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Alan Turing

Alan Mathison Turing OBE FRS (/ˈtjʊərɪŋ/; 23 June 1912 – 7 June 1954) was an English mathematician, computer scientist, logician, cryptanalyst, philosopher and theoretical biologist.[6] Turing was highly influential in the development of theoretical computer science, providing a formalisation of the concepts of algorithm and computation with the Turing machine, which can be considered a model of a general-purpose computer.[7][8][9] Turing is widely considered to be the father of theoretical computer science and artificial intelligence.[10] Despite these accomplishments, he was never fully recognised in his home country during his lifetime, due to his homosexuality, which was then a crime in the UK.

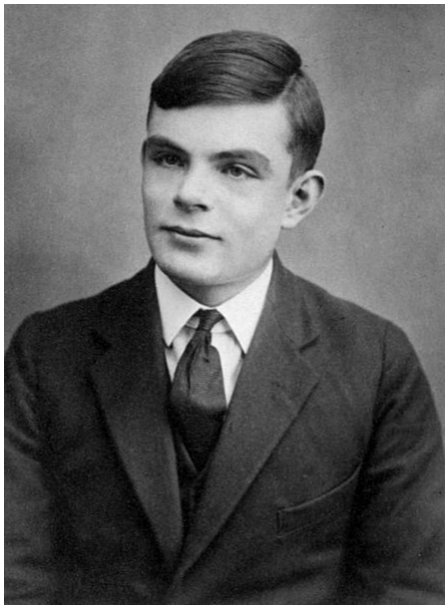
During the Second World War, Turing worked for the Government Code and Cypher School (GC&CS) at Bletchley Park, Britain's codebreaking centre that produced Ultra intelligence. For a time he led Hut 8, the section that was responsible for German naval cryptanalysis. Here, he devised a number of techniques for speeding the breaking of German ciphers, including improvements to the pre-war Polish bombe method, an electromechanical machine that could find settings for the Enigma machine.

Turing played a pivotal role in cracking intercepted coded messages that enabled the Allies to defeat the Nazis in many crucial engagements, including the Battle of the Atlantic, and in so doing helped win the war.[11][12] Counterfactual history is difficult with respect to the effect Ultra intelligence had on the length of the war,[13] but at the upper end it has been estimated that this work shortened the war in Europe by more than two years and saved over 14 million lives.[11]

After the war, Turing worked at the National Physical Laboratory, where he designed the Automatic Computing Engine, which was one of the first designs for a stored-program computer. In 1948, Turing joined Max Newman's Computing Machine Laboratory at the Victoria University of Manchester, where he helped develop the Manchester computers[14] and became interested in mathematical biology. He wrote a paper on the chemical basis of morphogenesis[1] and predicted oscillating chemical reactions such as the Belousov–Zhabotinsky reaction, first observed in the 1960s.

Turing was prosecuted in 1952 for homosexual acts; the Labouchere Amendment had mandated that "gross indecency" was a criminal offence in the UK. He accepted chemical castration treatment, with DES, as an alternative to prison. Turing died in 1954, 16 days before his 42nd birthday, from cyanide poisoning. An inquest determined his death as a suicide, but it has been noted that the known evidence is also consistent with accidental poisoning.[15]

Alan Turing
OBE FRS



Turing c. 1928

Born	Alan Mathison Turing 23 June 1912 Maida Vale, London, England
Died	7 June 1954 (aged 41) Wilmslow, Cheshire, England
Cause of death	Suicide (disputed) by cyanide poisoning
Resting place	Ashes scattered in gardens of Woking Crematorium
Residence	Wilmslow, Cheshire, England
Education	Sherborne School
Alma mater	University of Cambridge (BA, MA) Princeton University (PhD)
Known for	

In 2009, following an Internet campaign, British Prime Minister Gordon Brown made an official public apology on behalf of the British government for "the appalling way he was treated". Queen Elizabeth II granted Turing a posthumous pardon in 2013.[16][17][18] The Alan Turing law is now an informal term for a 2017 law in the United Kingdom that retroactively pardoned men cautioned or convicted under historical legislation that outlawed homosexual acts.[19]

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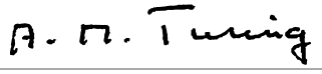
	Cryptanalysis of the Enigma Turing's proof Turing machine Turing test Unorganised machine
Partner(s)	Joan Clarke (engaged in 1941; did not marry)
Awards	Smith's Prize (1936)
Scientific career	
Fields	Logic Mathematics Cryptanalysis Computer science Mathematical and theoretical biology[1]
Institutions	University of Manchester Government Code and Cypher School National Physical Laboratory
Thesis	*Systems of Logic Based on Ordinals* (https://webspace.princeton.edu/users/jedwards/Turing%20Centennial%202012/Mudd%20Archive%20files/12285_AC100_Turing_1938.pdf) (1938)
Doctoral advisor	Alonzo Church[2]
Doctoral students	Robin Gandy,[2][3] Beatrice Worsley[4]
Influences	Max Newman[5]
Signature	
	

Early life and education

Family

Turing was born in Maida Vale, London,[6] while his father, Julius Mathison Turing (1873–1947), was on leave from his position with the Indian Civil Service (ICS) at Chatrapur, then in the Madras Presidency and presently in Odisha state, in India.[20][21] Turing's father was the son of a clergyman, the Rev. John Robert Turing, from a Scottish family of merchants that had been based in the Netherlands and included a baronet. Turing's mother, Julius' wife, was Ethel Sara Turing (née Stoney 1881–1976),[6] daughter of Edward Waller Stoney, chief engineer of the Madras Railways. The Stoneys were a Protestant Anglo-Irish gentry family from both County Tipperary and County Longford, while Ethel herself had spent much of her childhood in County Clare.[22]

Julius' work with the ICS brought the family to British India, where his grandfather had been a general in the Bengal Army. However, both Julius and Ethel wanted their children to be brought up in Britain, so they moved to Maida Vale,[23] London, where Alan Turing was born on 23 June 1912, as recorded by a blue plaque on the outside of the house of his birth,[24][25] later the Colonnade Hotel.[20][26] Turing had an elder brother, John (the father of Sir John Dermot Turing, 12th Baronet of the Turing baronets).[27]

Turing's father's civil service commission was still active and during Turing's childhood years Turing's parents travelled between Hastings in England[28] and India, leaving their two sons to stay with a retired Army couple. At Hastings, Turing stayed at Baston Lodge, Upper Maze Hill, St Leonards-on-Sea, now marked with a blue plaque.[29] The plaque was unveiled on 23 June 2012, the centenary of Turing's birth.[30]

Very early in life, Turing showed signs of the genius that he was later to display prominently.[31] His parents purchased a house in Guildford in 1927, and Turing lived there during school holidays. The location is also marked with a blue plaque.[32]

School

Turing's parents enrolled him at St Michael's, a day school at 20 Charles Road, St Leonards-on-Sea, at the age of six. The headmistress recognised his talent early on, as did many of his subsequent teachers.

