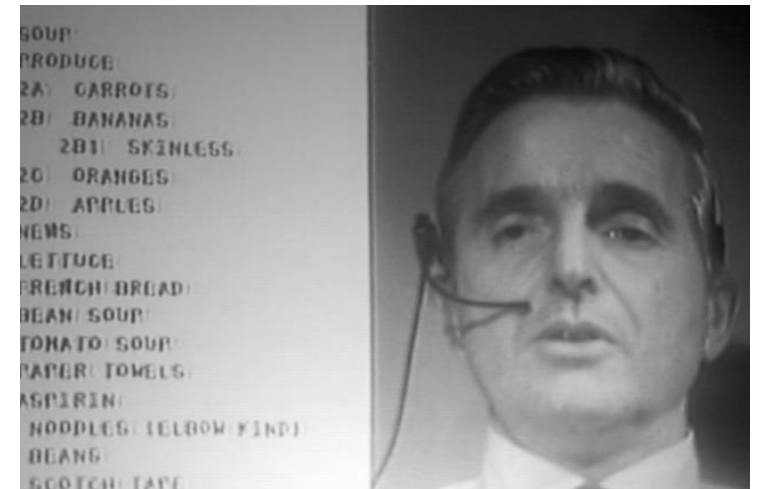


The Mother of All Demos

In 1968, Douglas Engelbart presented work he had done at the Augmentation Research Center at Stanford to a group of engineers at a computer conference. This 1.5 hour long presentation later became known as the Mother of All Demos, because it introduced an astounding number of technologies that we use to this day.

You can watch the demo for yourself online:

<https://www.youtube.com/watch?v=yJDv-zdhzMY>



Engelbart's Inventions

The technologies Engelbart introduced in this live demo include:

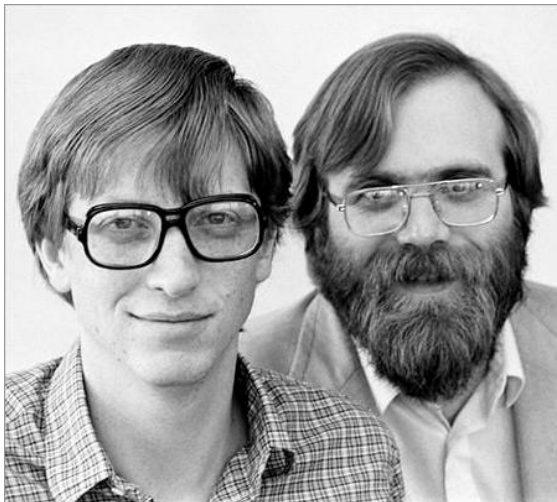
- The computer mouse
- The GUI (Graphical User Interface)
- The WYSIWIG (What You See Is What You Get) text editor
- The concept of multiple windows
- Revision control
- Video conferencing
- Real-time collaborative editing



Computing Companies

In 1975, Bill Gates and Paul Allen founded Microsoft. The company originally provided software (an interpreter for the language BASIC) to IBM.

Microsoft wanted to get into the personal computing business after seeing Apple's success.



In 1976, Steve Jobs and Steve Wozniak founded Apple. The company originally built and programmed the Apple I, one of the first personal computing devices.

The Apple I was originally entirely text-based in its interaction modality.



The First Killer App

In 1979, the application VisiCalc was produced by VisiCorp. This was a basic spreadsheet application that let the user modify values in a table and automatically re-calculate the results.

This was a huge development for business, as re-calculating tables by hand took teams of accountants long periods of time. The application became widely popular.

The launch of VisiCalc led to a boom in the personal computing business, and further competition.

B5 (U) +B3-B4
Command: BCDEFGIMPRSTUW-

	A	B	C	D	E
1	Year	1979	1980	1981	1982
2					
3	Sales	54321	59753	65728	72301
4	Cost	43457	47802	52583	57841
5	Profit	10864	11951	13146	14460
6					
7					
8					
9					
10					
11					
12					

Launch of the GUI

After the Mother of All Demos in 1968, several people on Engelbart's team went to work at Xerox PARC, to further develop the concepts. But Xerox didn't know what to do with their work.

In 1979, Apple employees visited PARC, and stole the idea for the GUI. They then implemented it in the Apple Macintosh (released in 1984) to great acclaim.

