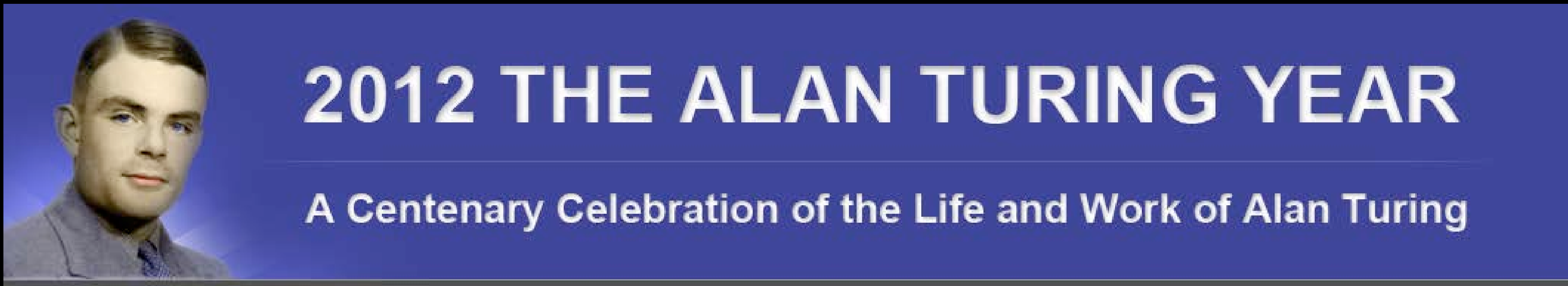


O SÍLE MATEMATICKÉHO OBJEVU: HOLD A. M. TURINGOVI KE STÉMU VÝROČÍ JEHO NAROZENÍ

Jiří Wiedermann
Akademie věd ČR

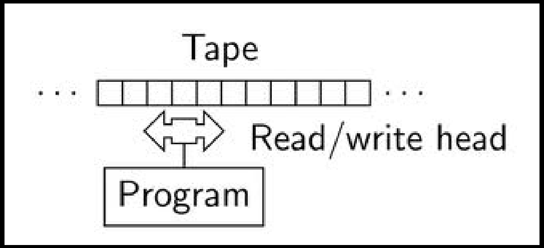
Přednáška pro Učenou společnost ČR, leden 2013

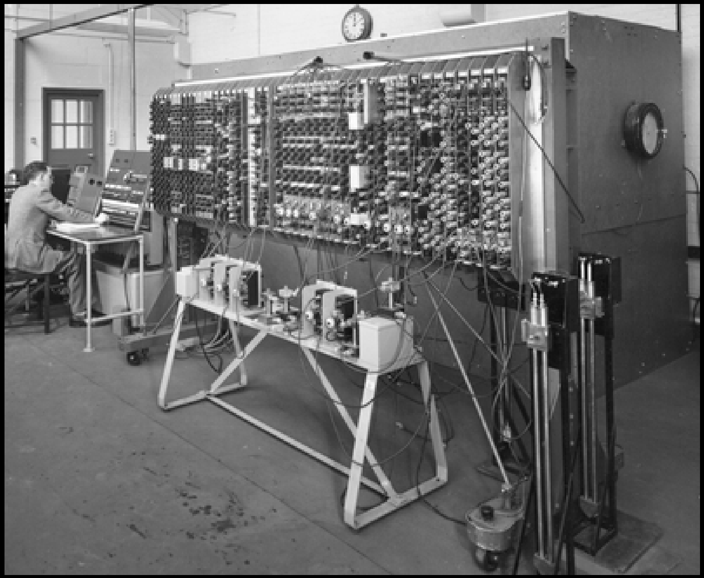
AMT: Genius and Master od Intuition
The Legacy of a Genius: AMT - the Father of AI
AMT: Pioneer of the Information Age
Turing Eclectic and Eccentric
AMT: Mathematical Genius, WWII Codebreaker, Pioneer of Computing, Gay Icon
Turing as a Natural Scientist

AMT: 1912-2012
Father of Computer Science
Mathematician, Logician
Wartime Codebreaker
Victim of Prejudice

Milestones of Turing's scientific life:

- Turing machine
- Cracking the code of Nazis' submarines
- First serious mathematical use of a computer
- Turing test
- Theory of biological growth





23 June 1912: Alan Mathison Turing was born in London

1926: Aged 14, he was sent to Sherborne School in Dorset. His first day of term coincided with the 1926 General Strike. Turing was so determined not to miss his first day of school that he cycled the 97km from his home in Southampton.

His teachers worried that he leaned too heavily towards maths and science, at the expense of the classics. The headmaster wrote to his parents: "If he is to be solely a scientific specialist, he is wasting his time at a public school".