Between January 1922 and 1926, Turing was educated at Hazelhurst Preparatory School, an independent school in the village of Frant in Sussex (now East Sussex).[33] In 1926, at the age of 13, he went on to Sherborne School, a boarding independent school in the market town of Sherborne in Dorset. The first day of term coincided with the 1926 General Strike in Britain, but he was so determined to attend, that he rode his bicycle unaccompanied 60 miles (97 km) from Southampton to Sherborne, stopping overnight at an inn.[34]

Turing's natural inclination towards mathematics and science did not earn him respect from some of the teachers at Sherborne, whose definition of education placed more emphasis on the classics. His headmaster wrote to his parents: "I hope he will not fall between two stools. If he is to stay at public school, he must aim at becoming *educated*. If he is to be solely a *Scientific Specialist*, he is wasting his time at a public school".[35] Despite this, Turing continued to show remarkable ability in the studies he loved, solving advanced problems in 1927 without having studied even elementary calculus. In 1928, aged 16, Turing encountered Albert Einstein's work; not only did he grasp it, but it is possible that he managed to deduce Einstein's questioning of Newton's laws of motion from a text in which this was never made explicit.[36]

Christopher Morcom

At Sherborne, Turing formed a significant friendship with fellow pupil Christopher Morcom (1911 – 1930), who has been described as Turing's "first love". Their relationship provided inspiration in Turing's future endeavours, but it was cut short by Morcom's death, in February 1930, from complications of bovine tuberculosis, contracted after drinking infected

cow's milk some years previously.[37][38][39]

The event caused Turing great sorrow. He coped with his grief by working that much harder on the topics of science and mathematics that he had shared with Morcom. In a letter to Morcom's mother Turing said:

> I am sure I could not have found anywhere another companion so brilliant and yet so charming and unconceited. I regarded my interest in my work, and in such things as astronomy (to which he introduced me) as something to be shared with him and I think he felt a little the same about me ... I know I must put as much energy if not as much interest into my work as if he were alive, because that is what he would like me to do.[40]

Turing's relationship with Morcom's mother continued long after Morcom's death, with her sending gifts to Turing, and him sending letters, typically on Morcom's birthdays.[41] A day before the third anniversary of Morcom's death (12 February, 1933), he wrote to Mrs. Morcom:

> I expect you will be thinking of Chris when this reaches you. I shall too, and this letter is just to tell you that I shall be thinking of Chris and of you tomorrow. I am sure that he is as happy now as he was when he was here. Your affectionate Alan.[42]

Some have speculated that Morcom's death was the cause of Turing's atheism and materialism.[43] Apparently, at this point in his life he still believed in such concepts as a spirit, independent of the body and surviving death. In a later letter, also written to Morcom's mother, Turing said:

> Personally, I believe that spirit is really eternally connected with matter but certainly not by the same kind of body ... as regards the actual connection between spirit and body I consider that the body can hold on to a 'spirit', whilst the body is alive and awake the two are firmly connected. When the body is asleep I cannot guess what happens but when the body dies, the 'mechanism' of the body, holding the spirit is gone and the spirit finds a new body sooner or later, perhaps immediately.[44]

University and work on computability

After Sherborne, Turing studied as an undergraduate from 1931 to 1934 at King's College, Cambridge,[6] where he was awarded first-class honours in mathematics. In 1935, at the age of 22, he was elected a fellow of King's on the strength of a dissertation in which he proved the central limit theorem.[45] Unknown to the committee, the theorem had already been proven, in 1922, by Jarl Waldemar Lindeberg.[46] A blue plaque at the college was unveiled on the centenary of his birth on 23 June 2012 and is now installed at the college's Keynes Building on King's Parade.[47][48]

In 1936, Turing published his paper "On Computable Numbers, with an Application to the Entscheidungsproblem" (1936).[49] In this paper, Turing reformulated Kurt Gödel's 1931 results on the limits of proof and computation, replacing Gödel's universal arithmetic-based formal language with the formal and simple hypothetical devices that became known as Turing machines. The *Entscheidungsproblem* (decision problem) was originally posed by German mathematician David Hilbert in 1928. Turing proved that his "universal computing machine" would be capable of performing any conceivable mathematical computation if it were representable as an algorithm. He went on to prove that there was no solution to the *decision problem* by first showing that the halting problem for Turing machines is undecidable: It is not possible to decide algorithmically whether a Turing machine will ever halt.

Although Turing's proof was published shortly after Alonzo Church's equivalent proof using his lambda calculus,[50] Turing's approach is considerably more accessible and intuitive than Church's.[51] It also included a notion of a 'Universal Machine' (now known as a universal Turing machine), with the idea that such a machine could perform the tasks of any other computation machine (as indeed could Church's lambda calculus). According to the Church–Turing thesis, Turing machines and the lambda calculus are capable of computing anything that is computable. John von Neumann acknowledged that the central concept of the modern computer was due to Turing's paper.[52] To this day, Turing machines are a central object of study in theory of computation.

King's College, Cambridge, where Turing was a student in 1931 and became a Fellow in 1935. The computer room is named after him.

From September 1936 to July 1938, Turing spent most of his time studying under Church at Princeton University,[4] in the second year as a Jane Eliza Procter Visiting Fellow. In addition to his purely mathematical work, he studied cryptology and also built three of four stages of an electro-mechanical binary multiplier.[53] In June 1938, he obtained his PhD from the Department of Mathematics at Princeton;[54] his dissertation, *Systems of Logic Based on Ordinals*,[55][56] introduced the concept of ordinal logic and the notion of relative computing, where Turing machines are augmented with so-called oracles, allowing the study of problems that cannot be solved by Turing machines. John von Neumann wanted to hire him as his postdoctoral assistant, but he went back to England.[57]

Career and research

When Turing returned to Cambridge, he attended lectures given in 1939 by Ludwig Wittgenstein about the foundations of mathematics.[58] The lectures have been reconstructed verbatim, including interjections from Turing and other students, from students' notes.[59] Turing and Wittgenstein argued and disagreed, with Turing defending formalism and Wittgenstein propounding his view that mathematics does not discover any absolute truths, but rather invents them.[60]

Cryptanalysis

During the Second World War, Turing was a leading participant in the breaking of German ciphers at Bletchley Park. The historian and wartime codebreaker Asa Briggs has said, "You needed exceptional talent, you needed genius at Bletchley and Turing's was that genius."[61]

From September 1938, Turing had been working part-time with the Government Code and Cypher School (GC&CS), the British codebreaking organisation. He concentrated on cryptanalysis of the Enigma with Dilly Knox, a senior GC&CS codebreaker.[62] Soon after the July 1939 Warsaw meeting at which the Polish Cipher Bureau had provided the British and French with the details of the wiring of Enigma rotors and their method of decrypting Enigma code messages, Turing and Knox started to work on a less fragile approach to the problem.[63] The Polish method relied on an insecure indicator procedure that the Germans were likely to change, which they did in May 1940. Turing's approach was more general, using crib-based decryption for which he produced the functional specification of the bombe (an improvement of the Polish Bomba).[64]

On 4 September 1939, the day after the UK declared war on Germany, Turing reported to Bletchley Park, the wartime station of GC&CS.[65] Specifying the bombe was the first of five major cryptanalytical advances that Turing made during the war. The others were: deducing the indicator procedure used by the German navy; developing a statistical procedure for making much more efficient use of the bombes dubbed *Banburismus*; developing a procedure for working out the cam settings of the wheels of the Lorenz SZ 40/42 (*Tunny*) dubbed *Turingery* and, towards the end of the war, the development of a portable secure voice scrambler at Hanslope Park that was codenamed *Delilah*.

By using statistical techniques to optimise the trial of different possibilities in the code breaking process, Turing made an innovative contribution to the subject. He wrote two papers discussing mathematical approaches, titled *The Applications of Probability to Cryptography*[66] and *Paper on Statistics of Repetitions*,[67] which were of such value to GC&CS and its successor GCHQ that they were not released to the UK National Archives until April 2012, shortly before the centenary of his birth. A GCHQ mathematician, "who identified himself only as Richard," said at the time that the fact that the contents had been restricted for some 70 years demonstrated their importance, and their relevance to post-war cryptanalysis:[68]

Two cottages in the stable yard at Bletchley Park. Turing worked here in 1939 and 1940, before moving to Hut 8.

> [He] said the fact that the contents had been restricted "shows what a tremendous importance it has in the foundations of our subject". ... The papers detailed using "mathematical analysis to try and determine which are the more likely settings so that they can be tried as quickly as possible." ... Richard said that GCHQ had now "squeezed the juice" out of the two papers and was "happy for them to be released into the public domain".

