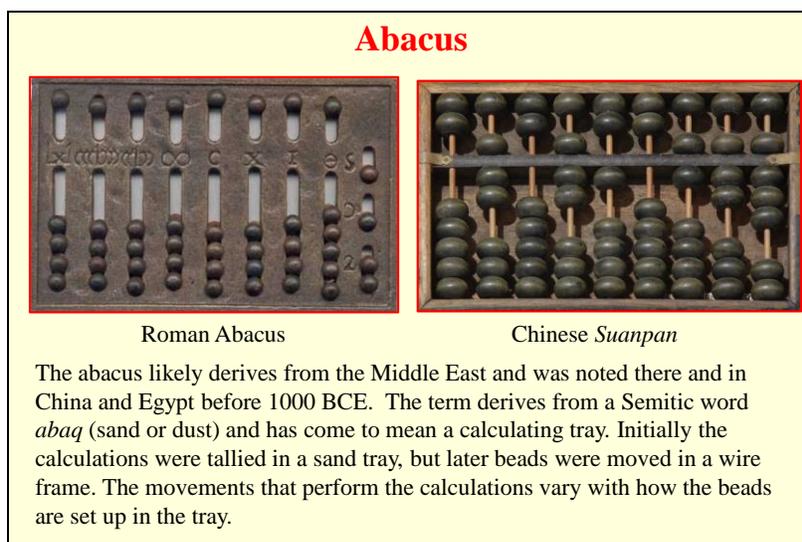


The illustration is a painting by Paul Klee in the Guggenheim Museum. It probably reflects Klee's impressions of the Nile River that he visited in 1928. It also suggests progression: in general the spaces get wider toward the right. The progression is geometric – 1, 2, 4. There are many partial symmetries between the sections of the painting – such as the green-purple spaces which shift back and forth between left and right.

Western scientific has perhaps gone through six changes. After the Renaissance and the Scientific Revolution there have been four industrial revolutions according to Klaus Schwab the chairman of the World Economic Forum:

- Steam engine circa 1800
- Electric Power and Combustion Engine circa 1900
- Digital Revolution circa 1980
- Cyber-physical interactions circa 2000



The abacus was the tool of accountants and merchants.

The Roman abacus used 1 marker above the divider and 4 below. This setup fits with the Roman numerals (a “biquinary decimal” system) which change in steps of 1 (below the divider), 5 (above the divider) and 10 (next column): I V X L C D M. The slots in the abacus put the Is below and the V above. In the Roman abacus the two right slots were related to measurements of weight.

The Chinese abacus uses two counters above and five below the divider. The beads above the divider represent 5s and the beads below represent 1s. The number represented on the Chinese abacus is 70710678.



This Ukiyo-e print of *A Merchant Making up the Account* is by Hokusai (1838).

This abacus in the print uses 5 beads and 1 bead. The modern Japanese abacus – the soraban – uses 4 beads and 1 bead

Born into the Scottish nobility at Merchiston Castle (in present day Edinburgh), Napier was privately tutored. He published his work on the calculation and use of logarithms in 1614. The English mathematician Henry Briggs visited Napier and then in 1617 published tables of logarithms to the base 10. In 1622, William Oughtred, an English clergyman, showed how logarithmic calculations could be made using a “slide rule.” In 1617, Napier also proposed another way to simplify calculations using a set of “Napier’s bones.”

John Napier (1550-1617)



Portrait dated 1616 is by an unknown artist.

Napier calculated his logarithms by comparing two scales – in one the distance increased regularly and in the other the distance increased geometrically (according to a power). It was only later that the full concept of logarithms was worked out. The easiest way to calculate the logarithms is to use the value “e” as a base which is then raised to a power (the natural logarithm) to get the number - e is Euler’s constant (sometimes called Napier’s constant). The natural logarithm (written \ln or \log_e) of a number is the area under the curve between 1 and the number for the function $1/x$:

$$\ln(a) = \int_1^a \frac{1}{x} dx$$

Logarithmic Calculations

The logarithm (a) of a number (x) to a particular base (b) is the power (or exponent) to which that base must be raised to give the number:

$$a = \log_b(x) \quad \text{means that} \quad b^a = x$$

Logarithmic tables can be helpful in performing multiplication and division. If we wish to multiply m by n, we can consider them as exponents of a base:

$$\text{where } m = \log_b(x) \text{ and } n = \log_b(y)$$

$$x \cdot y = b^m \cdot b^n = b^{m+n}$$

$$\log_b(xy) = \log_b(x) + \log_b(y)$$

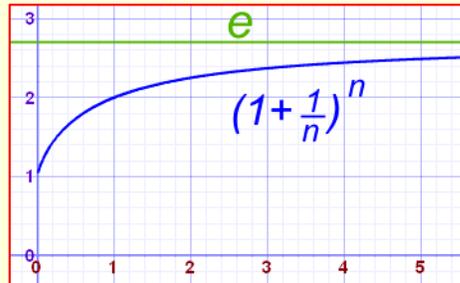
Then we just add the logarithms and look up the result in the tables.

Adding up numbers is far quicker than performing all the tedious steps involved in multiplication.

Division can be performed by subtracting the logarithms.

$$e = 2.71828$$

Napier understood the idea of e as the base of the natural logarithms but he never presented it in his writings. It was calculated by Jacob Bernoulli (1655-1705) in 1683, and its name comes from Leonhard Euler (1707-1783). It is the limit of the function $(1 + 1/n)^n$ as n approaches ∞



for $n = 2$, $e = 2.250$

for $n = 10$ $e = 2.594$

for $n = 1000$ $e = 2.717$

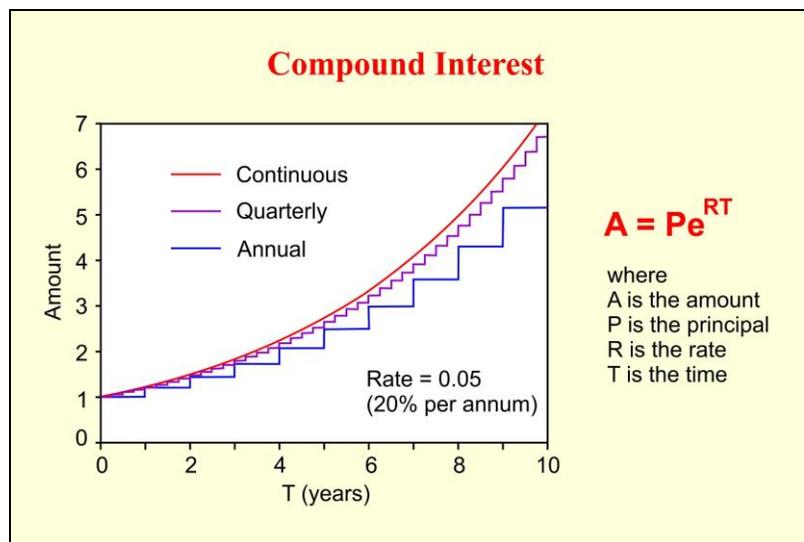
Jacob Bernoulli was concerned with the rate of interest paid and charged by banks. Mathematicians and accountants have the same concerns.

In 1669 Newton had suggested that e was the sum of the infinite series

$$1/1! + 1/2! + 1/3! \dots$$

where $!$ indicates the “factorial” – $n!$ is the product of all numbers up to and including n . Thus $4!$ equals $1 \times 2 \times 3 \times 4$ or 24.

This infinite series equality was finally proven by Euler.



The actual return on an investment depends on the annual rate of interest and on the rate at which the interest is compounded. Generally interest rates are stated as a per annum rate with compounding done annually.

The exponential formula for continuous compound interest is also applicable in other fields, such as to express the growth of a population.