1927: At the age of 16, Turing got to grips with Albert Einstein's work and extrapolated Einstein's questioning of Newton's Laws of Motion from a text in which this was never made explicit.

1930: Turing's close school friend Christopher Morcom dies suddenly from bovine tuberculosis. Turing renounces his religious faith and becomes an atheist.

Source: Alan Turing's Extraordinary, Tragically Short Life: A Timeline, wired.co.uk

1931: Turing goes to study Mathematics at King's College, Cambridge.

1932

1935

1935: Turing proves the central limit theorem in his dissertation and is made a fellow at King's at the age of just 22.

1936: Turing published his paper *On Computable Numbers and an Application to the Entscheidungsproblem* (decision problem) in which he outlines the Universal Machine, which later became known as the Turing Machine.

Source: Olivia Solon: Alan Turing's Extraordinary, Tragically Short Life: A Timeline, wired.co.uk

ON COMPUTABLE NUMBERS, WITH AN APPLICATION TO THE ENTSCHEIDUNGSPROBLEM

By A. M. Turing.

[Received 28 May, 1936.—Read 12 November, 1936.]

The "computable" numbers may be described briefly as the real numbers whose expressions as a decimal are calculable by finite means. Although the subject of this paper is ostensibly the computable *numbers*, it is almost equally easy to define and investigate computable functions of an integral variable or a real or computable variable, computable predicates, and so forth. The fundamental problems involved are, however, the same in each case, and I have chosen the computable numbers for explicit treatment as involving the least cumbrous technique. I hope shortly to give an account of the relations of the computable numbers, functions, and so forth to one another. This will include a development of the theory of functions of a real variable expressed in terms of computable numbers. According to my definition, a number is computable if its decimal can be written down by a machine.

In §§ 9, 10 I give some arguments with the intention of showing that the computable numbers include all numbers which could naturally be regarded as computable. In particular, I show that certain large classes of numbers are computable. They include, for instance, the real parts of all algebraic numbers, the real parts of the zeros of the Bessel functions, the numbers π, e, etc. The computable numbers do not, however, include all definable numbers, and an example is given of a definable number which is not computable.

Although the class of computable numbers is so great, and in many ways similar to the class of real numbers, it is nevertheless enumerable. In § 8 I examine certain arguments which would seem to prove the contrary. By the correct application of one of these arguments, conclusions are reached which are superficially similar to those of Gödel†. These results

† Gödel, "Über formal unentscheidbare Sätze der Principia Mathematica und verwandter Systeme, I", *Monatshefte Math. Phys.*, 38 (1931), 173–198.

Turing took the idea of a team of human computers working together and abstracted it, imagining a universal computing machine that could take on all of the individual tasks allocated to the women in the Scientific Computing Service (SCS)

Calculating machine used at SCS

The basic idea:

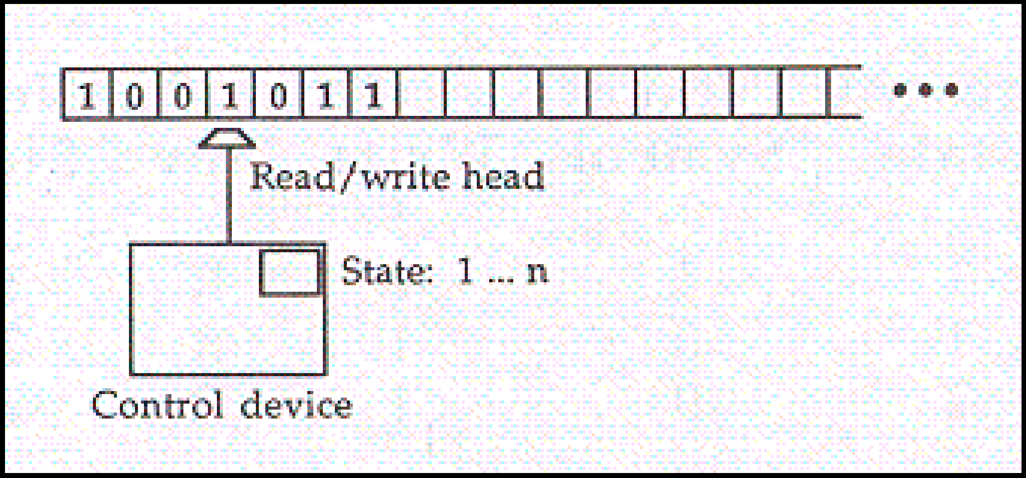
An abstract model of a human "computer"

- Finite control unit (i.e., a finte table of "behaviors", so-called finite automaton)
- Read/write head
- Potentially infinite tape

$$T=(\Sigma,Q,\delta,q,f)$$

$$\delta: \Sigma x Q \rightarrow \Sigma x Q x \{-1,0,1\},\ q,f \in Q$$

The scheme of a Turing machine



Main results:

