Alan Turing

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<th>Alan Turing</th>
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<td>Turing at the time of his election to Fellowship of the Royal Society.</td>
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| Born | Alan Mathison Turing  
23 June 1912  
Maida Vale, London, England, United Kingdom |
| Died | 7 June 1954 (aged 41)  
Wilmslow, Cheshire, England, United Kingdom |
| Residence | United Kingdom |
| Nationality | British |
| Fields | Mathematics, Cryptanalysis, Computer science |
| Institutions | University of Cambridge  
Government Code and Cypher School  
National Physical Laboratory  
University of Manchester |
| Alma mater | King's College, Cambridge  
Princeton University |
| Doctoral advisor | Alonzo Church |
| Doctoral students | Robin Gandy |
| Known for | Halting problem  
Turing machine  
Cryptanalysis of the Enigma  
Automatic Computing Engine  
Turing Award  
Turing test  
Turing patterns |
| Notable awards | Officer of the Order of the British Empire  
Fellow of the Royal Society |

Alan Mathison Turing, OBE, FRS (ˈtjuːrɪŋ/ TEWR-ing; 23 June 1912 – 7 June 1954), was a British mathematician, logician, cryptanalyst, and computer scientist. He was highly influential in the development of computer science, giving a formalisation of the concepts of "algorithm" and "computation" with the Turing machine, which can be considered a model of a general purpose computer.[1][2][3] Turing is widely considered to be the father of computer science and artificial intelligence.[4]

During World War II, Turing worked for the Government Code and Cypher School (GC&CS) at Bletchley Park, Britain's codebreaking centre. For a time he was head of Hut 8, the section responsible for German naval cryptanalysis. He devised a number of techniques for breaking German ciphers, including the method of the bombe, an electromechanical machine that could find settings for the Enigma machine.

After the war, he worked at the National Physical Laboratory, where he created one of the first designs for a stored-program computer, the ACE. In 1948 Turing joined Max Newman's Computing Laboratory at Manchester University, where he assisted in the development of the Manchester computers[5] and became interested in mathematical biology. He wrote a paper on the chemical basis of morphogenesis, and predicted oscillating chemical reactions such as the Belousov–Zhabotinsky reaction, which were first observed in the 1960s.
Turing's homosexuality resulted in a criminal prosecution in 1952, when homosexual acts were still illegal in the United Kingdom. He accepted treatment with female hormones (chemical castration) as an alternative to prison. Turing died in 1954, just over two weeks before his 42nd birthday, from cyanide poisoning. An inquest determined that his death was suicide; his mother and some others believed his death was accidental. On 10 September 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". As of May 2012 a private member's bill was before the House of Lords which would grant Turing a statutory pardon if enacted.[6]

**Early life and career**

Turing was conceived at Chhatrapur, Orissa, in British India.[7][8] His father, Julius Mathison Turing (1873–1947), was a member of an old aristocratic family of Scottish descent who worked for the Indian Civil Service (the ICS). Julius's wife, Alan's mother, was Ethel Sara (née Stoney; 1881–1976), 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.[9] Julius's 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 England, so they moved to Maida Vale.[10] London, where Turing was born on 23 June 1912, as recorded by a blue plaque on the outside of the house of his birth,[11] later the Colonnade Hotel.[7][12] He had an elder brother, John (the father of Sir John Dermot Turing, 12th Baronet of the Turing Baronets). His father's civil service commission was still active, and during Turing's childhood years his parents travelled between Hastings in England[13] and India, leaving their two sons to stay with a retired Army couple. Very early in life, Turing showed signs of the genius he was later to display prominently.[14]

His 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 educators. In 1926, at the age of 13, he went on to Sherborne School, a well known independent school in the market town of Sherborne in Dorset. The first day of term coincided with the 1926 General Strike in Britain, but so determined was he to attend that he rode his bicycle unaccompanied more than 60 miles (97 km) from Southampton to Sherborne, stopping overnight at an inn.[15]