Turing had a reputation for eccentricity at Bletchley Park. He was known to his colleagues as "Prof" and his treatise on Enigma was known as the "Prof's Book".[69] According to historian Ronald Lewin, Jack Good, a cryptanalyst who worked with Turing, said of his colleague:

> In the first week of June each year he would get a bad attack of hay fever, and he would cycle to the office wearing a service gas mask to keep the pollen off. His bicycle had a fault: the chain would come off at regular intervals. Instead of having it mended he would count the number of times the pedals went round and would get off the bicycle in time to adjust the chain by hand. Another of his eccentricities is that he chained his mug to the radiator pipes to prevent it being stolen.[70]

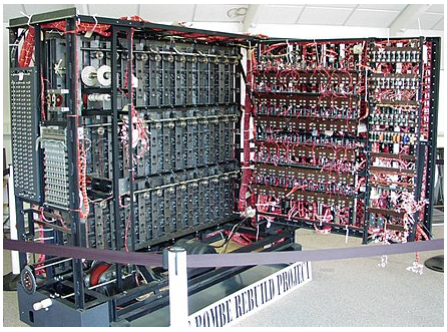
While working at Bletchley, Turing, who was a talented long-distance runner, occasionally ran the 40 miles (64 km) to London when he was needed for meetings,[71] and he was capable of world-class marathon standards.[72][73] Turing tried out for the 1948 British Olympic team but he was hampered by an injury. His tryout time for the marathon was only 11 minutes slower than British silver medallist Thomas Richards' Olympic race time of 2 hours 35 minutes. He was Walton Athletic Club's best runner, a fact discovered when he passed the group while running alone.[74][75][76]

In 1946, Turing was appointed an Officer of the Order of the British Empire (OBE) by King George VI for his wartime services, but his work remained secret for many years.[77][78]

Bombe

Within weeks of arriving at Bletchley Park,[65] Turing had specified an electromechanical machine called the bombe, which could break Enigma more effectively than the Polish *bomba kryptologiczna*, from which its name was derived. The bombe, with an enhancement suggested by mathematician Gordon Welchman, became one of the primary tools, and the major automated one, used to attack Enigma-enciphered messages.[79]

The bombe searched for possible correct settings used for an Enigma message (i.e., rotor order, rotor settings and plugboard settings) using a suitable *crib*: a fragment of probable plaintext. For each possible setting of the rotors (which had on the order of 10^{19} states, or 10^{22} states for the four-rotor U-boat variant),[80] the bombe performed a chain of logical deductions based on the crib, implemented electromechanically.


A complete and working replica of a bombe now at The National Museum of Computing on Bletchley Park

The bombe detected when a contradiction had occurred and ruled out that setting, moving on to the next. Most of the possible settings would cause contradictions and be discarded, leaving only a few to be investigated in detail. A contradiction would occur when an enciphered letter would be turned back into the same plaintext letter, which was impossible with the Enigma. The first bombe was installed on 18 March 1940.[81]

By late 1941, Turing and his fellow cryptanalysts Gordon Welchman, Hugh Alexander and Stuart Milner-Barry were frustrated. Building on the work of the Poles, they had set up a good working system for decrypting Enigma signals, but their limited staff and bombes meant they could not translate all the signals. In the summer, they had considerable success, and shipping losses had fallen to under 100,000 tons a month; however, they badly needed more resources to keep abreast of German adjustments. They had tried to get more people and fund more bombes through the proper channels, but had failed.[82]

On 28 October they wrote directly to Winston Churchill explaining their difficulties, with Turing as the first named. They emphasised how small their need was compared with the vast expenditure of men and money by the forces and compared with the level of assistance they could offer to the forces.[82] As Andrew Hodges, biographer of Turing, later wrote, "This letter had an electric effect."[83] Churchill wrote a memo to General Ismay, which read: "ACTION THIS DAY. Make sure they have all they want on extreme priority and report to me that this has been done." On 18 November, the chief of the secret service reported that every possible measure was being taken.[83] The cryptographers at Bletchley Park did not know of the Prime Minister's response, but as Milner-Barry recalled, "All that we did notice was that almost from that day the rough ways began miraculously to be made smooth."[84] More than two hundred bombes were in operation by the end of the war.[85]

Hut 8 and the naval Enigma

Turing decided to tackle the particularly difficult problem of German naval Enigma "because no one else was doing anything about it and I could have it to myself".[87] In December 1939, Turing solved the essential part of the naval indicator system, which was more complex than the indicator systems used by the other services.[87][88]

That same night, he also conceived of the idea of *Banburismus*, a sequential statistical technique (what Abraham Wald later called sequential analysis) to assist in breaking the naval Enigma, "though I was not sure that it would work in practice, and was not, in fact, sure until some days had actually broken."[87] For this, he invented a measure of weight of evidence that he called the *ban*. *Banburismus* could rule out certain sequences of the Enigma rotors, substantially reducing the time needed to test settings on the bombes.[89] Later this sequential process of accumulating sufficient weight of evidence using decibans (one tenth of a ban) was used in Cryptanalysis of the Lorenz cipher[90]

Turing travelled to the United States in November 1942[91] and worked with US Navy cryptanalysts on the naval Enigma and bombe construction in Washington; he also visited their Computing Machine Laboratory in Dayton, Ohio.

Turing's reaction to the American bombe design was far from enthusiastic:

> The American Bombe programme was to produce 336 Bombes, one for each wheel order. I used to smile inwardly at the conception of Bombe hut routine implied by this programme, but thought that no particular purpose would be served by pointing out that we would not really use them in that way.
>
> Their test (of commutators) can hardly be considered conclusive as they were not testing for the bounce with electronic stop finding devices. Nobody seems to be told about rods or offiziers or banburismus unless they are really going to do something about it.[92]

Statue of Turing by Stephen Kettle at Bletchley Park, commissioned by Sidney Frank, built from half a million pieces of Welsh slate.[86]

During this trip, he also assisted at Bell Labs with the development of secure speech devices.[93] He returned to Bletchley Park in March 1943. During his absence, Hugh Alexander had officially assumed the position of head of Hut 8, although Alexander had been *de facto* head for some time (Turing having little interest in the day-to-day running of the section). Turing became a general consultant for cryptanalysis at Bletchley Park.[94]

Alexander wrote of Turing's contribution:

> There should be no question in anyone's mind that Turing's work was the biggest factor in Hut 8's success. In the early days, he was the only cryptographer who thought the problem worth tackling and not only was he primarily responsible for the main theoretical work within the Hut, but he also shared with Welchman and Keen the chief credit for the invention of the bombe. It is always difficult to say that anyone is 'absolutely indispensable', but if anyone was indispensable to Hut 8, it was Turing. The pioneer's work always tends to be forgotten when experience and routine later make everything seem easy and many of us in Hut 8 felt that the magnitude of Turing's contribution was never fully realised by the outside world.[95]

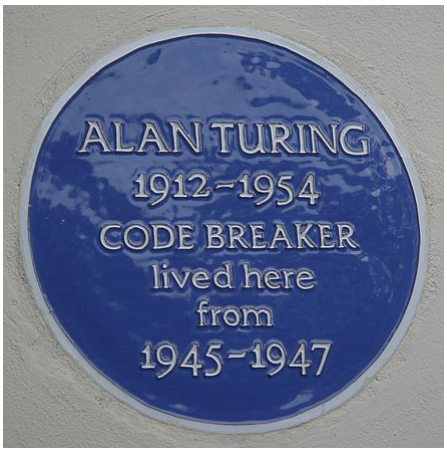
Turingery

In July 1942, Turing devised a technique termed *Turingery* (or jokingly *Turingismus*)[96] for use against the Lorenz cipher messages produced by the Germans' new *Geheimschreiber* (secret writer) machine. This was a teleprinter rotor cipher attachment codenamed *Tunny* at Bletchley Park. Turingery was a method of *wheel-breaking*, i.e., a procedure for working out the cam settings of Tunny's wheels.[97] He also introduced the Tunny team to Tommy Flowers who, under the guidance of Max Newman, went on to build the Colossus computer, the world's first programmable digital electronic computer, which replaced a simpler prior machine (the Heath Robinson), and whose superior speed allowed the statistical decryption techniques to be applied usefully to the messages.[98] Some have mistakenly said that Turing was a key figure in the design of the Colossus computer. Turingery and the statistical approach of Banburismus undoubtedly fed into the thinking about cryptanalysis of the Lorenz cipher,[99][100] but he was not directly involved in the Colossus development.[101]