- A hardware-trivial machine, a mechanical equivalent of today's notion of "algorithm", or "program"
- Computes "anything" computable
- All computing power lies in the program
- Construction of a universal, i.e., of a programmable Turing machine
- Anticipation of the stored program computer, and "program as data" key to the first computers
- Existence of problems without algorithmic procedure for their solution (cf. halting problem)

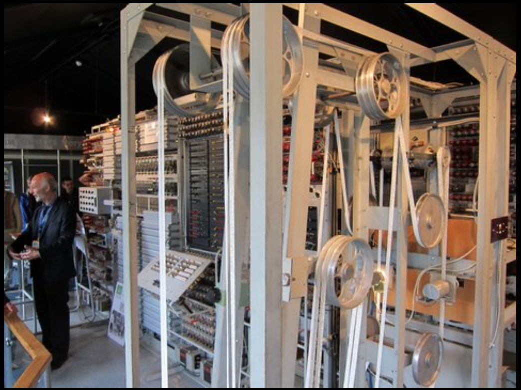
1936-1938: Turing spent time at Princeton in the US studying under Alonzo Church. There he started to study cryptology as well as mathematics. In 1938 he received his PhD; his dissertation was called Systems of Logic Based on Ordinals and introduced original logic and relative computing. The work on 'ordinal logics', probably his most difficult and deepest mathematical work, was an attempt to bring some kind of order to the realm of the *uncomputable.* This also was connected to the question of the nature of mind, as Turing's interpretation of his ideas suggested that human 'intuition' could correspond to uncomputable steps in an argument.

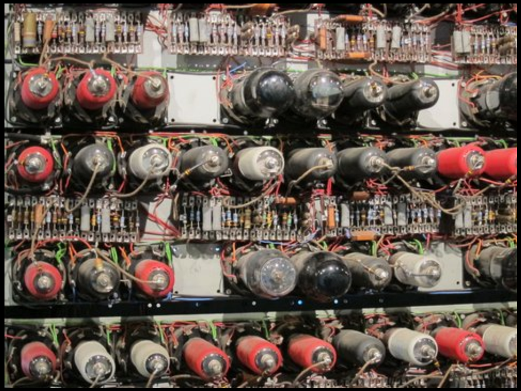
September 1938: return to Cambridge. Turing started to work part-time at the Government Code and Cypher School. Introduced to German Enigma cipher machine

1939: Churchill's Government searched the country for the best mathematicians, chess champions, Egyptologists and others of suitable ability. The day after war is declared in September 1939, Turing arrives at Bletchley Park. There he works to develop the Bombe, a device for decrypting the messages sent by Germans using their Enigma machines.

Source: Olivia Solon: Alan Turing's Extraordinary, Tragically Short Life: A Timeline, wired.co.uk


THE NATIONAL MUSEUM OF COMPUTING
Colossus & Tunny Galleries
(Open 7 Days a Week)






Hut 1 an original wartime code breaking hut. Now used to display a collection of Diplomatic Wireless equipment

Porgy

1942: Turing sent to the US as part of an intelligence collaboration. He shared what he knew about Enigma in return for being allowed to inspect the speech encryption system being set up to allow conversations between Churchill and Roosevelt. Turing was somewhat dismissive of US cryptanalysis, believing the Americans to rely too heavily on machinery instead of thought.

1941-43: Breaking of U-boat Enigma, saving battle of the Atlantic . Turing and colleagues manage to break the more complicated German Naval Enigma system. This is extremely helpful for the Allies during the Battle of the Atlantic as it could help them avoid the fearsome German U-boats, which had been responsible for sinking more than 700 Allied ships with 2.3 million tons of vital cargo.

Source: Olivia Solon: Alan Turing's Extraordinary, Tragically Short Life: A Timeline, wired.co.uk

1941: Turing proposes to his co-worker Joan Clarke, a fellow mathematician and cryptanalyst. Shortly after, Turing had second thoughts, admitting to his fiancée that he was homosexual.

Born: 24 June 1917 in London, England
Died: 4 Sept 1996 in Headington, Oxfordshire, England

1945: At the end of World War II, Turing is awarded an OBE for his services to his country

Turing
Officer of the Order of the British Empire

In 1947, Turing competed in the Amateur Athletic Association Championships marathon finishing in 4th place in 2:46:03 - an amazing time for a non-professional runner even today.

October 1945: Turing joined the National Physical Laboratory where he worked on developing an electronic digital stored-program computing machine that would later become the ACE (Automatic Computing Engine). By 1946 he had a finished proposal for the computer, but NPL did not have the resources to turn it into reality.

1947: Turing returned to Cambridge for a sabbatical year. The Pilot ACE was built in his absence and executed its first program on 10 May 1950.