Turing's natural inclination toward mathematics and science did not earn him respect with 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".[16] Despite this, Turing continued to show remarkable ability in the studies he loved, solving advanced problems in 1927 without having even studied elementary calculus. In 1928, aged 16, Turing encountered Albert Einstein's work; not only did he grasp it, but he extrapolated Einstein's questioning of Newton's laws of motion from a text in which this was never made explicit.[17]

At Sherborne, Turing formed an important friendship with fellow pupil Christopher Morcom, which provided inspiration in his future endeavours. When the friendship 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,[18][19] Turing's religious faith was shattered and he became an atheist. He adopted the conviction that all phenomena, including the workings of the human brain, must be materialistic,[20] but he still believed in the survival of the spirit after death.[21]
University and work on computability

After Sherborne, Turing studied as an undergraduate at King's College, Cambridge from 1931 to 1934, where he gained first-class honours in Mathematics. In 1935, at the young age of 22, he was elected a fellow at King's on the strength of a dissertation in which he proved the central limit theorem,[22] despite the fact that he had failed to find out that it had already been proved in 1922 by Jarl Waldemar Lindeberg.[23]

In 1928, German mathematician David Hilbert had called attention to the Entscheidungsproblem (decision problem). In his momentous paper "On Computable Numbers, with an Application to the Entscheidungsproblem" (submitted on 28 May 1936 and delivered 12 November),[24] 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. He proved that some such 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 Entscheidungsproblem by first showing that the halting problem for Turing machines is undecidable: in general, it is not possible to decide algorithmically, whether a given Turing machine will ever halt.

Although Turing's proof was published shortly after Alonzo Church's equivalent proof using his lambda calculus, Turing had been unaware of Church's work.[25] Turing's approach is considerably more accessible and intuitive than Church's. It was also novel in its 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 machine, or in other words, is provably capable of computing anything that is computable. Von Neumann acknowledged that the central concept of the modern computer was due to this paper.[26] Turing machines are to this day a central object of study in theory of computation.

From September 1936 to July 1938 he spent most of his time studying under Church at Princeton University. In addition to his purely mathematical work, he studied cryptology and also built three of four stages of an electro-mechanical binary multiplier.[27] In June 1938 he obtained his PhD from Princeton; his dissertation, Systems of Logic Based on Ordinals,[28] introduced the concept of ordinal logic and the notion of relative computing, where Turing machines are augmented with so-called oracles, allowing a study of problems that cannot be solved by a Turing machine.

Back in Cambridge, he attended lectures by Ludwig Wittgenstein about the foundations of mathematics.[29] The two argued and disagreed, with Turing defending formalism and Wittgenstein propounding his view that mathematics does not discover any absolute truths but rather invents them.[30] He also started to work part-time with the Government Code and Cypher School (GCCS).
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.\[31\]

From September 1938, Turing had been working part-time with the Government Code and Cypher School (GCCS), the British code breaking organisation. He concentrated on Cryptanalysis of the Enigma, with Dilly Knox, a senior GCCS codebreaker.\[32\] 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 messages, Turing and Knox started to work on a less fragile approach to the problem.\[33\] 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 initial functional specification of the bombe.

On 4 September 1939, the day after the UK declared war on Germany, Turing reported to Bletchley Park, the wartime station of GCCS.\[34\] 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 boxes 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 which were entitled Report on the applications of probability to cryptography\[35\] and Paper on statistics of repetitions\[36\] which were of such value to GCCS 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 said at the time that the fact that the contents had been restricted for some 70 years demonstrated their importance.\[37\]

Turing had something of 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'.\[38\] Jack Good, a cryptanalyst who worked with him, is quoted by Ronald Lewin as having said of Turing:

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.\[39\]

While working at Bletchley, Turing, a talented long-distance runner, occasionally ran the 40 miles (64 km) to London when he was needed for high-level meetings,\[40\] and he was capable of world-class marathon standards.\[41\][42]

In 1945, Turing was awarded the OBE by King George VI for his wartime services, but his work remained secret for many years.\[43\]
Turing–Welchman bombe

Within weeks of arriving at Bletchley Park,[34] Turing had specified an electromechanical machine that could help break Enigma more effectively than the Polish bomba kryptologiczną, 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.