**Leonhard Euler
(1707-1783)**

Born and educated in Basel, Euler worked in St Petersburg and then in Berlin. He contributed immensely to all areas of mathematics. He linked the constant e to trigonometry with the equations:

$$e^{i\phi} = \cos\phi + i\sin\phi$$

$$e^{i\pi} + 1 = 0 \text{ (Euler's identity)}$$

The latter is considered the most beautiful of all equations since it links the transcendental constants e and π with the imaginary unit i and the numbers 1 and 0



Portrait by Emmanuel Handmann,
1753

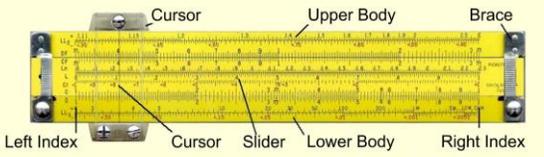
In later life Euler became blind in his right eye. He also has one of the most wonderful thinking hats. Most surveys conclude that his is the best hat in any portrait.

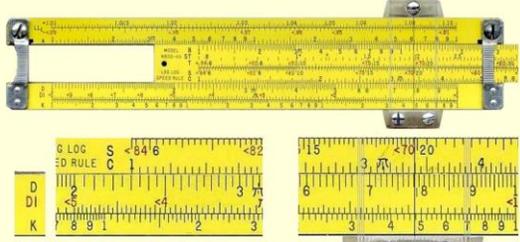
Wilson, R. J. (2018). *Euler's pioneering equation: The most beautiful theorem in mathematics*. Oxford: Oxford University Press.

But we should return to Napier's logarithms and the slide rule that William Oughtred invented:

Slide Rule

Multiplying
2.3 by 3.4





Set Left Index of Slider at 2.3 on the lower body

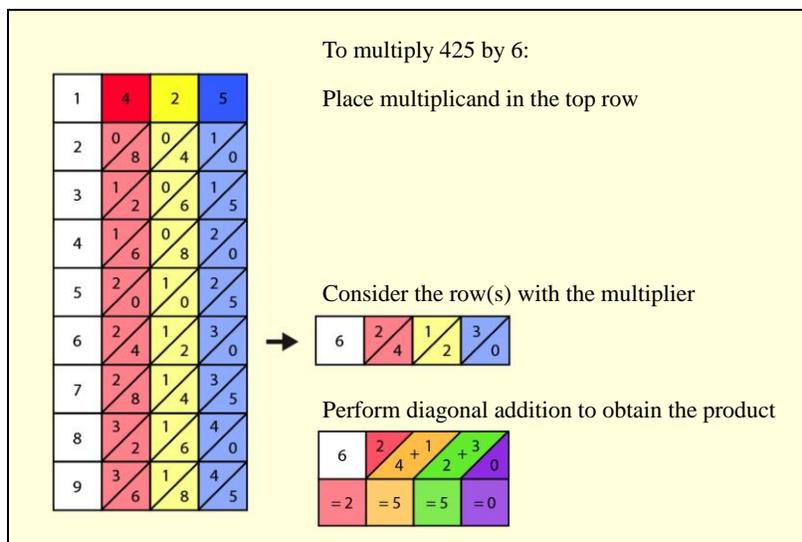
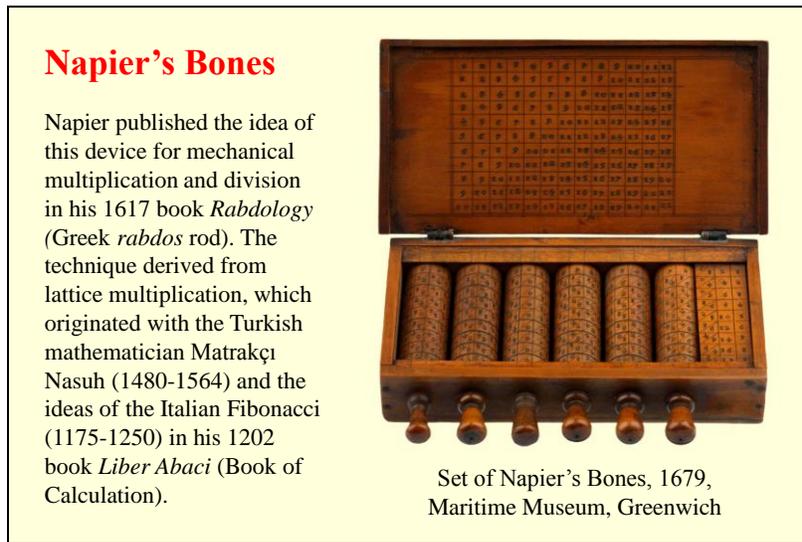
Move cursor to 3.4 on the slider and read answer 7.8 on the body

To learn how to use a slide rule:
https://sliderulemuseum.com/SR_Course.htm

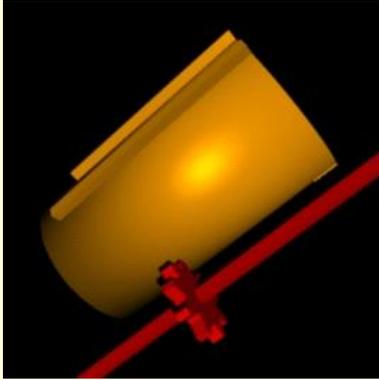
The scales of the slide rule are set up so that they vary as the logarithm of the number. Thus to multiply you add the logarithms of the two numbers being multiplied. To divide one subtracts.

The slide rule is only approximate – it usually gives 2 significant digits clearly and one might guess the third. Thus in the illustrated calculation the true answer is 7.82. The operator may quickly multiply the last digits 3 and 4 to get 12 and conclude that the true answer is 7.82.

For multiplication with many significant digits, Napier produced a technique where on manipulated tables of numbers that were written out on wood or ivory rods – Napier’s bones:



for more information on how to multiply larger numbers and how to divide see https://en.wikipedia.org/wiki/Napier%27s_bones



Mechanical Calculators

Blaise Pascal (1623-1662) invented the Pascaline calculator to help his father's work as a tax supervisor. This used wheels to add or subtract numbers, and had an ingenious *sautoir* latch to cause the necessary carry-overs.

Gottfried Leibniz (1646-1716) invented a mechanism whereby a "stepped reckoner" wheel (yellow) would turn a register wheel with the number of turns depending on the relative depths of the wheels.

Leibniz Wheel

Pascal was famous for many things. He studied atmospheric pressure with the mercury barometer invented by Evangelista Toricelli (1608-1647). The unit of pressure – the pascal – is named after him. He also studied probability. This led to the idea of Pascal's wager: it is better to believe in God than not because the loss if He doesn't exist (the pleasures foregone) is much less than the loss if He does (hell's fire and brimstone), and the gains much lower (earthly pleasures versus heaven's joy).

Leibniz was famous for his invention of the calculus at about the same time as Newton, and for the idea that we live in the best of all possible worlds, satirized by Voltaire in *Candide*. In addition he was the first person to consider binary arithmetic – the foundation of the modern electronic computer.

Arithmometer

Patented in 1820 by Thomas de Colmar (1785-1970) and manufactured from 1851 to 1915, this was the first commercial mechanical calculator.