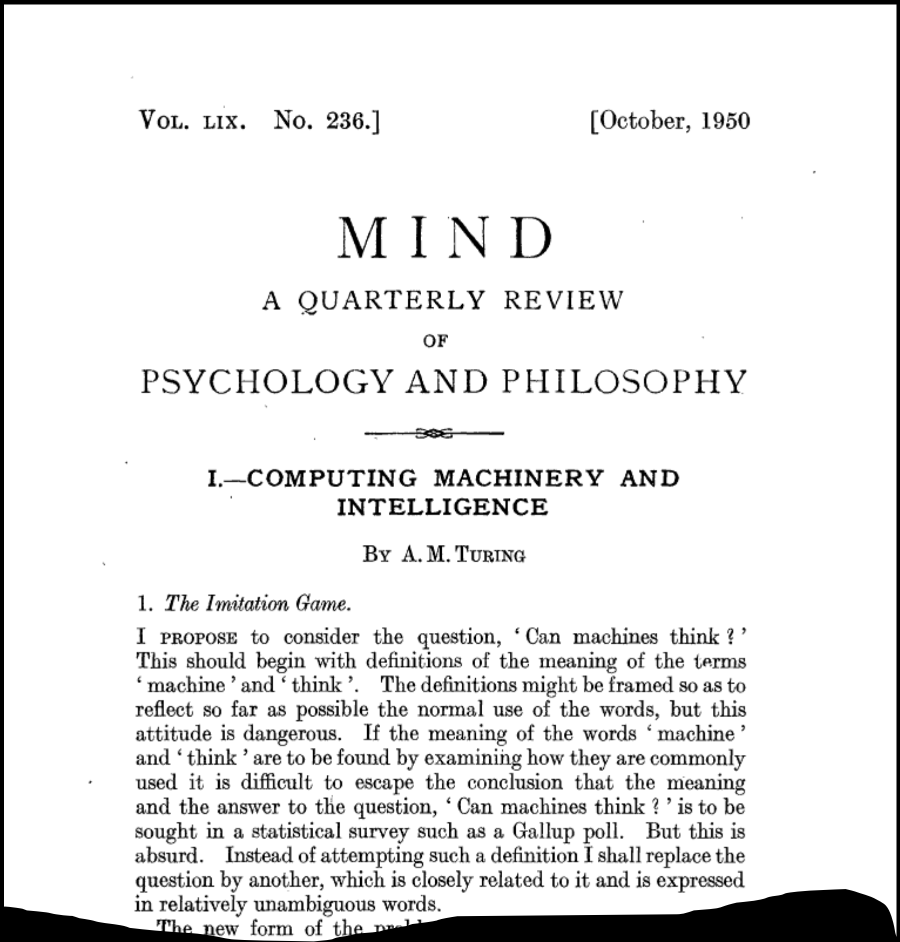
1948: First serious mathematical use of a computer (floating point arithmetic). Turing introduced the *LU* decomposition of a matrix.

$$\begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} = \begin{bmatrix} l_{11} & 0 & 0 \\ l_{21} & l_{22} & 0 \\ l_{31} & l_{32} & l_{33} \end{bmatrix} \begin{bmatrix} u_{11} & u_{12} & u_{13} \\ 0 & u_{22} & u_{23} \\ 0 & 0 & u_{33} \end{bmatrix}$$

A. M. Turing, Rounding-off errors in matrix processes. Quart. J Mech. Appl. Math. 1 (1948), 287–308.

1949: Turing became deputy director of the Computing Laboratory at Manchester University, working on software for one of the earliest stored program computers — the Manchester Mark 1. He also explored the problem of artificial intelligence and proposed an experiment (in his seminal paper *Computing Machinery and Intelligence*) which became that attempted to define a standard for machine intelligence, which would later become known as the Turing test. The core idea was that a computer could be said to "think" if a human interrogator could not tell it apart, through conversation, from a human being.

Source: Olivia Solon: Alan Turing's Extraordinary, Tragically Short Life: A Timeline, wired.co.uk