Delilah

Following his work at Bell Labs in the US,[102] Turing pursued the idea of electronic enciphering of speech in the telephone system. In the latter part of the war, he moved in order to work for the Secret Service's Radio Security Service (later HMGCC) at Hanslope Park. At the park, he further developed his knowledge of electronics with the assistance of engineer Donald Bayley. Together they undertook the design and construction of a portable secure voice communications machine codenamed *Delilah*.[103] The machine was intended for different applications, but it lacked the capability for use with long-distance radio transmissions. In any case, Delilah was completed too late to be used during the war. Though the system worked fully, with Turing demonstrating it to officials by encrypting and decrypting a recording of a Winston Churchill speech, Delilah was not adopted for use.[104] Turing also consulted with Bell Labs on the development of SIGSALY, a secure voice system that was used in the later years of the war.

Early computers and the Turing test



Plaque, 78 High Street, Hampton

Between 1945 and 1947, Turing lived in Hampton, London,[105] while he worked on the design of the ACE (Automatic Computing Engine) at the National Physical Laboratory (NPL). He presented a paper on 19 February 1946, which was the first detailed design of a stored-program computer.[106] Von Neumann's incomplete *First Draft of a Report on the EDVAC* had predated Turing's paper, but it was much less detailed and, according to John R. Womersley, Superintendent of the NPL Mathematics Division, it "contains a number of ideas which are Dr. Turing's own".[107] Although ACE was a feasible design, the secrecy surrounding the wartime work at Bletchley Park led to delays in starting the project and he became disillusioned. In late 1947 he returned to Cambridge for a sabbatical year during which he produced a seminal work on *Intelligent Machinery* that was not published in his lifetime.[108] While he was at Cambridge, the Pilot ACE was being built in his absence. It executed its first program on 10 May 1950, and a number of later computers around the world owe much to it, including the English Electric DEUCE and the American Bendix G-15. The full version of Turing's ACE was not built until after his death.[109]

According to the memoirs of the German computer pioneer Heinz Billing from the Max Planck Institute for Physics, published by Genscher, Düsseldorf, there was a meeting between Turing and Konrad Zuse.[110] It took place in Göttingen in 1947. The interrogation had the form of a colloquium. Participants were Womersley, Turing, Porter from England and a few German researchers like Zuse, Walther, and Billing (for more details see Herbert Bruderer, *Konrad Zuse und die Schweiz*).

In 1948, Turing was appointed reader in the Mathematics Department at the Victoria University of Manchester. A year later, he became Deputy Director of the Computing Machine Laboratory, where he worked on software for one of the earliest stored-program computers—the Manchester Mark 1. Turing wrote the first version of the Programmer's Manual for this machine, and was recruited by Ferranti as a consultant in the development of their commercialised machine, the Ferranti Mark 1. He continued to be paid consultancy fees by Ferranti until his death.[111] During this time, he continued to do more abstract work in mathematics,[112] and in "Computing Machinery and Intelligence" (*Mind*, October 1950), Turing addressed the problem of artificial intelligence, and proposed an experiment that became known as the Turing test, an attempt to define a standard for a machine to be called "intelligent". The 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.[113] In the paper, Turing

suggested that rather than building a program to simulate the adult mind, it would be better rather to produce a simpler one to simulate a child's mind and then to subject it to a course of education. 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.

In 1948 Turing, working with his former undergraduate colleague, D.G. Champernowne, began writing a chess program for a computer that did not yet exist. By 1950, the program was completed and dubbed the Turbochamp.[114] In 1952, he tried to implement it on a Ferranti Mark 1, but lacking enough power, the computer was unable to execute the program. Instead, Turing "ran" the program by flipping through the pages of the algorithm and carrying out its instructions on a chessboard, taking about half an hour per move. The game was recorded.[115] According to Garry Kasparov, Turing's program "played a recognizable game of chess."[116] The program lost to Turing's colleague Alick Glennie, although it is said that it won a game against Champernowne's wife, Isabel.[117]

His Turing test was a significant, characteristically provocative, and lasting contribution to the debate regarding artificial intelligence, which continues after more than half a century.[118]

Pattern formation and mathematical biology

When Turing was 39 years old in 1951, he turned to mathematical biology, finally publishing his masterpiece "The Chemical Basis of Morphogenesis" in January 1952. He was interested in morphogenesis, the development of patterns and shapes in biological organisms. Among other things, he wanted to understand Fibonacci phyllotaxis, the existence of Fibonacci numbers in plant structures.[119] He suggested that a system of chemicals reacting with each other and diffusing across space, termed a reaction-diffusion system, could account for "the main phenomena of morphogenesis".[120] He used systems of partial differential equations to model catalytic chemical reactions. For example, if a catalyst A is required for a certain chemical reaction to take place, and if the reaction produced more of the catalyst A, then we say that the reaction is autocatalytic, and there is positive feedback that can be modelled by nonlinear differential equations. Turing discovered that patterns could be created if the chemical reaction not only produced catalyst A, but also produced an inhibitor B that slowed down the production of A. If A and B then diffused through the container at different rates, then you could have some regions where A dominated and some where B did. To calculate the extent of this, Turing would have needed a powerful computer, but these were not so freely available in 1951, so he had to use linear approximations to solve the equations by hand. These calculations gave the right qualitative results, and produced, for example, a uniform mixture that oddly enough had regularly spaced fixed red spots. The Russian biochemist Boris Belousov had performed experiments with similar results, but could not get his papers published because of the contemporary prejudice that any such thing violated the second law of thermodynamics. Belousov was not aware of Turing's paper in the *Philosophical Transactions of the Royal Society*.[121]

Although published before the structure and role of DNA was understood, Turing's work on morphogenesis remains relevant today and is considered a seminal piece of work in mathematical biology.[122] One of the early applications of Turing's paper was the work by James Murray explaining spots and stripes on the fur of cats, large and small.[123][124][125] Further research in the area suggests that Turing's work can partially explain the growth of "feathers, hair follicles, the branching pattern of lungs, and even the left-right asymmetry that puts the heart on the left side of the chest."[126] In 2012, Sheth, et al. found that in mice, removal of Hox genes causes an increase in the number of digits without an increase in the overall size of the limb, suggesting that Hox genes control digit formation by tuning the wavelength of a Turing-type mechanism.[127] Later papers were not available until *Collected Works of A. M. Turing* was published in 1992.[128]

Personal life

In 1941, Turing proposed marriage to Hut 8 colleague Joan Clarke, a fellow mathematician and cryptanalyst, but their engagement was short-lived. After admitting his homosexuality to his fiancée, who was reportedly "unfazed" by the revelation, Turing decided that he could not go through with the marriage.[129]

Conviction for indecency

In January 1952, Turing was 39 when he started a relationship with Arnold Murray, a 19-year-old unemployed man. Just before Christmas, Turing was walking along Manchester's Oxford Road when he met Murray just outside the Regal Cinema and invited him to lunch. On 23 January, Turing's house was burgled. Murray told Turing that he and the burglar were acquainted, and Turing reported the crime to the police. During the investigation, he acknowledged a sexual relationship with Murray. Homosexual acts were criminal offences in the United Kingdom at that time,[130] and both men were charged with "gross indecency" under Section 11 of the Criminal Law Amendment Act 1885.[131] Initial committal proceedings for the trial were held on 27 February during which Turing's solicitor "reserved his defence", i.e., did not argue or provide evidence against the allegations.