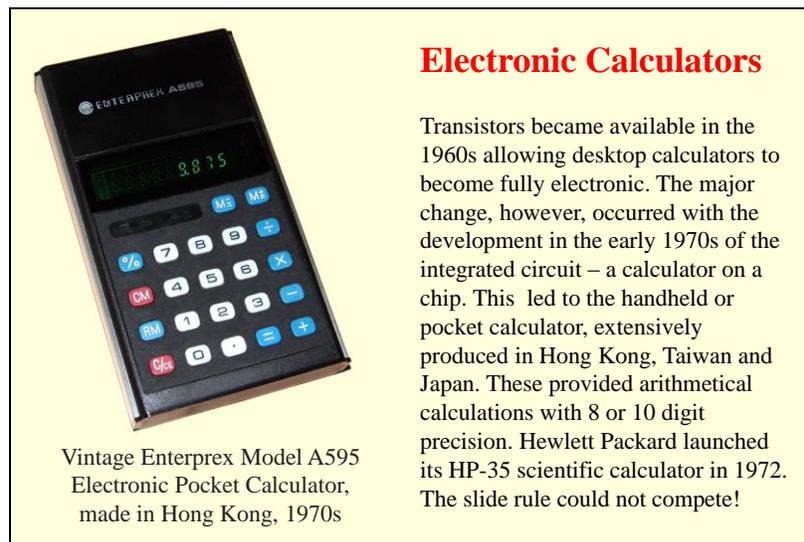
Burroughs Calculator

Founded in 1886, by William Seward Burroughs, this company was by far the most successful manufacturer of calculating machines.

Various mechanical calculators based on the ideas of Pascal and Leibniz were marketed in the late 19th and early 20th century. Of note are the arithmometer of Thomas de Colmar and the calculator of William Seward Burroughs.

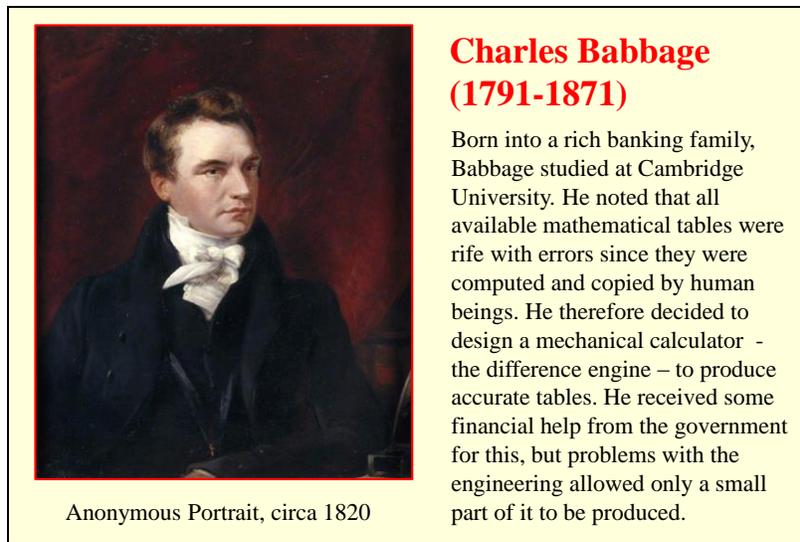
Thomas de Colmar also directed several highly successful insurance companies in France. The long period of time between the arithmometer's patent and production is likely related to the work of Babbage on his difference engine. When in 1849 the British government declined to support Babbage's machine any further, it became appropriate to market the arithmometer.

The illustrated Burroughs calculator is from the 1920s. The author William S. Burroughs (*Naked Lunch*, 1959) is the grandson of the founder of the Burroughs corporation. Toward the middle of the 20th Century the calculators came to be operated electromechanically rather than by hand, but the operating principle were still mechanical. In 1953 the Burroughs Corporation became involved in electronic computers. It merged with Sperry in 1986.



The HP-35 was a little counterintuitive in that it used reverse Polish notation. Instead of “8 +9 =” one had to input “8 enter 9 +”

I remember the advent of these tiny calculators well. I bought myself a really good slide rule in 1971 – and wound up never using it!



The British government was interested in accurate tables since this were necessary for navigation. However, the government lost interest when disputes between Babbage and his engineer caused innumerable delays. Babbage's difference engine was finally constructed by technicians at the Science Museum in London in 1991 and a version of the printer he designed was made in 2000.



This is a Babbage's Difference Engine built from his second design (1849) by the Science Museum in London

<http://www.computerhistory.org/babbage/>

Video:

<https://youtu.be/KBuJqUfO4-w>

The Analytical Engine

From 1833 until the end of his life Babbage worked on the designed of a machine which could be programmed to perform specified calculations and store the results in a memory. He called the arithmetic unit the “mill” and the memory the “store” – terms that came from the mechanical weaving industry. He also proposed that data and instructions could be input using punched cards, much like those used by the Jacquard loom to control which threads were woven. Ada Lovelace, the only legitimate child of Lord Byron, became interested in his design and made suggestions about how the machine could be programmed.



Ada Lovelace (1815-1852) by Alfred Chalon, 1840

The First Computer Program

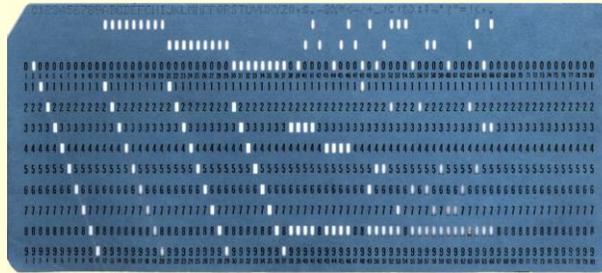
Number of Operation	Variables acted upon	Variables receiving results	Indication of change in the value on any Variable	Statement of Results	Data								Working Variables						
					V_1	V_2	V_3	V_4	V_5	V_6	V_7	V_8	V_9	V_{10}	V_{11}	V_{12}	V_{13}		
1	$V_1 \times V_2$	V_3, V_4, V_5	$V_3 = V_2$	$-2x$															
2	$V_4 - V_5$	V_6	$V_6 = V_4$	$-2x-1$	1														
3	$V_4 + V_7$	V_8	$V_8 = V_4$	$-2x-1$	1														
4	$V_8 - V_9$	V_{10}	$V_{10} = V_8$	$-2x-1$															
5	$V_{10} - V_{11}$	V_{12}	$V_{12} = V_{10}$	$\frac{1}{2} \frac{2x-1}{2x+1}$															
6	$V_{12} - V_{13}$	V_{14}	$V_{14} = V_{12}$	$\frac{1}{2} \frac{2x-1}{2x+1}$															
7	$V_{14} - V_{15}$	V_{16}	$V_{16} = V_{14}$	$\frac{1}{2} \frac{2x-1}{2x+1} = B_n$															
8	$V_{16} - V_{17}$	V_{18}	$V_{18} = V_{16}$	$x-1 (=B)$	1														

The illustration shows Ada Lovelace’s proposal for how the Analytical Engine could be programmed to calculate the Bernoulli numbers. These were a set of numbers put together by Jacob Bernoulli and used in the power series approximations of various mathematical functions. Lovelace’s program inputs the operation to be performed, the variables to be acted upon and the location of the results, indicators to monitor the flow, and the formula of the operation.

Lovelace’s “program” was published as an appendix to a paper that she wrote on Babbage’s Analytical Engine. This paper translated and expanded a French paper about Babbage’s design.

Jacob Bernoulli was the mathematician who first calculated the value of e.

Punched Cards



Herman Hollerith (1860-1929) designed a punched card system for compiling statistical data in his 1889 doctoral thesis at Columbia University. This was used to collect data for the 1890 US Census. Hollerith formed his own company The Tabulating Machine Company in 1896. The company merged with others to form the Computing Tabulating Recording Company in 1911. This ultimately became the International Business Machines Corporation (IBM) in 1934.

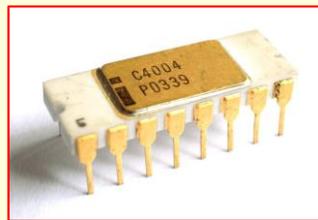
The punched card remained the main way of storing data (and programs) until late in the 20th Century. Magnetic Storage began with magnetic tape in 1951, magnetic disks in 1956 and floppy disks in 1970.