Jack Good opined:

> Turing’s most important contribution, I think, was of part of the design of the bombe, the cryptanalytic machine. He had the idea that you could use, in effect, a theorem in logic which sounds to the untrained ear rather absurd; namely that from a contradiction, you can deduce everything.[44]

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 of the order of $10^{19}$ states, or $10^{22}$ for the four-rotor U-boat variant),[45] the bombe performed a chain of logical deductions based on the crib, implemented electrically. 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. The first bombe was installed on 18 March 1940.[46]

By the Autumn of 1941, Turing and his fellow cryptanalysts Gordon Welchman, Hugh Alexander, and Stuart Milner-Barry were frustrated. Building on the brilliant work of the Poles, they had set up a good working system for decrypting Enigma signals but they only had a few people and a few bombes so they didn’t have time to translate all the signals. In the summer they had had considerable success and shipping losses had fallen to under 100,000 tons a month but they were still on a knife-edge. 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 they were getting nowhere. Finally, on 28 of October, they wrote direct to Churchill, breaking all the rules, and spelling out their difficulties. They emphasized 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.[47]

The effect was electric, Churchill minuted to General Ismay, "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.[48] More than two hundred bombes were in operation by the end of the war.[49]
Hut 8 and 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". 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. 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 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". 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 bombs.

In 1941, Turing proposed marriage to Hut 8 co-worker 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.

Turing travelled to the United States in November 1942 and worked with U.S. Navy cryptanalysts on Naval Enigma and bombe construction in Washington, visiting their Computing Machine Laboratory at Dayton, Ohio. His reaction to the American Bombe design was far from enthusiastic:

> It seems a pity for them to go out of their way to build a machine to do all this stopping if it is not necessary. I am now converted to the extent of thinking that starting from scratch on the design of a Bombe, this method is about as good as our own. The American Bombe program was to produce 336 Bombes, one for each wheel order. I used to smile inwardly at the conception of test (of commutators) can hardly be considered conclusive as they were not testing for the bounce with electronic stop finding devices.

During this trip, he also assisted at Bell Labs with the development of secure speech devices.

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. Alexander wrote as follows about his 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 realized by the outside world.
Turingery

In July 1942, Turing devised a technique termed Turingery (or jokingly Turingismus) 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. 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. 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, but he was not directly involved in the Colossus development.

Secure speech device (Delilah)

Following his work at Bell Labs in the US, Turing pursued the idea of electronic enciphering of speech in the telephone system, and in the latter part of the war, he moved to work for the Secret Service's Radio Security Service (later HMGCC) at Hanslope Park. There 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. It was intended for different applications, lacking capability for use with long-distance radio transmissions, and 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. The Delilah system had no more than 30 valve-envelopes in each unit, and it would be another 15 years before the systems in use caught up with it.

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

From 1945 to 1947 Turing lived in Richmond, London 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. 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". 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. While he was at Cambridge, the Pilot ACE was being built in his absence. It executed its first program on 10 May 1950. Although the full version of Turing's ACE was never built, a number of computers around the world owe much to it, for example, the English Electric DEUCE and the American Bendix G-15.