Turing was later convinced by the advice of his brother and his own solicitor, and he entered a plea of guilty.[132] The case, *Regina v. Turing and Murray,* was brought to trial on 31 March 1952.[133] Turing was convicted and given a choice between imprisonment and probation, which would be conditional on his agreement to undergo hormonal treatment designed to reduce libido. He accepted the option of treatment via injections of what was then called stilboestrol (now known as diethylstilbestrol or DES), a synthetic oestrogen; this treatment was continued for the course of one year. The treatment rendered Turing impotent and caused gynaecomastia,[134] fulfilling in the literal sense Turing's prediction that "no doubt I shall emerge from it all a different man, but quite who I've not found out".[135][136] Murray was given a conditional discharge.[137]

Turing's conviction led to the removal of his security clearance and barred him from continuing with his cryptographic consultancy for the Government Communications Headquarters (GCHQ), the British signals intelligence agency that had evolved from GC&CS in 1946, though he kept his academic job. He was denied entry into the United States after his conviction in 1952, but was free to visit other European countries. Turing was never accused of espionage but, in common with all who had worked at Bletchley Park, he was prevented by the Official Secrets Act from discussing his war work.[138]

Death

On 8 June 1954, Turing's housekeeper found him dead; he had died the previous day. Cyanide poisoning was established as the cause of death.[139] When his body was discovered, an apple lay half-eaten beside his bed, and although the apple was not tested for cyanide,[140] it was speculated that this was the means by which Turing had consumed a fatal dose. An inquest determined that he had committed suicide. Andrew Hodges and another biographer, David Leavitt, have both speculated that Turing was re-enacting a scene from the Walt Disney film *Snow White and the Seven Dwarfs* (1937), his favourite fairy tale. Both men noted that (in Leavitt's words) he took "an especially keen pleasure in the scene where the Wicked Queen immerses her apple in the poisonous brew."[141] Turing's remains were cremated at Woking Crematorium on 12 June 1954[142] and his ashes were scattered in the gardens of the crematorium, just as his father's had been.[143]

Philosophy professor Jack Copeland has questioned various aspects of the coroner's historical verdict. He suggested an alternative explanation for the cause of Turing's death: the accidental inhalation of cyanide fumes from an apparatus used to electroplate gold onto spoons. The potassium cyanide was used to dissolve the gold. Turing had such an apparatus set up in his tiny spare room. Copeland noted that the autopsy findings were more consistent with inhalation than with ingestion of the poison. Turing also habitually ate an apple before going to bed, and it was not unusual for the apple to be discarded half-eaten.[144] In addition, Turing had reportedly borne his legal setbacks and hormone treatment (which had

been discontinued a year previously) "with good humour" and had shown no sign of despondency prior to his death. He even set down a list of tasks that he intended to complete upon returning to his office after the holiday weekend.[144] Turing's mother believed that the ingestion was accidental, resulting from her son's careless storage of laboratory chemicals.[145] Biographer Andrew Hodges theorised that Turing arranged the delivery of the equipment in order to deliberately allow his mother plausible deniability in regard to any suicide claims.[146]

Conspiracy theorists pointed out that Turing was the cause of intense anxiety to the British authorities at the time of his death. The secret services feared that communists would entrap prominent homosexuals and use them to gather intelligence. Turing was still engaged in highly classified work when he was also a practising homosexual who holidayed in European countries near the Iron Curtain. It is possible that the secret services considered him too great a security risk and assassinated one of the most brilliant minds in their employ.[147]

Turing's OBE currently held in Sherborne School archives

Turing believed in extrasensory perception,[148][149] and it has been suggested that his belief in fortune-telling may have caused his depressed mood. As a youth, Turing had been told by a gypsy fortune-teller that he would be a genius.[143] Shortly before his death, during a day-trip to St Annes-on Sea with the Greenbaum family, Turing again decided to consult a fortune-teller.[143] According to the Greenbaums' daughter, Barbara:

> But it was a lovely sunny day and Alan was in a cheerful mood and off we went... Then he thought it would be a good idea to go to the Pleasure Beach at Blackpool. We found a fortune-teller's tent and Alan said he'd like to go in so we waited around for him to come back... And this sunny, cheerful visage had shrunk into a pale, shaking, horror-stricken face. Something had happened. We don't know what the fortune-teller said but he obviously was deeply unhappy. I think that was probably the last time we saw him before we heard of his suicide."[150]

Government apology and pardon

In August 2009, British programmer John Graham-Cumming started a petition urging the British government to apologise for Turing's prosecution as a homosexual.[151][152] The petition received more than 30,000 signatures.[153][154] The Prime Minister, Gordon Brown, acknowledged the petition, releasing a statement on 10 September 2009 apologising and describing the treatment of Turing as "appalling":[153][155]

> Thousands of people have come together to demand justice for Alan Turing and recognition of the appalling way he was treated. While Turing was dealt with under the law of the time and we can't put the clock back, his treatment was of course utterly unfair and I am pleased to have the chance to say how deeply sorry I and we all are for what happened to him ... So on behalf of the British government, and all those who live freely thanks to Alan's work I am very proud to say: we're sorry, you deserved so much better.[153][156]

In December 2011, William Jones created an e-petition[157] requesting that the British government pardon Turing for his conviction of "gross indecency":[158]

> We ask the HM Government to grant a pardon to Alan Turing for the conviction of "gross indecency". In 1952, he was convicted of "gross indecency" with another man and was forced to undergo so-called "organo-therapy"—chemical castration. Two years later, he killed himself with cyanide, aged just 41. Alan Turing was driven to a terrible despair and early death by the nation he'd done so much to save. This remains a shame on the British government and British history. A pardon can go some way to healing this damage. It may act as an apology to many of the other gay men, not as well-known as Alan Turing, who were subjected to these laws.[157]

The petition gathered over 37,000 signatures,[18][157] and was supported by Manchester MP John Leech but the request was discouraged by Justice Minister Lord McNally, who said:[159]

> A posthumous pardon was not considered appropriate as Alan Turing was properly convicted of what at the time was a criminal offence. He would have known that his offence was against the law and that he would be prosecuted. It is tragic that Alan Turing was convicted of an offence that now seems both cruel and absurd—particularly poignant given his outstanding contribution to the war effort. However, the law at the time required a prosecution and, as such, long-standing policy has been to accept that such convictions took place and, rather than trying to alter the historical context and to put right what cannot be put right, ensure instead that we never again return to those times.[160]

John Leech, the MP for Manchester Withington (2005–15), submitted several bills to Parliament[161] and campaigned with Jones to secure the pardon. Leech made the case in the House of Commons that Turing's contribution to the war made him a national hero and that it was "ultimately just embarrassing" that the conviction still stood.[162] Leech continued to take the bill through Parliament and campaigned for several years until it was passed.[163]

At the UK premiere of a film based on Turing's life, *The Imitation Game*, the producers thanked Leech for bringing the topic to public attention and securing Turing's pardon.[164] His campaign turned to acquiring pardons for the 75,000 other men convicted of the same crime. Leech's campaign gained public support from leading scientists, including Stephen Hawking.[165]