The IBM punched card provided 80 columns and ten rows, with two supplementary rows at the top. The coding system is shown in the printed top line of the illustrated card – the codes represent the numbers 012...9 and then the alphabet ABC...Z, and then various arithmetical and financial symbols. Other cards used different coding systems.

From Mechanical Calculator to Electronic Computer



Electronic circuits work much more rapidly than mechanical gears. However, they cannot operate easily in terms of decimal numbers. Nevertheless, they can provide simple yes-no logical decisions, which are characteristic of binary arithmetic.

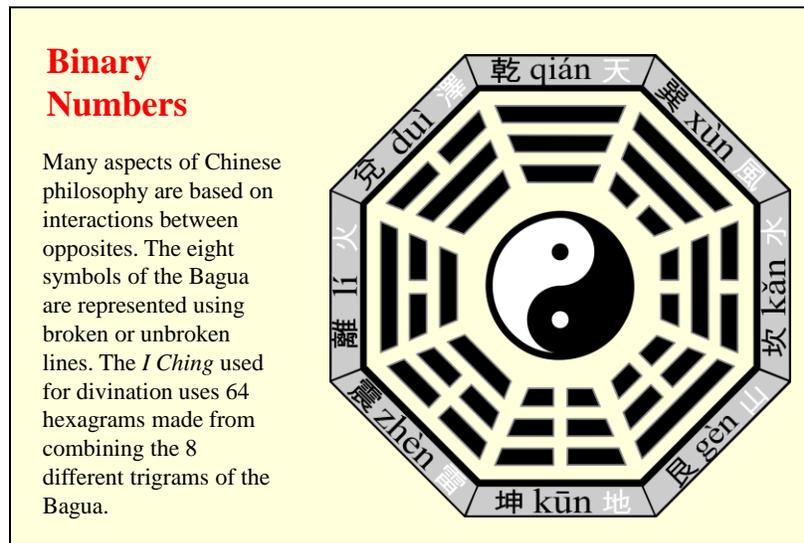


The illustration on the left shows a part of Babbage's Differential Engine made by his son Henry Babbage to demonstrate how the engine could work. This demonstration instrument is in the Science Museum in London. The full machine would have stood 8 ft high and weighed 4 tons.

The illustration on the right shows the Intel 4004 microprocessor, a 4 bit CPU, designed by Federico Gaggin and made commercially available in 1971. The dimensions are 12X4X3 mm. It includes 2300 transistors.

To get from Babbage to Intel we needed to develop

- binary arithmetic - first considered by Gottfried Leibniz.
- logic operations –based on the work of George Boole.
- electronics – initially based on vacuum tubes and ultimately on the transistors of William Shockley.



The explanation of the Bagua:

The *Taiji* (the two opposing forces in embryonic form) produces two forms, named yin and yang (陰陽) which are called *Liangyi* (the manifested opposing forces). These two forms produce four phenomena: named lesser yin (少陰, *shaoyin*), greater yin (太陰; *taiyin*), lesser yang (少陽, *shaoyang*), and greater yang (太陽; *taiyang*). The *four phenomena* (四象; Sixiang) lead to the eight trigrams (八卦; *Bagua*).

In the beginning was *yang* – the unbroken line – and *yin* – the broken line.

Bagua trigrams can be converted into binary digits by making the unbroken lines equivalent to 1 and the broken lines equivalent to 0. The numbers are read so that upward. Thus *qián* is 111 (the creative force) and *xùn* is 011 (the wind), etc.

Binary Arithmetic

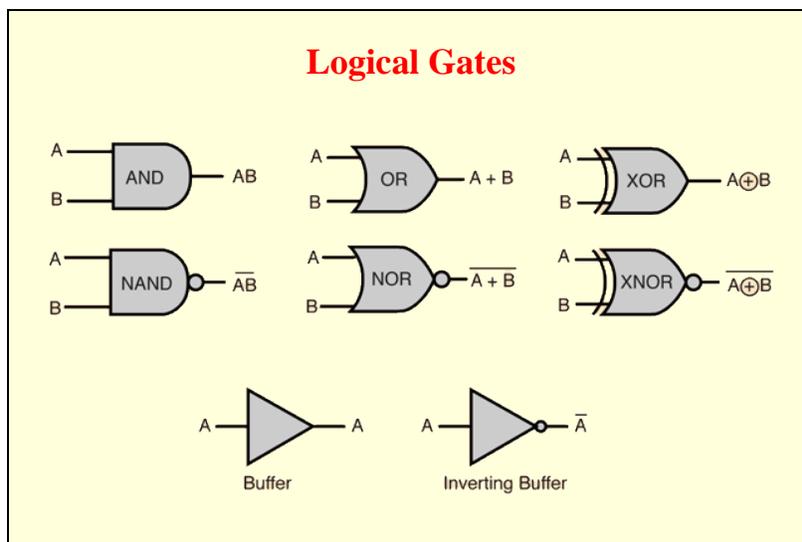
Cette expression des Nombres étant établie, sert à faire très facilement toutes sortes d'opérations.

0000 0000 0000 0001 0000 0010 0000 0011 0000 0100 0000 0101 0000 0110 0000 0111 0000 1000 0000 1001 0000 1010 0000 1011 0000 1100 0000 1101 0000 1110 0000 1111 0001 0000	<p><i>Pour l'Addition</i> par exemple.</p> $\begin{array}{r} 110 \parallel 6 \\ 111 \parallel 7 \\ \hline 1101 \parallel 13 \end{array}$	<p><i>Pour la Sou-</i> <i>straction.</i></p> $\begin{array}{r} 1101 \parallel 13 \\ 111 \parallel 7 \\ \hline 110 \parallel 6 \end{array}$	<p><i>Pour la Mul-</i> <i>tiplication.</i></p> $\begin{array}{r} 11 \parallel 3 \\ 11 \parallel 3 \\ \hline 11 \parallel 3 \\ 101 \parallel 9 \end{array}$	<p><i>Pour la Division.</i></p> $\begin{array}{r} 15 \parallel 1111 \\ 3 \parallel 1111 \\ \hline 101 \parallel 5 \end{array}$
---	--	--	--	--

Gottfried Leibniz (1646-1716) became fascinated by the *I Ching* and in 1703 published a paper on the binary number system and how it could be used to perform arithmetical calculations. The illustration is from that paper.

Addition of 1 and 0 yields 1. When adding 1 + 1 in binary we get 10 – the number in the column we are adding becomes 0 and a one is carried leftward to add to whatever is in that column.

Subtracting 1 from 1 yields 0. Subtraction of 1 from 0 yields 1 but 1 must be carried leftward to be subtracted from the numbers in that column.



The illustration is from <http://hyperphysics.phy-astr.gsu.edu/hbase/Electronic/gate.html#c1>
The site provides excellent documentation about digital electronics.

These symbols depict integrated transistor circuits that perform the simple operations of Boolean logic. Hooking the circuits together can make larger circuits that perform binary arithmetic operations.

In Boolean logic the operations give outputs that are true or false. Thus the output of an AND gate is true if both inputs A and B are true but not if either is false.