VOL. LIX. No. 236.] [October, 1950

M I N D

A QUARTERLY REVIEW

OF

PSYCHOLOGY AND PHILOSOPHY

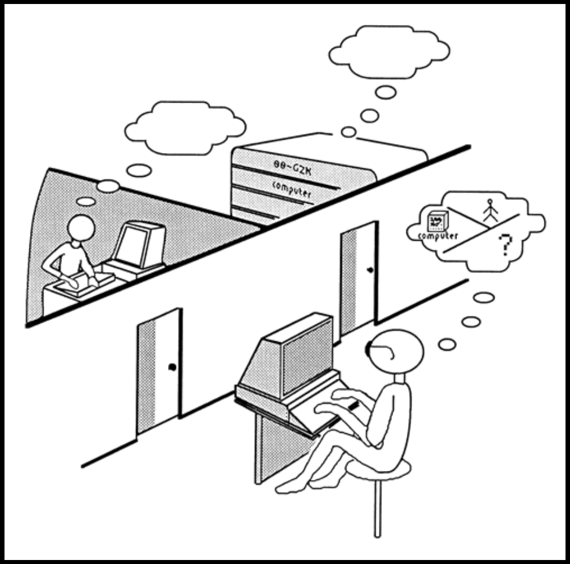
I.—COMPUTING MACHINERY AND INTELLIGENCE

BY A. M. TURING

1. *The Imitation Game.*

I PROPOSE to consider the question, 'Can machines think?' This should begin with definitions of the meaning of the terms 'machine' and 'think'. The definitions might be framed so as to reflect so far as possible the normal use of the words, but this attitude is dangerous. If the meaning of the words 'machine' and 'think' are to be found by examining how they are commonly used it is difficult to escape the conclusion that the meaning and the answer to the question, 'Can machines think?' is to be sought in a statistical survey such as a Gallup poll. But this is absurd. Instead of attempting such a definition I shall replace the question by another, which is closely related to it and is expressed in relatively unambiguous words.

The new form of the

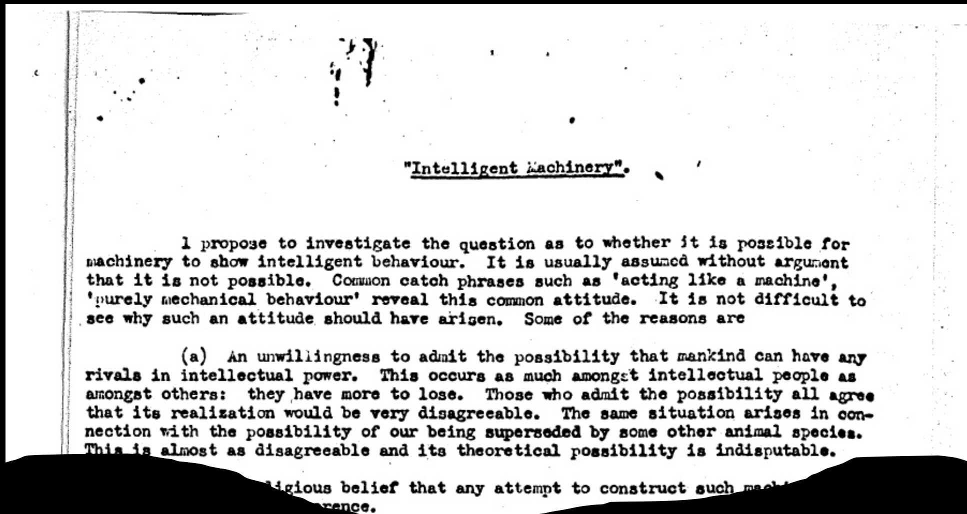


A reversed form of the Turing test is widely used on the Internet; the CAPTCHA test is intended to determine whether the user is a human or a computer.

Limited form of Turing's question-answer game comparing the machine against the abilities of experts in specific fields:

- Deep Blue (Chess) 1997
- Watson the Computer (Jeopardy) 2011

Completely **A**utomated **P**ublic **T**uring test to tell **C**omputers and **H**umans **A**part, Luis von Ahn, Manuel Blum, Nicholas J. Hopper, and John Langford, 2000



"Intelligent Machinery".

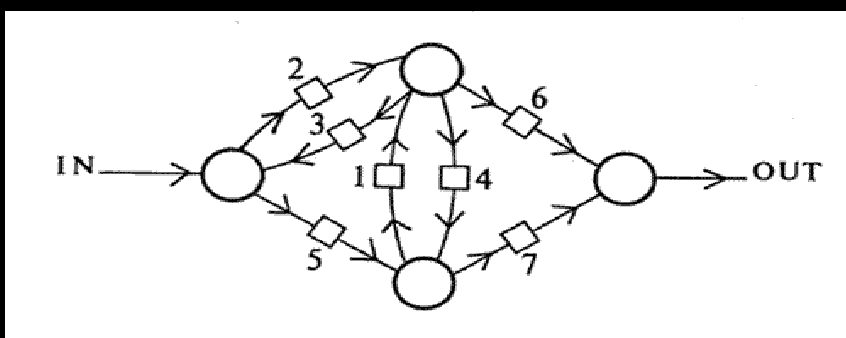
I propose to investigate the question as to whether it is possible for machinery to show intelligent behaviour. It is usually assumed without argument that it is not possible. Common catch phrases such as 'acting like a machine', 'purely mechanical behaviour' reveal this common attitude. It is not difficult to see why such an attitude should have arisen. Some of the reasons are