On 26 July 2012, a bill was introduced in the House of Lords to grant a statutory pardon to Turing for offences under section 11 of the Criminal Law Amendment Act 1885, of which he was convicted on 31 March 1952.[166] Late in the year in a letter to *The Daily Telegraph*, the physicist Stephen Hawking and 10 other signatories including the Astronomer Royal Lord Rees, President of the Royal Society Sir Paul Nurse, Lady Trumpington (who worked for Turing during the war) and Lord Sharkey (the bill's sponsor) called on Prime Minister David Cameron to act on the pardon request.[167] The government indicated it would support the bill,[168][169][170] and it passed its third reading in the Lords in October.[171]

At the bill's second reading in the House of Commons on 29 November 2013, Conservative MP Christopher Chope objected to the bill, delaying its passage. The bill was due to return to the House of Commons on 28 February 2014,[172] but before the bill could be debated in the House of Commons,[173] the government elected to proceed under the royal prerogative of mercy. On 24 December 2013, Queen Elizabeth II signed a pardon for Turing's conviction for "gross indecency", with immediate effect.[17] Announcing the pardon, Lord Chancellor Chris Grayling said Turing deserved to be "remembered and recognised for his fantastic contribution to the war effort" and not for his later criminal conviction.[16][18] The Queen officially pronounced Turing pardoned in August 2014.[174] The Queen's action is only the fourth royal pardon granted since the conclusion of the Second World War.[175] Pardons are normally granted only when the person is technically innocent, and a request has been made by the family or other interested party; neither condition was met in regard to Turing's conviction.[176]

In a letter to the Prime Minister, David Cameron, human rights advocate Peter Tatchell criticised the decision to single out Turing due to his fame and achievements when thousands of others convicted under the same law have not received pardons.[177] Tatchell also called for a new investigation into Turing's death:

> A new inquiry is long overdue, even if only to dispel any doubts about the true cause of his death—including speculation that he was murdered by the security services (or others). I think murder by state agents is unlikely. There is no known evidence pointing to any such act. However, it is a major failing that this possibility has never been considered or investigated.[178]

In September 2016, the government announced its intention to expand this retroactive exoneration to other men convicted of similar historical indecency offences, in what was described as an "Alan Turing law".[179][180] The Alan Turing law is now an informal term for the law in the United Kingdom, contained in the Policing and Crime Act 2017, which serves as an amnesty law to retroactively pardon men who were cautioned or convicted under historical legislation that outlawed homosexual acts. The law applies in England and Wales.[181]

Awards, honours, and tributes

Turing was appointed an officer of the Order of the British Empire 1946.[78] He was also elected a Fellow of the Royal Society (FRS) in 1951.[7] Several things are named in his honour:

The Alan Turing Building at the University of Manchester in 2008

- Alan Turing Institute
- Church-Turing thesis
- Good–Turing frequency estimation
- Turing completeness
- Turing degree
- Turing fixed-point combinator
- Turing Institute
- Turing Lecture
- Turing machine
- Turing patterns
- Turing reduction
- Turing switch
- Turing test

Posthumous tributes

Various institutions have paid tribute to Turing by naming things after him including:

- The computer room at King's College, Cambridge, Turing's alma mater, is called the Turing Room.[182]
- The Turing Room at the University of Edinburgh's School of Informatics houses a bust of Turing by Eduardo Paolozzi, and a set (No. 42/50) of his Turing prints (2000).[183]
- The University of Surrey has a statue of Turing on their main piazza[184] and one of the buildings of Faculty of Engineering and Physical Sciences is named after him.[185]
- Istanbul Bilgi University organises an annual conference on the theory of computation called "Turing Days".[186]
- The University of Texas at Austin has an honours computer science programme named the Turing Scholars.[187]
- In the early 1960s, Stanford University named the sole lecture room of the Polya Hall Mathematics building "Alan Turing Auditorium".[188]

- One of the amphitheatres of the Computer Science department (LIFL[189]) at the University of Lille in northern France is named in honour of Alan M. Turing (the other amphitheatre is named after Kurt Gödel).
- The University of Washington has a computer laboratory named after Turing.[190]
- Oxford Brookes University,[191] the University of Manchester, the Open University, the University of Wolverhampton and Aarhus University (in Aarhus, Denmark) all have buildings named after Turing.
- Alan Turing Road in the Surrey Research Park[185] and the Alan Turing Way, part of the Manchester inner ring road. Alan Turing road in Loughborough[192] are named after Turing.
- Carnegie Mellon University has a granite bench, situated in the Hornbostel Mall, with the name "A.M. Turing" carved across the top, "Read" down the left leg, and "Write" down the other.[193]
- The University of Oregon has a bust of Turing on the side of Deschutes Hall, the computer science building.[194]
- The École Polytechnique Fédérale de Lausanne has a road and a square named after Turing (Chemin Alan Turing and Place Alan Turing).[195]
- The Faculty of Informatics and Information Technologies Slovak University of Technology in Bratislava, Slovakia, has a lecture room named "Turing Auditorium".[196]
- The Paris Diderot University has a lecture room named "Amphithéâtre Turing".[197]
- The Faculty of Mathematics and Computer Science at the University of Würzburg has a lecture hall named "Turing Hörsaal".[198]
- The Paul Sabatier University in Toulouse has a lecture room named "Amphithéâtre Turing" (Bâtiment U4).[199]
- The largest conference hall at the Amsterdam Science Park is named Turingzaal.[200]
- King's College London's School of Natural and Mathematical Sciences awards the Alan Turing Centenary Prize.[201]
- The University of Kent named the Turing College after him at their Canterbury campus.[202]
- The campus of the École polytechnique has a building named after Turing; it is a research centre whose premises are shared by the École Polytechnique, the INRIA and Microsoft.[203]
- The University of Toronto developed the Turing programming language in 1982, named after Turing.
- The campus of State University of Campinas in Brazil has an avenue, one of its largest, named after Turing.[204]
- The Department of Computer Science at Pontifical Catholic University of Chile, the University of Buenos Aires, the Polytechnic University of Puerto Rico, Los Andes University in Bogotá, Colombia, King's College, Cambridge, Bangor University in Wales, the University of Mons in Belgium, the University of Turin (Università degli Studi di Torino), the University of Puerto Rico at Humacao, Keele University and the Faculty of Computer Science, Electronics and Telecommunications of AGH University of Science and Technology, have buildings named after Turing.
- Ghent University named a computer room after Turing, in their department of Computer Science and Applied Mathematics.[205]
- Nvidia unveiled their line of GeForce Graphics Cards based on the Turing microarchitecture, which in turn was named after Turing. The architecture introduces the first consumer products capable of real-time raytracing, which has been a longstanding goal of the computer graphics industry.

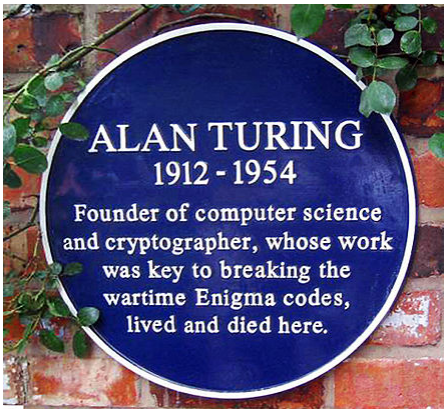
A biography published by the Royal Society shortly after Turing's death,[7] while his wartime work was still subject to the Official Secrets Act, recorded:

> Three remarkable papers written just before the war, on three diverse mathematical subjects, show the quality of the work that might have been produced if he had settled down to work on some big problem at that critical time. For his work at the Foreign Office he was awarded the OBE.[7]

Since 1966, the Turing Award has been given annually by the Association for Computing Machinery for technical or theoretical contributions to the computing community. It is widely considered to be the computing world's highest honour, equivalent to the Nobel Prize.[206]