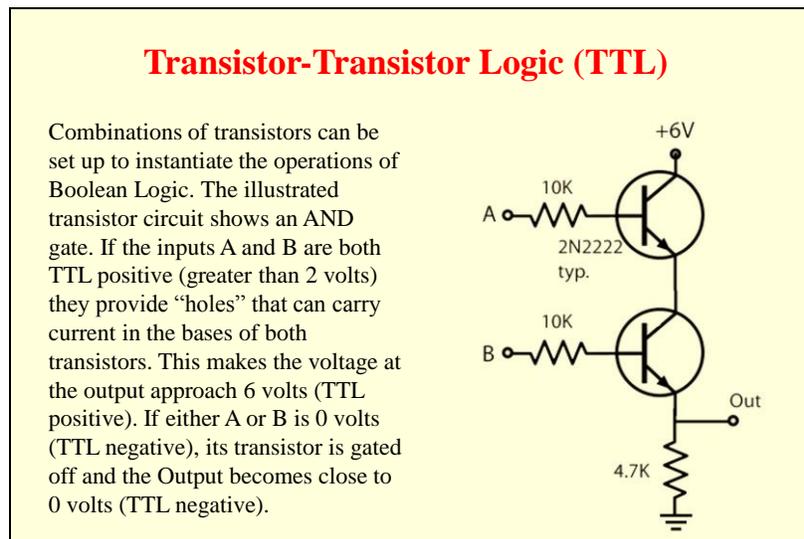
This can be presented as a truth table:

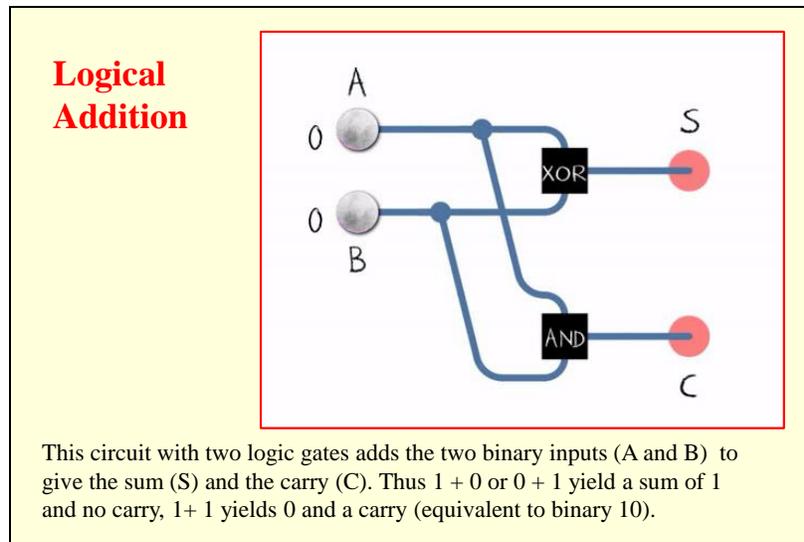
A	B	Output
T	F	F
T	T	T
F	F	F
F	T	F

In Binary Arithmetic T becomes 1 and F becomes 0.

In Transistor-Transistor Logic T becomes +5 volts and F becomes 0 volts. In actual fact the T values can be any voltage greater than 2 volts and F is between 0 and 0.8 volts.

Binary Logic was used by Claude Shannon (2012-2001) to assess the amount of information carried by a communication channel. In his *A Mathematical Theory of Communication* (1948) he characterized the smallest amount of information as 1 bit since it could be represented by 1 binary digit. Computer scientists later used the term byte to refer to 8 bits of information (i.e., values from 0 to 255) since this was the commonest length of a number in the early computers





The XOR or “exclusive or” gate is a more complicated logic gate than the AND and OR gates. It is true if either one of the inputs is true but not if both are true.

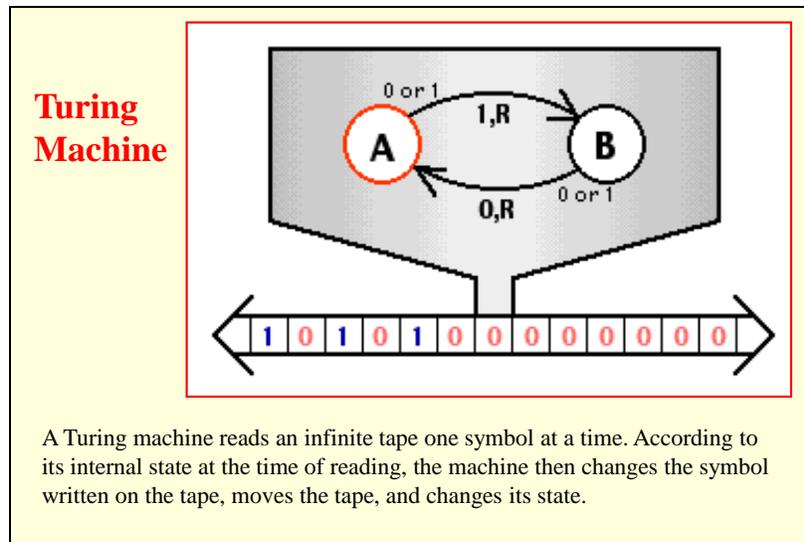
An integrated circuit can contain multiple versions of this and similar circuits. A large integrated circuit can thus provide all the calculations necessary for a computer’s “central processing unit.”

But we are ahead of ourselves! We need to go back and consider those who worked on the theory of electronic computers. There were two giants in the field – Alan Turing and John von Neumann.

Alan Turing (1912-1954)

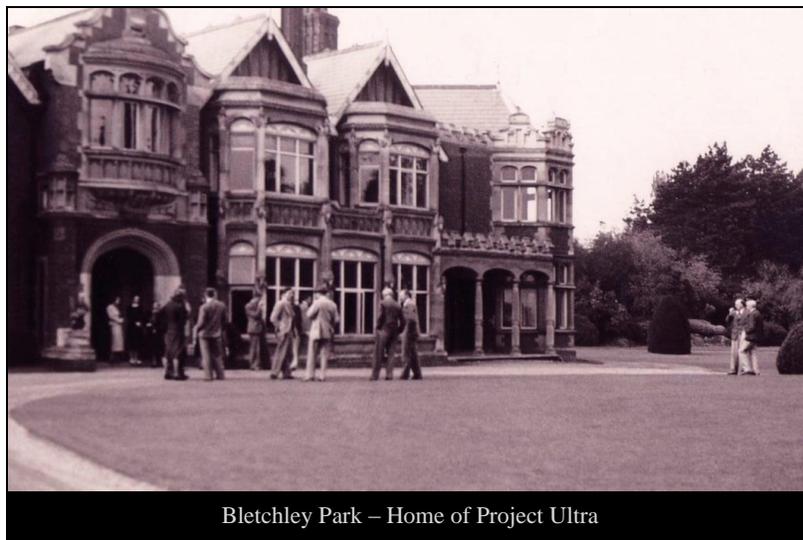
Educated at Cambridge University, Turing worked on the logic of computing in the 1930s and then was appointed to the Ultra Program at Bletchley Park. He and his colleagues was able to break the Enigma code used for German signals. This saved numerous lives, and in some estimates was instrumental in winning the war. His work remained secret and he was never honored during his lifetime. In 1952 he was prosecuted for his homosexuality and underwent chemical castration in order not to be imprisoned. He committed suicide in 1954.

It was not until 2013 that Turing was posthumously pardoned for his offence of “gross indecency”



In his 1937 paper *On Computable Numbers, with an Application to the Entscheidungsproblem*, Turing described a hypothetical computing machine that could read from a tape alter its state and then write on the tape before reading from the tape again. This setup had the necessary requisites for a computer – the state possesses the memory, the tape provides input and output and the process of changing state instantiates the computations.