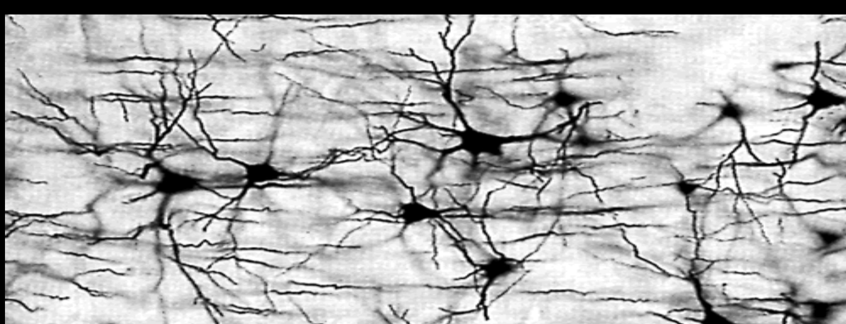
(a) An unwillingness to admit the possibility that mankind can have any rivals in intellectual power. This occurs as much amongst intellectual people as amongst others: they have more to lose. Those who admit the possibility all agree that its realization would be very disagreeable. The same situation arises in connection with the possibility of our being superseded by some other animal species. This is almost as disagreeable and its theoretical possibility is indisputable.

1948: an unpublished manuscript entitled "Intelligent Machinery" on the possibility of a machine possessing the intelligence of man

"schoolboy essay, not suitable for publication" !?

Turing's neural networks of 1948 ("unorganized machines")





What can disembodied brain do:

(i) Games (chess, bridge, poker…)
(ii) The learning of languages
(iii) Translation of languages
(iv) Cryptography
(v) Mathematics

"Of these (i), (iv), and to a lesser extent (iii) and (v) are good in that they require little contact with the outside world."

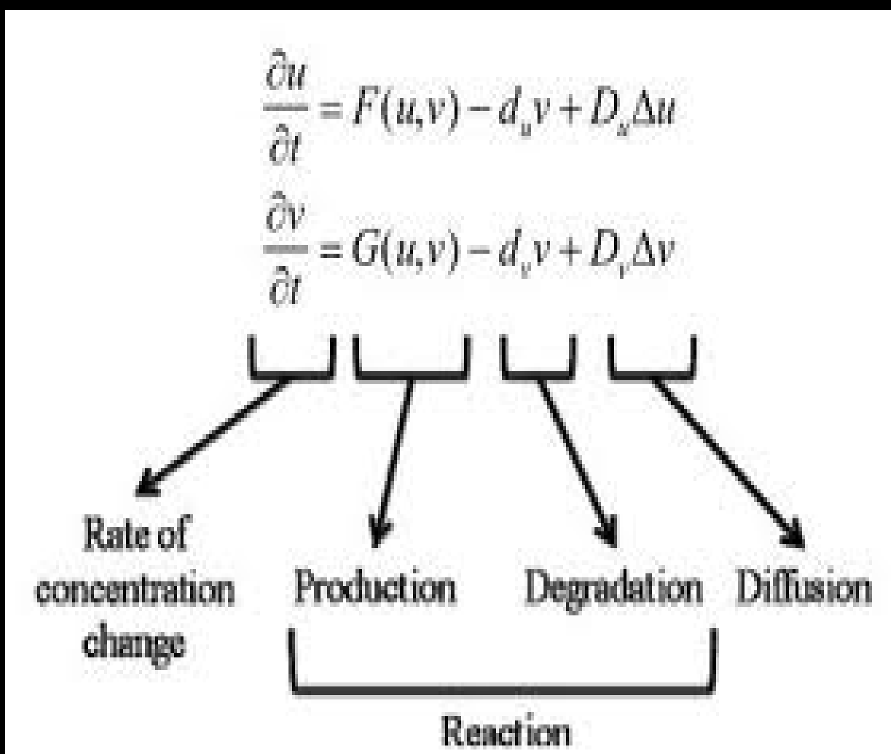
Intellectual, genetical and cultural searches

1949: Turing also worked with his former colleague D G Champernowne on a chess program for a computer that did not exist yet.

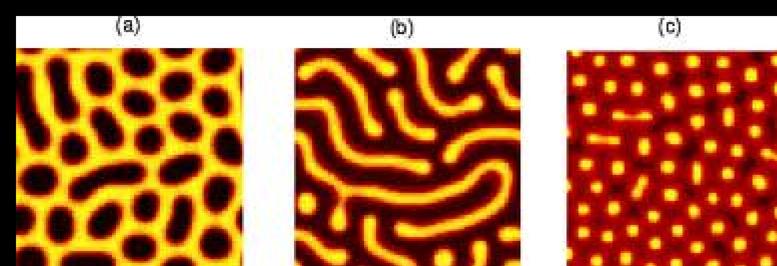
1951: Elected Fellow of the Royal Society. (FRS).