On 23 June 1998, on what would have been Turing's 86th birthday, his biographer, Andrew Hodges, unveiled an official English Heritage blue plaque at his birthplace in Warrington Crescent, London, later the Colonnade Hotel.[207][208] To mark the 50th anniversary of his death, a memorial plaque was unveiled on 7 June 2004 at his former residence, Hollymeade, in Wilmslow, Cheshire.[209]

On 13 March 2000, Saint Vincent and the Grenadines issued a set of postage stamps to celebrate the greatest achievements of the 20th century, one of which carries a portrait of Turing against a background of repeated 0s and 1s, and is captioned: "1937: Alan Turing's theory of digital computing". On 1 April 2003, Turing's work at Bletchley Park was named an IEEE Milestone.[210] On 28 October 2004, a bronze statue of Turing sculpted by John W. Mills was unveiled at the University of Surrey in Guildford, marking the 50th anniversary of Turing's death; it portrays him carrying his books across the campus.[184]

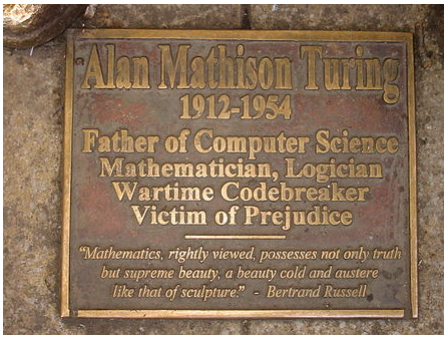


A blue plaque marking Turing's home at Wilmslow, Cheshire

Turing was one of four mathematicians examined in the BBC documentary entitled *Dangerous Knowledge* (2008).[211] The *Princeton Alumni Weekly* named Turing the second most significant alumnus in the history of Princeton University, second only to President James Madison. A 1.5-ton, life-size statue of Turing was unveiled on 19 June 2007 at Bletchley Park. Built from approximately half a million pieces of Welsh slate, it was sculpted by Stephen Kettle, having been commissioned by the American billionaire Sidney Frank.[212]

Turing has been honoured in various ways in Manchester, the city where he worked towards the end of his life. In 1994, a stretch of the A6010 road (the Manchester city intermediate ring road) was named "Alan Turing Way". A bridge carrying this road was widened, and carries the name Alan Turing Bridge. A statue of Turing was unveiled in Manchester on 23 June 2001 in Sackville Park, between the University of Manchester building on Whitworth Street and Canal Street. The memorial statue depicts the "father of computer science" sitting on a bench at a central position in the park. Turing is shown holding an apple. The cast bronze bench carries in relief the text 'Alan Mathison Turing 1912–1954', and the motto 'Founder of Computer Science' as it could appear if encoded by an Enigma machine: 'IEKYF ROMSI ADXUO KVKZC GUBJ'. However, the meaning of the coded message is disputed, as the 'u' in 'computer' matches up with the 'u' in 'ADXUO'. As a letter encoded by an enigma machine can not appear as itself, the actual message behind the code is uncertain.[213]

A plaque at the statue's feet reads 'Father of computer science, mathematician, logician, wartime codebreaker, victim of prejudice'. There is also a Bertrand Russell quotation: "Mathematics, rightly viewed, possesses not only truth, but supreme beauty—a beauty cold and austere, like that of sculpture." The sculptor buried his own old Amstrad computer under the plinth as a tribute to "the godfather of all modern computers".[214]



Turing memorial statue plaque in Sackville Park, Manchester

In 1999, *Time* magazine named Turing as one of the 100 Most Important People of the 20th century and stated, "The fact remains that everyone who taps at a keyboard, opening a spreadsheet or a word-processing program, is working on an incarnation of a Turing machine."[8]

In 2002, Turing was ranked twenty-first on the BBC's poll of the 100 Greatest Britons following a UK-wide vote.[215] In 2006, British writer and mathematician Ioan James chose Turing as one of twenty people to feature in his book about famous historical figures who may have had some of the traits of Asperger syndrome.[216] In 2010, actor/playwright Jade Esteban Estrada portrayed Turing in the solo musical, *Icons: The Lesbian and Gay History of the World, Vol. 4*. In 2011, in *The Guardian*'s "My hero" series, writer Alan Garner chose Turing as his hero and described how they had met while out jogging in the early 1950s. Garner remembered Turing as "funny and witty" and said that he "talked endlessly".[217] In 2006, Turing was named with online resources as an LGBT History Month Icon.[218] In 2006, Boston Pride named Turing their Honorary Grand Marshal.[219]

The logo of Apple Inc. is often erroneously referred to as a tribute to Turing, with the bite mark a reference to his death.[220] Both the designer of the logo[221] and the company deny that there is any homage to Turing in the design.[222][223] Stephen Fry has recounted asking Steve Jobs whether the design was intentional, saying that Jobs' response was, "God, we wish it were."[224] In February 2011, Turing's papers from the Second World War were bought for the nation with an 11th-hour bid by the National Heritage Memorial Fund, allowing them to stay at Bletchley Park.[225]


Turing memorial statue in Sackville Park, Manchester

In 2012, Turing was inducted into the Legacy Walk, an outdoor public display that celebrates LGBT history and people.[226][227]

The song "Alan et la Pomme", by francophone singer-songwriter Salvatore Adamo, is a tribute to Turing.[228] Turing's life and work featured in a BBC children's programme about famous scientists, *Absolute Genius with Dick and Dom*, first broadcast on 12 March 2014.

On 17 May 2014, the world's first work of public art to recognise Turing as gay was commissioned in Bletchley, close by to Bletchley Park where his war-time work was carried out. The commission was announced to mark International Day Against Homophobia and Transphobia. The work was unveiled at a ceremony on Turing's birthday, 23 June 2014, and is placed alongside busy Watling Street, the old main road to London, where Turing himself would have passed by on many occasions. On 22 October 2014, Turing was inducted into the NSA Hall of Honor.[229][230]

In February 2019, in the BBC eight-part series *Icons: The Greatest Person of the 20th Century*, Turing was voted by viewers to be the Greatest Person.[231]

Centenary celebrations

To mark the 100th anniversary of Turing's birth, the Turing Centenary Advisory Committee (TCAC) co-ordinated the Alan Turing Year, a year-long programme of events around the world honouring Turing's life and achievements. The TCAC, chaired by S. Barry Cooper with Turing's nephew Sir John Dermot Turing acting as Honorary President, worked with the University of Manchester faculty members and a broad spectrum of people from Cambridge University and Bletchley Park.

David Chalmers on stage for an Alan Turing Year conference at De La Salle University, Manila, 27 March 2012

On 23 June 2012, Google featured an interactive doodle where visitors had to change the instructions of a Turing Machine, so when run, the symbols on the tape would match a provided sequence, featuring "Google" in Baudot-Murray code.[232]

The Bletchley Park Trust collaborated with Winning Moves to publish an Alan Turing edition of the board game Monopoly. The game's squares and cards have been revised to tell the story of Turing's life, from his birthplace in Maida Vale to Hut 8 at Bletchley Park.[233] The game also includes a replica of an original hand-drawn board created by William Newman, son of Turing's mentor, Max Newman, which Turing played on in the 1950s.[234]

In the Philippines, the Department of Philosophy at De La Salle University-Manila hosted Turing 2012, an international conference on philosophy, artificial intelligence, and cognitive science from 27 to 28 March 2012 to commemorate the centenary birth of Turing.[235][236] Madurai, India held celebrations with a programme attended by 6,000 students.[237]

There was a three-day conference in Manchester in June, the Alan Turing Centenary Conference, a two-day conference in San Francisco, organised by the ACM, and a birthday party and Turing Centenary Conference in Cambridge organised at King's College, Cambridge, and the University of Cambridge, the latter organised by the association Computability in Europe.[238]

The London 2012 Olympic Torch flame was passed on in front of Turing's statue in Manchester on his 100th birthday.