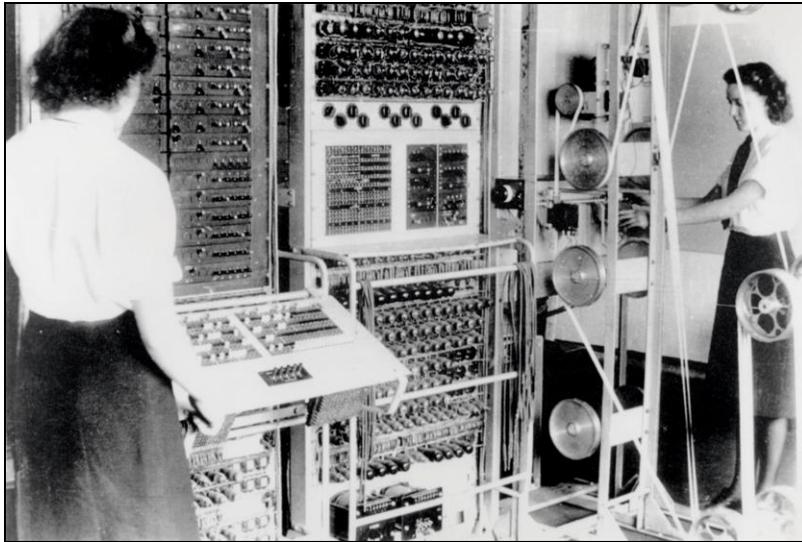
Turing used this hypothetical computer to show that some decision problems are undecidable. Turing reasoned that one could never prove whether or not the machine would ever stop computing when it was given a particular problem. Turing's conclusion is related to the logical problem proposed by Gödel – that any consistent logical or numerical system could not be proven within itself, i.e. was necessarily incomplete.



Bletchley was the location for the British cryptography program during World War II. The colored photograph shows the main building at present. The old black and white photograph shows the building in September 1938, when the British intelligence services had their first

meeting there. It was disguised as “Captain Ridley’s Shooting Party.” At the beginning British intelligence were more interested in the Italian navy’s codes, because of fears of Italy’s influence in the Mediterranean. And there were no computers, just human cryptographers.

<https://www.theguardian.com/world/2018/sep/18/bletchley-discloses-real-intention-1938-shooting-party-wapark-r>



This is the Colossus computer built by Tommy Flowers from 1943-1945 to aid in the analysis of German radio telegraph signals. The signals were run through the computer via paper tape being handled by the WREN (Women’s Royal Naval Service) at the right. They were decoded on circuits containing some 1700 vacuum tubes. Colossus was a fixed program computer – the algorithms were put into the computer by hand. This computer worked together with the Bombe, the electromechanical computer built by Alan Turing which determined the Enigma code.

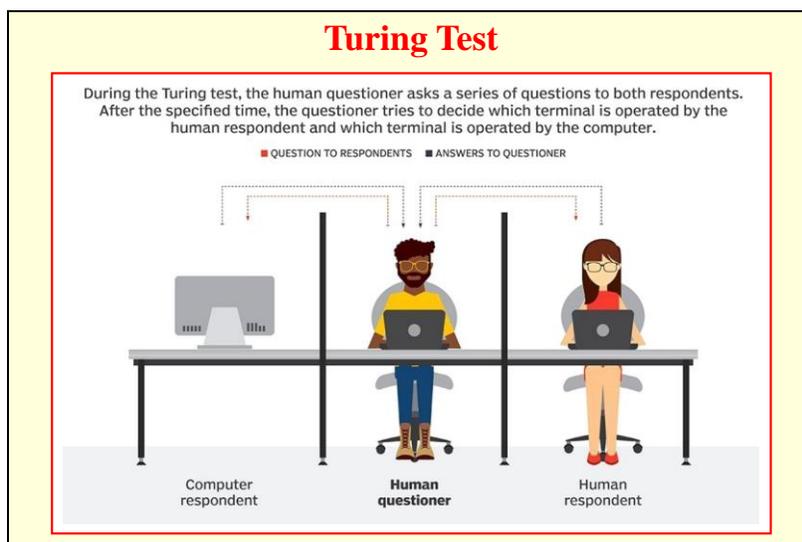


illustration from

<https://searchenterpriseai.techtargget.com/definition/Turing-test>

Computers can do many things much better than human beings. However, they cannot yet act sufficiently like a human being that we cannot recognize the difference.

In 1950, Turing suggested that computers would soon show intelligent behavior. He proposed a test: a human interrogator (or jury) would not be able to distinguish the computer from another human being, after a brief conversation.

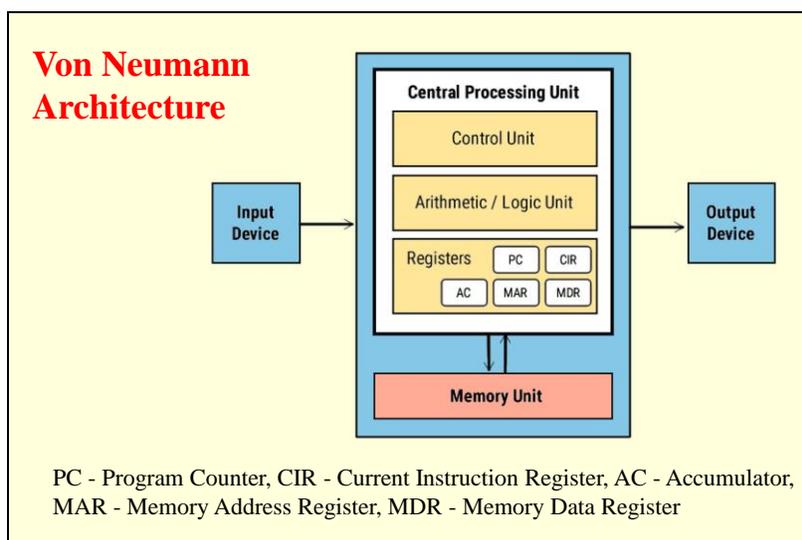
In 1991, Hugh Loebner, an American inventor, established prizes for the first computers to pass the Turing test. None has yet won the silver (text only) or gold (audio and visual) prize.

**John von Neumann
(1903-1957)**

Born to a secular Jewish family in Budapest Von Neumann was a child prodigy who conversed in Ancient Greek and understood calculus by age 8 yr. He attended university in Zurich and Budapest, and then made significant contributions to the logic of sets, the theory of games, and the mathematics of the new quantum physics. In 1933 he came to Princeton University's Institute for Advanced Study. During the war he consulted on the Manhattan project and after the war on the development of the hydrogen bomb.



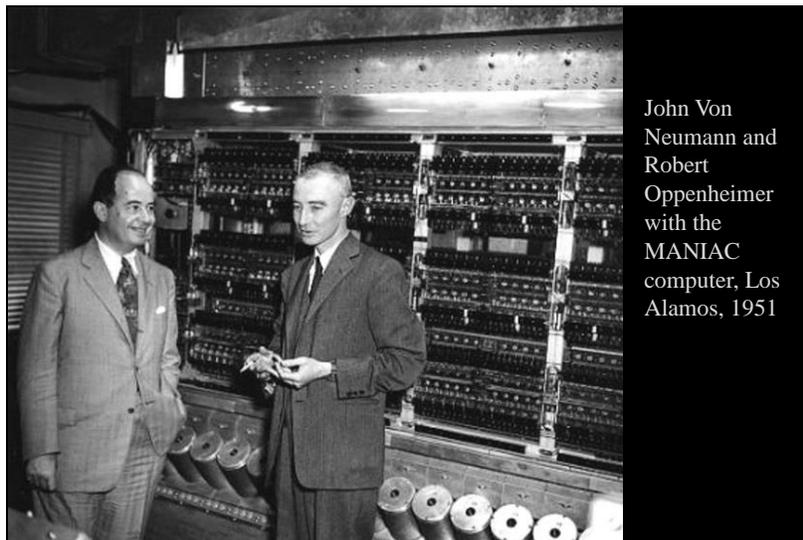
Photograph , circa 1951



This description of the way a computer works was first published in 1945 by Von Neumann in his *First Draft of a Report on the EDVAC* based on his experience with the Electronic Discrete Variable Automatic Computer.