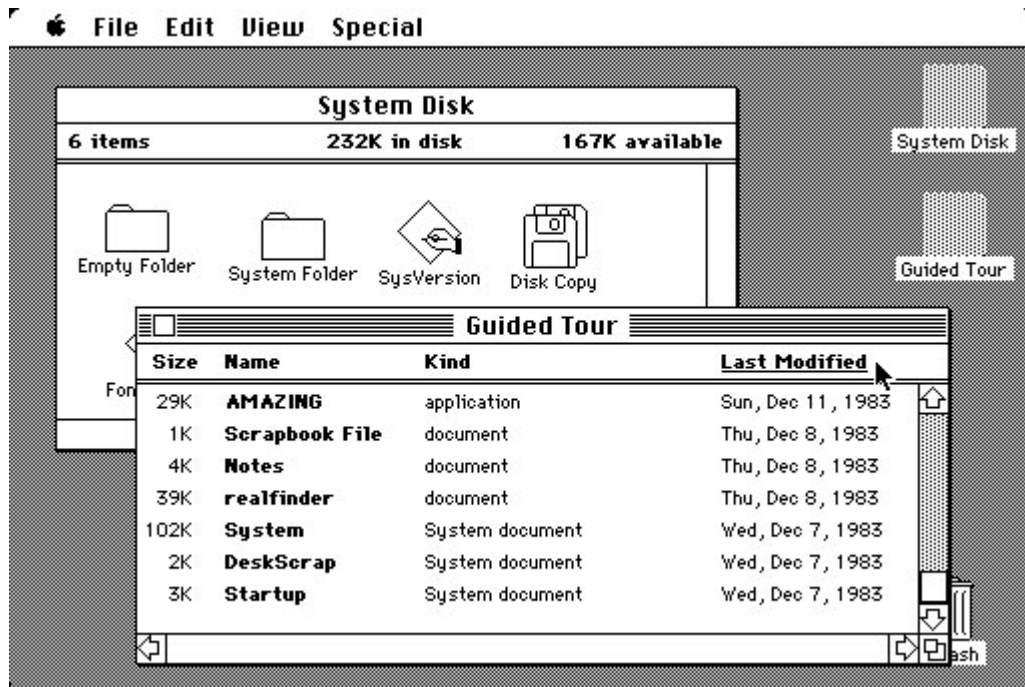
In 1981, Microsoft visited Apple and helped them develop some apps. They stole the GUI idea from them and used it in their first operating system, MS-DOS, released in 1985.

This was dramatized in the 1999 film "Pirates of Silicon Valley":

<https://www.youtube.com/watch?v=CBri-xgYvHQ>

Apple vs. Microsoft GUIs

The rise of the GUI and competition between these two companies led to the personal computing revolution we see today.



Main Takeaways

- The invention of the transistor, the integrated circuit, and the microprocessor made it possible to make computers smaller and cheaper
- Many of the core ideas used in personal computing came from the Mother of All Demos, and were later adopted by major computing companies

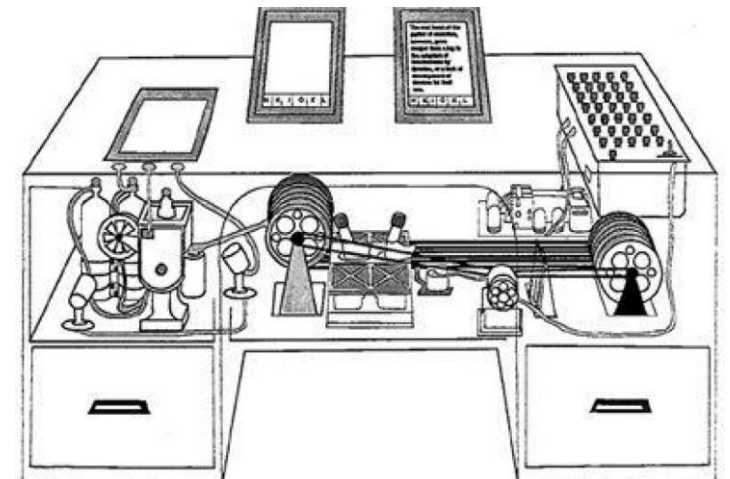
The Internet

Ideating the Internet – the Memex

Some of the core concepts of how the internet would work came about well before it was implemented.

In 1945, Vannevar Bush published [As We May Think](#), which envisioned a system (Memex) to aid in research work. He invented the concept of hypertext!