According to the memoirs of the German computer pioneer Heinz Billing from the Max Planck Institute for Physics, published by Genscher, Düsseldorf (1997), there was a meeting between Alan Turing and Konrad Zuse. 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, he was appointed Reader in the Mathematics Department at the University of Manchester. In 1949, he became Deputy Director of the Computing Laboratory there, working on software for one of the earliest stored-program computers—the Manchester Mark 1. During this time he continued to do more abstract work in mathematics, and in "Computing machinery and intelligence" (Mind, October 1950), Turing addressed the
problem of artificial intelligence, and proposed an experiment which 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.\textsuperscript{[72]} 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. In 1952, lacking a computer powerful enough to execute the program,
Turing played a game in which he simulated the computer, taking about half an hour per move. The game was
recorded.\textsuperscript{[73]} The program lost to Turing's colleague Alick Glennie, although it is said that it won a game against
Champernowne's wife.

His Turing test was a significant and characteristically provocative and lasting contribution to the debate regarding
artificial intelligence, which continues after more than half a century.\textsuperscript{[74]}

He also invented the LU decomposition method in 1948, used today for solving matrix equations.\textsuperscript{[75]}

Pattern formation and mathematical biology

Turing worked from 1952 until his death in 1954 on mathematical biology, specifically morphogenesis. He
published one paper on the subject called The Chemical Basis of Morphogenesis in 1952, putting forth the Turing
hypothesis of pattern formation.\textsuperscript{[76]}\textsuperscript{[77]} His central interest in the field was understanding Fibonacci phyllotaxis, the
existence of Fibonacci numbers in plant structures. He used reaction–diffusion equations which are central to the
field of pattern formation. Later papers went unpublished until 1992 when Collected Works of A.M. Turing was
published. His contribution is considered a seminal piece of work in this field.\textsuperscript{[78]}

Conviction for indecency

In January 1952, Turing met 19-year-old working-class Arnold Murray outside a cinema in Manchester.\textsuperscript{[79]} After a
lunch date, Turing invited Murray to spend the weekend with him at his house, an invitation which Murray accepted
although he did not show up. The pair met again in Manchester the following Monday, when Murray agreed to
accompany Turing to the latter's house. A few weeks later Murray visited Turing's house again, and apparently spent
the night there.\textsuperscript{[80]}

After Murray helped an accomplice to break into Turing's house, Turing reported the crime to the police and during
the investigation acknowledged a sexual relationship with Murray. Homosexual acts were illegal in the United
Kingdom at that time,\textsuperscript{[81]} and both were charged with gross indecency under Section 11 of the Criminal Law
Amendment Act 1885.\textsuperscript{[82]} Turing was given a choice between imprisonment or probation conditional on his
agreement to undergo hormonal treatment designed to reduce libido. He accepted the option of treatment via
injections of stilboestrol, a synthetic oestrogen; this treatment was continued for the course of one year. The
treatment rendered Turing impotent and caused gynecomastia.\textsuperscript{[83]}

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 GCCS in 1946. At the time, there was acute public anxiety about
homosexual entrapment of spies by Soviet agents,\textsuperscript{[84]} due to the recent exposure of the first two members of the
Cambridge Five, Guy Burgess and Donald Maclean, as KGB double agents. Turing was never accused of espionage
but, in common with all who had worked at Bletchley Park, was prevented from discussing his war work by the
Official Secrets Act.\textsuperscript{[85]}
Death

On 8 June 1954, Turing's cleaner found him dead; he had died the previous day. A post-mortem examination established that the cause of death was cyanide poisoning. When his body was discovered, an apple lay half-eaten beside his bed, and although the apple was not tested for cyanide, it is speculated that this was the means by which a fatal dose was consumed. An inquest determined that he had committed suicide, and he was cremated at Woking Crematorium on 12 June 1954. Turing's ashes were scattered at Woking Crematorium as had been those of his father.

Hodges and David Leavitt have suggested that Turing was re-enacting a scene from the 1937 Walt Disney film Snow White, his favourite fairy tale, both noting 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". This interpretation was supported in an article in The Guardian written by Turing's friend, the author Alan Garner, in 2011.