Three main electronic computers were developed in the US during and just after the war:
ENIAC Electronic Numerical Integrator and Computer completed in 1945
EDVAC Electronic Discrete Variable Automatic Computer completed in 1949
MANIAC Mathematical Analyzer, Numerical Integrator, and Computer completed in 1952
The US Military's penchant for acronyms is clearly on display.

All these computers used vacuum tube circuits and were notoriously unreliable. The first transistorized computer was built in Manchester England in 1953. The first commercially successful transistorized computer was the IBM 7070 marketed in 1958. Digital Equipment Corporation began producing their PDP (Programmable Data Processor) systems in 1959.



The MANIAC computer provided essential calculations for the development of the Hydrogen bomb, the first test of which was carried out in 1952 at the Enewetak Atoll in the Marshall Islands in the Pacific Ocean.

Programming Languages

General programming languages could be translated (compiled) into the specific format of any machine's instruction set. The first such language was FORTRAN developed at IBM in 1956.

```

C AREA OF A TRIANGLE - HERON'S FORMULA
C INPUT - CARD READER UNIT 5, INTEGER INPUT
C BLANK CARD FOR END-OF-DATA
C OUTPUT - LINE PRINTER UNIT 6, REAL OUTPUT
C INPUT ERROR DISPLAY ERROR MESSAGE ON OUTPUT
501 FORMAT (3I5)
601 FORMAT (4H A= ,I5,5H B= ,I5,5H C= ,I5,8H AREA= ,F10.2,
$13H SQUARE UNITS)
602 FORMAT (10HNORMAL END)
603 FORMAT (23HINPUT ERROR, ZERO VALUE)
INTEGER A,B,C
10 READ (5,501) A,B,C
IF (A.EQ.0 .AND. B.EQ.0 .AND. C.EQ.0) GO TO 50
IF (A.EQ.0 .OR. B.EQ.0 .OR. C.EQ.0) GO TO 90
S = (A + B + C) / 2.0
AREA = SQRT ( S * (S - A) * (S - B) * (S - C) )
WRITE (6,601) A,B,C,AREA
GO TO 10
50 WRITE (6,602)
STOP
90 WRITE (6,603)
STOP
END

```

Heron's formula for the area of a triangle was first proposed by Hero of Alexandria in the first century CE.

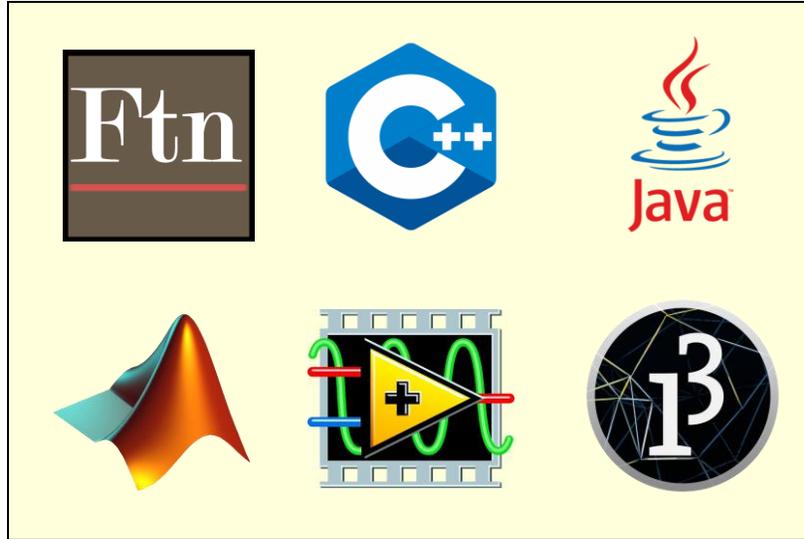
When the three sides are A, B and C and $S = (A + B + C)/2$
the area is the square root of $S*(S-A)*(S-B)*(S-C)$

FORTRAN shows many of the characteristic features of all programming languages:

- Comments explaining the program
- Input (READ) and output (WRITE) instructions
- Formatting information, e.g. whether to use an integer (e.g. 600) or a floating point (e.g. 6.0e2 which means 6.0 multiplied by 10^2)
- Logical statements such as IF, AND and OR
- Arithmetic statements such as $S=(A+B+C)/2.0$
- Control statements such as GO TO and STOP

This particular program does not illustrate the DO LOOP which repeats calculations until a certain criterion is met, or the SUBROUTINE and FUNCTION calls which can use code in a separate part of the program

https://en.wikibooks.org/wiki/Fortran/Fortran_examples



Fortran developed in 1956 at IBM. It has been modified extensively and is still in use.

C began in 1972 and C++, an object based language derived from C, came out in 1979. Java which is also based on C came out in 1995. It was directed to internet operations and was made to work on almost any computer.

Originally developed in the 1970s at the University of New Mexico, to compute and plot large engineering data sets, MATLAB was re-written in C and made commercially available in 1984.

Labview was developed in 1986 as a visual programming language – it uses icons rather than words. It facilitates the development of scientific instruments.

Processing used the Java language and is focused on media art and visual design. It was developed at the MIT Media Lab in 2001.

Bill Gates (1955-)

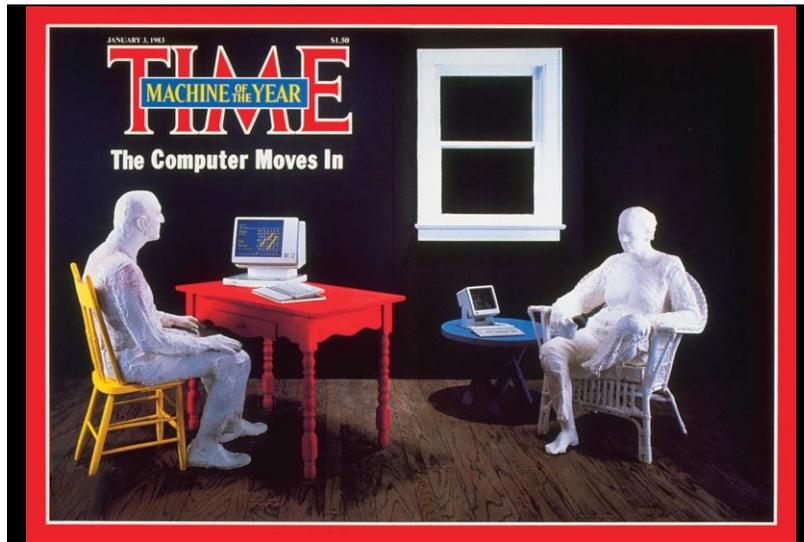
Gates dropped out of Harvard University to found Microsoft together with Paul Allen in 1975. Their first project was to provide a BASIC interpreter for the Altair microcomputer. When IBM was developing the first personal computer, Microsoft provided the disk operating system (DOS). Gates did not transfer the copyright and was able to supply the operating system to all the manufacturers of PC clones. The main later developments were Windows in 1985 and the Office suite of programs in 1988.



Portrait by Stephen Voss, 2015

Much of the success of Microsoft came from the fact that DOS and its later operating systems were used on all the different brands of PCs that were marketed. The components of the Office

suite of programs – Word, Excel, Outlook and Powerpoint – quickly replaced competing programs such as WordPerfect and VisiCalc. Powerpoint was initially developed for the Macintosh computer by the company Forethought but the company was bought by Microsoft in 1987.



The IBM Personal Computer was introduced in 1981, and became enormously successful. In 1983, Time magazine nominated the personal computer as the “machine of the year” for 1982. The computers in the fold-out cover are generic. The sculptures are by George Segal.

Because Microsoft could supply the same operating system to other companies who built PC clones, it was not a great business success for IBM. In 1984, they tried another simpler computer – the PC Junior – but this was a complete failure. IBM continued to manufacture various versions of their PC but finally withdrew from the personal computer market in 2002.