The Science Museum in London launched a free exhibition devoted to Turing's life and achievements in June 2012, to run until July 2013.[239] In February 2012, the Royal Mail issued a stamp featuring Turing as part of its "Britons of Distinction" series.[240] The London 2012 Olympic Torch flame was passed on in front of Turing's statue in Sackville Gardens, Manchester, on the evening of 23 June 2012, the 100th anniversary of his birth.

On 22 June 2012 Manchester City Council, in partnership with the Lesbian and Gay Foundation, launched the Alan Turing Memorial Award, which will recognise individuals or groups who have made a significant contribution to the fight against homophobia in Manchester.[241]

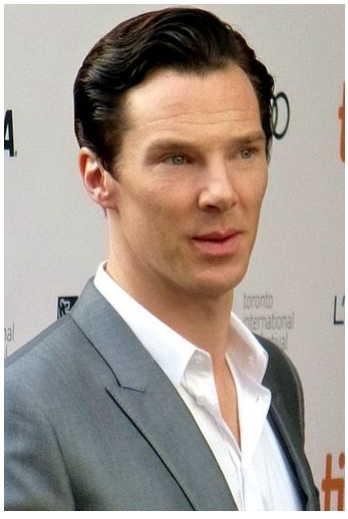
At the University of Oxford, a new course in Computer Science and Philosophy was established to coincide with the centenary of Turing's birth.[242]

Previous events have included a celebration of Turing's life and achievements, at the University of Manchester, arranged by the British Logic Colloquium and the British Society for the History of Mathematics on 5 June 2004.[243]

Portrayal

In theatre

- *Breaking the Code* is a 1986 play by Hugh Whitemore about Turing. The play ran in London's West End beginning in November 1986 and on Broadway from 15 November 1987 to 10 April 1988. In these performances Turing was played by Derek Jacobi. The Broadway production was nominated for three Tony Awards including Best Actor in a Play, Best Featured Actor in a Play, and Best Direction of a Play, and for two Drama Desk Awards, for Best Actor and Best Featured Actor. Turing was again portrayed by Jacobi in the 1996 television film adaptation of *Breaking the Code*.[244]
- In 2012, in honour of the Turing Centennial, American Lyric Theater commissioned an operatic exploration of the life and death of Turing from composer Justine F. Chen and librettist David Simpatico.[245] Titled *The Life and Death(s) of Alan Turing*, the opera is a historical fantasia on the life of Turing. In November 2014, the opera and several other artistic works inspired by Turing's life were featured on Studio 360.[246] The opera received its first public performance in January 2017.[247]



Benedict Cumberbatch portrayed Turing in the 2014 film *The Imitation Game*

In literature

- In William Gibson's *Neuromancer* the Turing police have jurisdiction over AIs. (1984)[248]
- Turing is featured in the Neal Stephenson novel *Cryptonomicon* (1999).[249]
- The 2000 Doctor Who novel *The Turing Test* features Turing and the writer Graham Greene.[250]

- The 2006 novel *A Madman Dreams of Turing Machines* contrasts fictionalised accounts of the lives and ideas of Turing and Kurt Gödel.[251]
- The 2015 novel *Speak*, written by Louisa Hall, includes a series of fictional letters written from Turing to his best friend's mother throughout his life, detailing his research about artificial intelligence.[252][253]
- In the graphic novel series *Über*, in which a fictionalised version of WWII plays out involving superhuman soldiers called "Tank-Men", Turing is one of the researchers as well as a Tank-Man himself.[254]
- Turing is featured in Ian McEwan's 2019 novel, *Machines Like Me* ISBN 978-1787331662.

In music

- Electronic music duo Matmos released an EP titled *For Alan Turing* in 2006, which was based on material commissioned by Dr. Robert Osserman and David Elsenbud of the Mathematical Sciences Research Institute.[255] In one of its tracks, an original Enigma Machine is sampled.[256]
- In 2012, Spanish group Hidrogenesse dedicated their LP *Un dígito binario dudoso. Recital para Alan Turing* (*A dubious binary digit. Concert for Alan Turing*) to the memory of the mathematician.[257]
- A musical work inspired by Turing's life, written by Neil Tennant and Chris Lowe of the Pet Shop Boys, entitled *A Man from the Future*, was announced in late 2013.[258] It was performed by the Pet Shop Boys and Juliet Stevenson (narrator), the BBC Singers, and the BBC Concert Orchestra conducted by Dominic Wheeler at the BBC Proms in the Royal Albert Hall on 23 July 2014.[259]
- *Codebreaker* is also the title of a choral work by the composer James McCarthy. It includes settings of texts by the poets Wilfred Owen, Sara Teasdale, Walt Whitman, Oscar Wilde and Robert Burns that are used to illustrate aspects of Turing's life. It was premiered on 26 April 2014 at the Barbican Centre in London, where it was performed by the Hertfordshire Chorus, who commissioned the work, led by David Temple with the soprano soloist Naomi Harvey providing the voice of Turing's mother.[260][261]

In film

- *Codebreaker*, original UK title *Britain's Greatest Codebreaker*, is a TV film that aired on 21 November 2011 by Channel 4 about Turing's life. It had a limited release in the US beginning on 17 October 2012. The story is told as a discussion between Turing and his psychiatrist Dr. Franz Greenbaum. The story is based on journals maintained by Greenbaum and others who have studied Turing's life as well as some of his colleagues.[262]
- The historical drama film *The Imitation Game*, directed by Morten Tyldum and starring Benedict Cumberbatch as Turing and Keira Knightley as Joan Clarke, was released in the UK on 14 November 2014 and released theatrically in the US on 28 November 2014. The story concentrates on the period of Turing's life where he breaks the Enigma code with other codebreakers in Bletchley Park.[263][264][265][266] It received the academy award for best adapted screenplay in 2015. It was a tremendous success, bringing in $233.6 million[267] for a production cost of $14 million[268].

See also

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- List of things named after Alan Turing

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External links

- Oral history interview with Nicholas C. Metropolis (http://purl.umn.edu/107493), Charles Babbage Institute, University of Minnesota. Metropolis was the first director of computing services at Los Alamos National Laboratory; topics include the relationship between Turing and John von Neumann
- How Alan Turing Cracked The Enigma Code (http://www.iwm.org.uk/history/how-alan-turing-cracked-the-enigma-code) Imperial War Museums

- Alan Turing (https://web.archive.org/web/20080828060019/http://www.rkbexplorer.com/explorer/#display=person%2D{http://dblp.rkbexplorer.com/id/people-a27f18ebafc0d76ddb05173ce7b9873d-e0b388b7c1e0985b1371d73ee1fae8b5}) RKBExplorer
- Alan Turing Year (http://www.turingcentenary.eu/)
- CiE 2012: Turing Centenary Conference (http://cie2012.eu/)
- Science in the Making (https://makingscience.royalsociety.org/s/rs/people/fst00117605) Alan Turing's papers in the Royal Society's archives
- Alan Turing (http://www.turing.org.uk/) site maintained by Andrew Hodges including a short biography (http://www.turing.org.uk/bio/part1.html)
- AlanTuring.net – Turing Archive for the History of Computing (https://web.archive.org/web/20181012014022/http://www.alanturing.net/) by Jack Copeland
- The Turing Archive (http://www.turingarchive.org/) – contains scans of some unpublished documents and material from the King's College, Cambridge archive
- Alan Turing Papers, (https://archiveshub.jisc.ac.uk/manchesteruniversity/data/gb133-tur/add)University of Manchester Library, Manchester
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- Sherborne School Archives (https://web.archive.org/web/20160104203150/http://oldshirburnian.org.uk/wp-content/uploads/2015/09/TURING-Alan-Mathison.pdf) – holds papers relating to Turing's time at Sherborne School
- Alan Turing plaques (https://openplaques.org/people/368) recorded on openplaques.org

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