Professor of Philosophy Jack Copeland has questioned various aspects of the coroner's historical verdict, suggesting the alternate explanation of the accidental inhalation of cyanide fumes from an apparatus for gold electroplating spoons, using potassium cyanide to dissolve the gold, which Turing had set up in his tiny spare room. Copeland notes that the autopsy findings were more consistent with inhalation than with ingestion of the poison. Turing also habitually ate an apple before bed, and it was not unusual for it to be discarded half-eaten. 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, in fact, setting down a list of tasks he intended to complete upon return to his office after the holiday weekend. At the time, Turing's mother believed that the ingestion was accidental, caused by her son's careless storage of laboratory chemicals. Biographer Andrew Hodges suggests that Turing may have arranged the cyanide experiment deliberately, to give his mother some plausible deniability.

Recognition and tributes

A biography published by the Royal Society shortly after Turing's death, 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.

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.

Breaking the Code is a 1986 play by Hugh Whitemore about Alan Turing. The play ran in London's West End beginning in November 1986 and on Broadway from 15 November 1987 to 10 April 1988. There was also a 1996 BBC television production (broadcast in the United States by PBS). In all three 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.

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 and childhood home in Warrington Crescent, London, later the
Colonnade Hotel.\textsuperscript{[93][94]} 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.\textsuperscript{[95]}

On 13 March 2000, Saint Vincent and the Grenadines issued a set of postage stamp 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.\textsuperscript{[96]} On 28 October 2004, a bronze statue of Alan 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.\textsuperscript{[97]} In 2006, Boston Pride named Turing their Honorary Grand Marshal.\textsuperscript{[98]}

Turing was one of four mathematicians examined in the 2008 BBC documentary entitled "Dangerous Knowledge".\textsuperscript{[99]} 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 late American billionaire Sidney Frank.\textsuperscript{[100]}

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 the Canal Street gay village. 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—a symbol classically used to represent forbidden love, the object that inspired Isaac Newton's theory of gravitation, and the assumed means of Turing's own death. The cast bronze bench carries in relief the text 'Alan Mathison Turing 1912–1954', and the motto 'Founder of Computer Science' as it would appear if encoded by an Enigma machine: 'IEKYF ROMSI ADXUO KVKZC GUBJ'.

A plinth at the statue's feet says 'Father of computer science, mathematician, logician, wartime codebreaker, victim of prejudice'. There is also a Bertrand Russell quotation saying 'Mathematics, rightly viewed, possesses not only truth, but supreme beauty—a beauty cold and austere, like that of sculpture.' The sculptor buried his old Amstrad computer, which was an early popular home computer, under the plinth, as a tribute to "the godfather of all modern computers".\textsuperscript{[101]}

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."\textsuperscript{[2]} Turing is featured in the 1999 Neal Stephenson novel Cryptonomicon.

In 2002, Turing was ranked twenty-first on the BBC nationwide poll of the 100 Greatest Britons.\textsuperscript{[102]} 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.\textsuperscript{[103]} 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 whilst out jogging in the early 1950s. Garner remembered Turing as "funny and witty" and said that he "talked endlessly".\textsuperscript{[104]}

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.\textsuperscript{[105]}
In November 2011, Channel 4 aired the docudrama *Britain's Greatest Codebreaker* about the life of Turing. The logo of Apple Computer is often erroneously referred to as a tribute to Alan Turing, with the bite mark a reference to his method of suicide. Both the designer of the logo and the company deny that there is any homage to Turing in the design of the logo. Stephen Fry has recounted asking Steve Jobs whether the design was intentional, saying that Jobs' response was, "God, we wish it were."

The Turing Rainbow Festival, held in Madurai, India in 2012 to celebrating the LGBT cause, was named in honour of Alan Turing.

**Government apology**

In August 2009, John Graham-Cumming started a petition urging the British Government to posthumously apologise to Alan Turing for prosecuting him as a homosexual. The petition received thousands of signatures. Prime Minister Gordon Brown acknowledged the petition, releasing a statement on 10 September 2009 apologising and describing the treatment of Turing as "appalling".