Steve Jobs (1955-2011)

After dropping out of college and traveling to India, Jobs founded Apple Corporation with Steve Wozniak in 1976 and marketed the Apple I computer for electrical hobbyists. In 1984 they announced their Macintosh computer. Jobs later went on to develop many ingenious and commercially successful products – iTunes to sell digital music (2001), iPod to play the music (2001), and the iPhone (2007), the first phone with a touch screen that could play music, browse the web, and take photographs, as well as make phone calls.

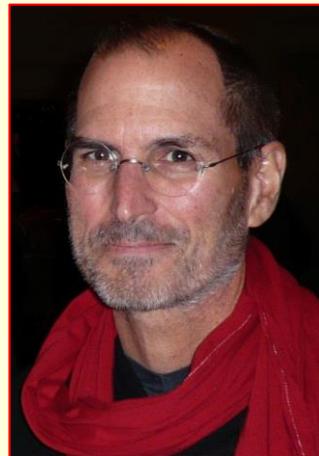


Photo by Steve Jurvetson, 2007



The 1984 Macintosh commercial for Apple Computer was conceived by the Chiat/Day advertising company (Jay Chiat and Guy Day) and directed by Ridley Scott. It was aired on television only once – during the 3rd quarter of the 1984 Super Bowl football game.

What was the world-changing new development? Before this the input and output of a personal computer, and indeed of most computers, were text-based.

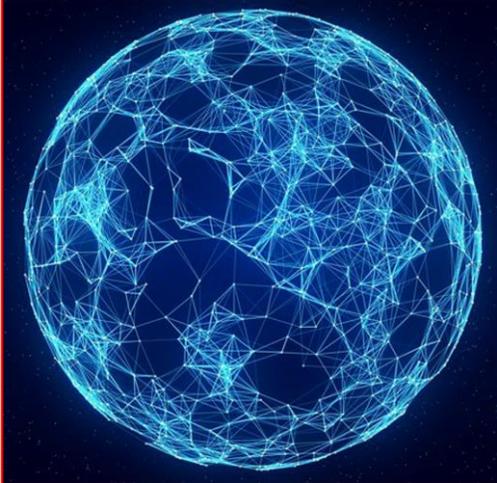
**Graphic
User
Interface
(GUI)**

GUI concepts were initially developed at Xerox's Palo Alto Research Center under the direction of Douglas Englebart. The main components were a screen that presented both text and graphics, a pointer that could be operated by a handheld "mouse," and separate pop-up displays of data, menus, programs, etc.

Although Xerox marketed computers with these features, it was not until Apple developed the new operating system for the Macintosh computer, that computers with a GUI became commercially successful. Microsoft quickly followed with the Windows operating system.

The Internet

After the 1960s several networks connecting different computers were established such as the US ARPANET. In 1989 Tim Berners-Lee (1955 -), and English engineer, set up the protocols and algorithms that operated the World Wide Web. As of 2018 55% of the world's population have internet access.



ARPANET - Advanced Research Projects Agency Network

The main features of the world wide web are

- the uniform resource locator (URL) and the uniform resource identifier (URI) to denote websites or pages
- hypertext markup language (HTML) which allows links between resources
- hypertext transfer protocol (HTTP) which transfers between resources
- a browser program that connects to the different websites

The first web browser was developed in 1993 – Mosaic. This became Netscape in 1994, and later became Mozilla in 1998. Microsoft produced Internet Explorer in 1995. The Google Search Engine began in 1998. Google Chrome browser came out in 2008.



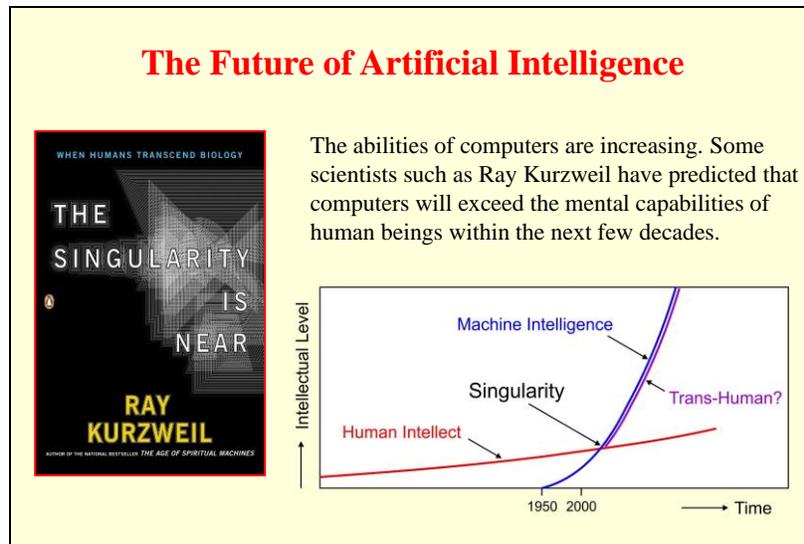
Garry Kasparov playing against Deep Blue in the 1997 rematch. This is the beginning of the 2nd game. Deep Blue's moves are being made by Murray Campbell. Kasparov, the world chess champion from 1983-1995, had won the first match against Deep Blue 4-2 in 1996. He lost this rematch 3½ - 2½.

This and other photographs from

<https://mashable.com/2016/02/10/kasparov-deep-blue/#dwKDasQavEq7>

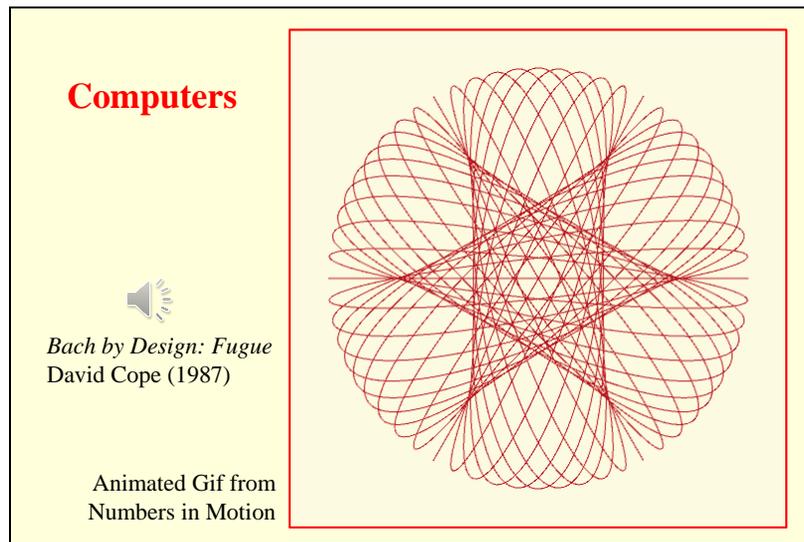
In 2011 IBM Watson defeated two previous champions on the quiz show Jeopardy.

In 2017 Alphago, a computer developed by Alphabet Google and DeepMind Technologies, defeated Ke Jie, the world's number-1 ranked Go player.



Ray Kurzweil (1948 -) studied computers at MIT with Marvin Minsky. In the late 20th Century he set up companies to consider new computer applications, most importantly in optical character recognition. His book on the predicted “singularity” came out in 2005. On the possibility of divine intelligence, Kurzweil has said, "Does God exist? I would say, 'Not yet.'" (in the film *Transcendent Man*, 2011)

Predictions about the future are notoriously difficult. Most people would have predicted that computers would have passed the Turing Test by now but they have not.



This final slide represents some simple computer-generated art.

The animated gif made using Processing comes from <http://numbersinmotion.tumblr.com/>

The fugue was written by a computer programmed by David Cope to follow the compositional rules used by Bach.