Non-linear theory of biological growth

1952: "The Chemical Basis of Morphogenesis". *Philosophical Transactions of the Royal Society of London* **237** (641): 37–72

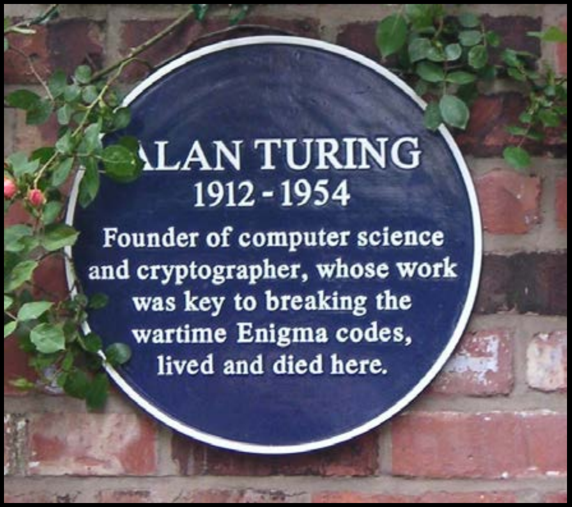


Turing sought to crack another kind of code – how animals could develop from chemical substrates. He believed development could be reduced to mathematical axioms and physical laws. He designed a system of two different interacting molecules, called morphogens, which could establish chemical gradients through a “reaction-diffusion system.”



1952: Without a computer powerful enough to execute his chess program Turochamp, Turing played a game in which he simulated the computer, taking about half an hour to perform each move. The program lost to Turing's colleague Alick Glennie, but won against Champernowne's wife

2012: Chess grandmaster Garry Kasparov completed a game of chess started more than 60 years ago by Alan Turing (Kasparov won in just 16 moves)



AMT's house Holymeade in Wilmslow

January 1952: Turing meets a man called Arnold Murray and invites him over to his house. Murray visits Turing's house on a number of occasions, staying the night. Murray later helps an accomplice break into Turing's house. Turing reports the crime and admits having a sexual relationship with Murray. Homosexual acts are illegal in the UK and so both were charged with gross indecency. Turing is given the choice of being imprisoned or chemically castrated with oestrogen hormone injections. He chooses the latter. Turing's conviction means his security clearance is removed which means he is barred from his cryptopgraphic consultancy for the British government.

07 June 1954: Turing's cleaner finds him dead. The inquest found he had commited suicide by eating an apple laced with cyanide. He was cremated at Woking, Surrey, England.

'The day he died felt like driving through a tunnel and the lights being switched off''

2009: Prime Minister Gordon Brown issued an unequivocal posthumous apology to Mr Turing on behalf of the Government, describing his treatment as "horrifying" and "utterly unfair".

2012: Government rejects a pardon for computer genius Alan Turing, from formal legal reasons

Turing Award

Alan Perlis (1966) · Maurice Vincent Wilkes (1967) · Richard Hamming (1968) · Marvin Minsky (1969) · James H. Wilkinson (1970) · John McCarthy (1971) · Edsger W. Dijkstra (1972) · Charles Bachman (1973) · Donald Knuth (1974) · Allen Newell / Herbert Simon (1975) · Michael O. Rabin / Dana Scott (1976) · John Backus (1977) · Robert Floyd (1978) · Kenneth E. Iverson (1979) · C. A. R. Hoare (1980) · Edgar F. Codd (1981) · Stephen Cook (1982) · Ken Thompson / Dennis Ritchie (1983) · Niklaus Wirth (1984) · Richard Karp (1985) · John Hopcroft / Robert Tarjan (1986) · John Cocke (1987) · Ivan Sutherland (1988) · William Kahan (1989) · Fernando J. Corbató (1990) · Robin Milner (1991) · Butler Lampson (1992) · Juris Hartmanis / Richard Stearns (1993) · Edward Feigenbaum / Raj Reddy (1994) · Manuel Blum (1995) · Amir Pnueli (1996) · Douglas Engelbart (1997) · Jim Gray (1998) · Fred Brooks (1999) · Andrew Yao (2000) · Ole-Johan Dahl / Kristen Nygaard (2001) · Ron Rivest / Adi Shamir / Leonard Adleman (2002) · Alan Kay (2003) · Vint Cerf / Bob Kahn (2004) · Peter Naur (2005) · Frances E. Allen (2006) · Edmund M. Clarke / E. Allen Emerson / Joseph Sifakis (2007) · Barbara Liskov (2008) · Charles P. Thacker (2009), L .Valiant (2010), J. Pearl (2011)