"Consider a future device... in which an individual stores all his books, records, and communications, and which is mechanized so that it may be consulted with exceeding speed and flexibility. It is an enlarged intimate supplement to his memory."



ARPANET

In 1969, the US military wanted to create a decentralized communication system, so that communications could not be knocked out entirely by a nuclear attack.

DARPA (Defense Advanced Research Projects Agency) collaborated with several universities to build the ARPANET, the Advanced Research Projects Agency Network. The initial network only connected four universities, but it grew over time.

This system first introduced the concept of packets.



Communication Protocols

In 1982, Vinton Cerf and Robert Kahn designed and advocated for the TCP/IP protocol. TCP organizes data that is being sent between computers; IP delivers that data to the correct destination (based on IP addresses!).



The invention of TCP/IP made it much easier to connect computers together, which helped ARPANET expand its reach. Because of this, Vint Cerf and Bob Kahn are known as the fathers of the internet.

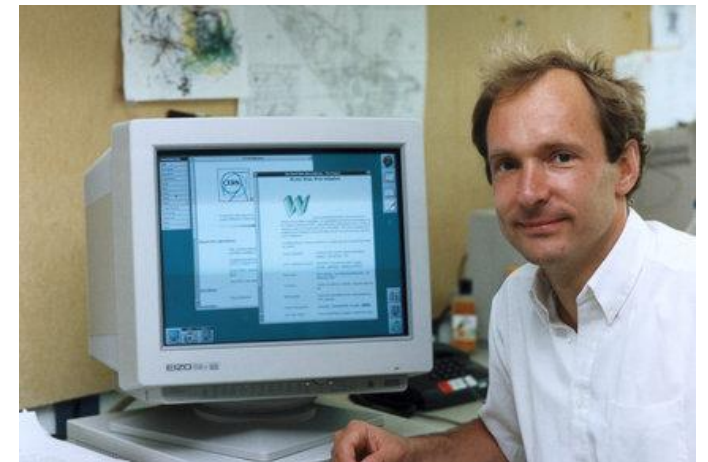


By 1984, the US military broke off from ARPANET to form their own private network (MILNET). More organizations and companies started to join the public network, forming the internet as we know it.

The World Wide Web

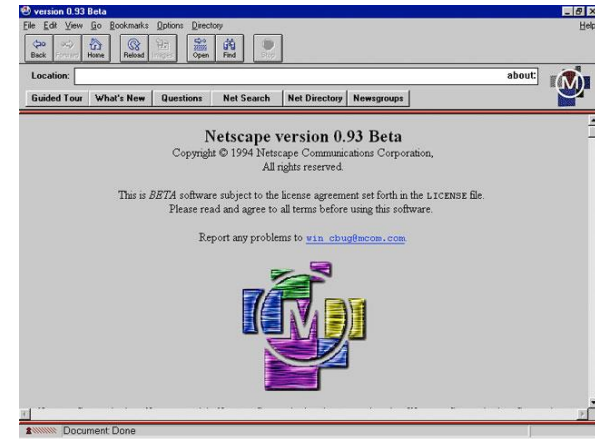
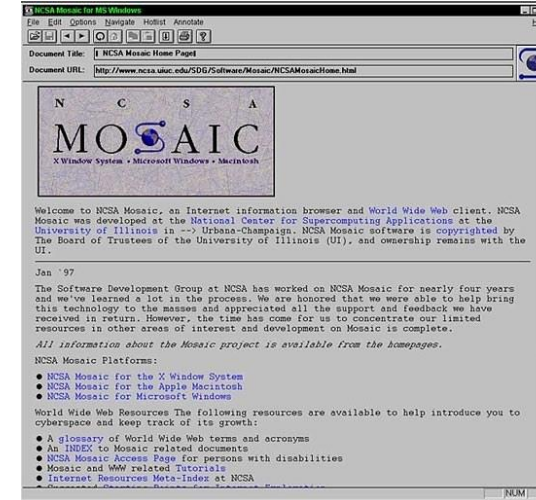
In 1989, Tim Berners-Lee invented two new languages – HTML and URL – that would revolutionize how people communicated with the internet. He wanted people to be able to share information more easily with each other.

This led to the beginning of websites as we know them. For this contribution, Tim Berners-Lee is known as the father of the World-Wide Web.



1990s: Web Browsers and Search Engines

With HTML came web browsers that could parse the HTML into structured text, to make it easier to read. Mosaic and Netscape Navigator were two of the first browsers.