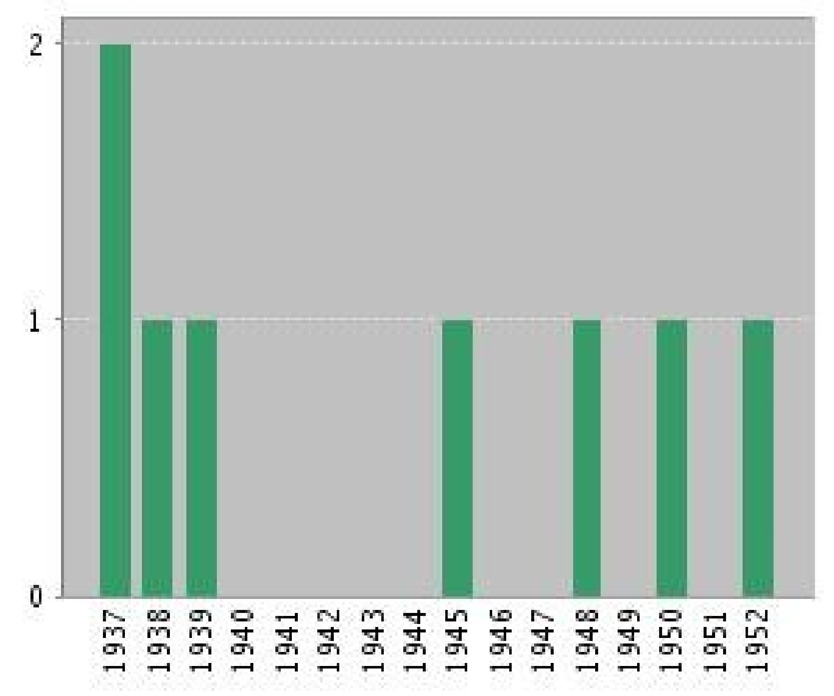
Loebner Prize

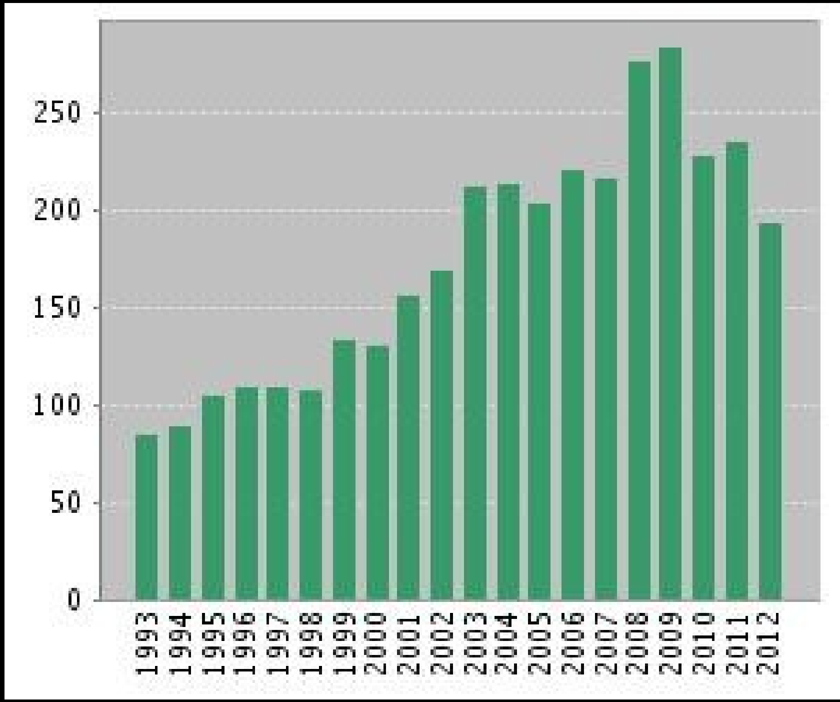
Since 1990, the Loebner Prize is an annual competition in artificial intelligence that awards prizes to the chatterbot considered by the judges to be the most human-like. The format of the competition is that of a standard Turing test

There is also a petition to erect a statue of Turing on the fourth plinth at Trafalgar Square.

Turing's Citation Analysis - Web of Knowledge

Published Items in Each Year **Citations in Each Year**





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Sum of the Times Cited: 4571
Average Citations per Item: 571.38
h-index: 6

Computation
has become
a universal
enabler
of sciences

Summary:

- 1936: On Computable Numbers and an Application to the Entscheidungsproblem
  Proceedings of the London Mathematical Society
- 1948: Rounding-off errors in matrix processes. Quart. J Mech. Appl. Math. 1
- 1950: Computing Machinery and Intelligence. Mind
- 1952: The Chemical Basis of Morphogenesis
  Philosophical Transactions of the Royal Society of London