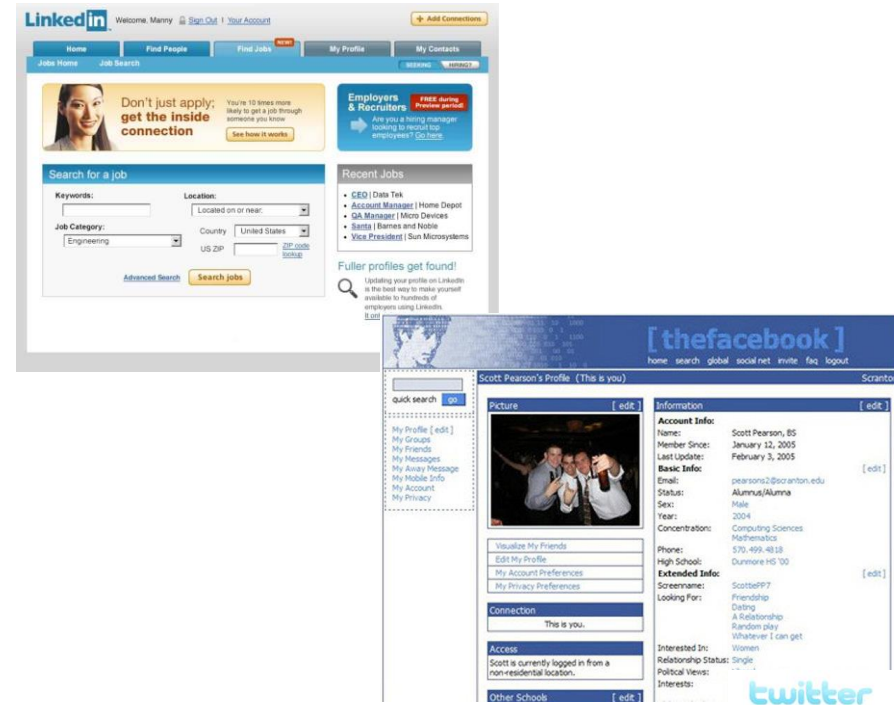
Search engines also started popping up in the 1990s. Google wasn't founded until 1998, and Wikipedia wasn't created until 2001!



2000s: Social Media and Cloud Computing

As more and more people got on the internet, social media networks started to pop up. Some started in the late 90s; of the current big networks, LinkedIn started in 2003, Facebook in 2004, and Twitter in 2006.

Cloud Computing also started in the 2000s. Amazon's Elastic Compute Cloud started in 2006; Microsoft Azure started in 2008.



A global community of friends and strangers answering one simple question: **What are you doing?**

What are you doing?

Thinking about sending my little sister some...

Once you join, the first thing you'll want to do is type your first ever Twitter update.

No pressure, just put something simple.

1 2 3

Update

Recent Public Updates

-  **Jacob Agh**, jet-lag. I might have to go and have a little lie-down. 1 minute ago from [im](#)
-  **Candice Siobhan** arguing with Frank 1 minutes ago from [web](#)
-  **Candice Siobhan** inviting friend to twitter, who invited me 5 minutes ago from [web](#)

Please Sign In!

Email or Mobile Number

Password

☐ Remember me

Sign In!

Want an account?

Join for Free!

It's fast and easy!

2010s: Smartphones and Tablets

The growth of the internet and the desire to remain connected led to portable computing devices.

Smartphones first appeared in 2007 with the release of the iPhone, and gained widespread popularity in the 2010s. Tablets also became popular in this timeframe.

Who knows what revelations the next decade will bring?



Main Takeaways

- The internet started out as a government project (ARPANET); when the government left it, it became more public
- The invention of TCP/IP and HTML made the internet more widely accessible.
- The internet as we know it has changed drastically over the past few decades, and will probably continue to change!

References

- Tom Cortina's class on Computing History:
cs.cmu.edu/~15292/index.html
- And many other helpful webpages:
- explainthatstuff.com/historyofcomputers.html
- [worldsciencefestival.com/infographics/a history of computer science/](http://worldsciencefestival.com/infographics/a_history_of_computer_science/)
- cs.uwaterloo.ca/~shallit/Courses/134/history.html
- [wikipedia.org/wiki/History of computer science](http://wikipedia.org/wiki/History_of_computer_science)