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.

In December 2011, William Jones created an e-petition requesting the British Government pardon Alan Turing for his conviction of "gross indecency". 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 UK government and UK history. A pardon can go to 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.

The petition has over 34,000 signatures, but the request was declined by Lord McNally: 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 which 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.

On 26 July 2012, a bill was introduced in the House of Lords to give 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.
Tributes by universities

- The Turing Room at the University of Edinburgh's School of Informatics houses a bust of Turing by Eduardo Paolozzi, and a set (42/50) of his Turing prints (2000).\[121]\]
- The University of Surrey has a statue of Turing on their main piazza and one of the buildings of Faculty of Engineering and Physical Sciences is named after him.
- Istanbul Bilgi University organises an annual conference on the theory of computation called "Turing Days".\[122]\]
- The University of Texas at Austin has an honours computer science programme named the Turing Scholars.\[123]\]
- In the early 1960s Stanford University named the sole lecture room of the Polya Hall Mathematics building "Alan Turing Auditorium".\[124]\]
- One of the amphitheatres of the Computer Science department (LIFL) 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 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 Universities of Ghent and Mons in Belgium, the University of Turin (Università degli Studi di Torino), the University of Puerto Rico at Humacao, and Keele University have computer laboratories named after Turing.
- The University of Manchester, the Open University, Oxford Brookes University and Aarhus University (in Århus, Denmark) all have buildings named after Turing.
- Alan Turing Road in the Surrey Research Park is named for Alan 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.
- The École Internationale des Sciences du Traitement de l’Information has named its recently acquired third building "Turing".
- The University of Oregon has a bust of Turing on the side of the Deschutes Hall, the computer science building.\[126]\]
- The École Polytechnique Fédérale de Lausanne has a road and a square named after Alan Turing (Chemin de Alan Turing and Place de Alan Turing).\[127]\]

Centenary celebrations

To mark the 100th anniversary of Turing's birth, the Turing Centenary Advisory Committee (TCAC) is coordinating 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 Alan Turing’s nephew Sir John Dermot Turing acting as Honorary President, is working with the University of Manchester faculty members and a broad spectrum of people from Cambridge University and Bletchley Park.

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.\[128]\]

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 Alan Turing’s life, from his birthplace in Maida Vale to Hut 8 at Bletchley Park.\[129]\] 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.\[130]\]
UK celebrations

Among the keystone events there was a three-day conference in Manchester, UK in June; a two-day conference in San Francisco, California, organized 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 organized by the association Computability in Europe.[131]

The Science Museum in London launched a free exhibition devoted to Turing's life and achievements in June 2012, to run until July 2013.[132] In February 2012, the Royal Mail issued a stamp featuring Turing as part its "Britons of Distinction" series.[133] 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 & 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.[134]

Previous celebrations of Turing's life and achievements include an event arranged by the British Logic Colloquium and the British Society for the History of Mathematics which was held on 5 June 2000.

Notes

[17] Hodges 1992, p. 34


[24] Turing 1937


[26] “von Neumann...firmly emphasized to me, and to others I am sure, that the fundamental conception is owing to Turing—insofar as not anticipated by Babbage, Lovelace and others.” Letter by Stanley Frankel to Brian Randell, 1972, quoted in Jack Copeland (2004) The Essential Turing, p.22.

[27] Hodges 1992, p. 138


[33] Copeland 2004a, p. 217

[34] Copeland, 2006 p. 378.


[38] Hodges 1992, p. 208

[39] Lewin 1978, p. 57


[46] Oakley 2006, p. 40/03B


[51] Mahon 1945, p. 14

[52] Leavitt 2007, pp. 184–186

[53] Leavitt 2007, pp. 176–178


[57] Alexander circa 1945, p. 42

[58] Copeland 2006, p. 380

[59] Copeland 2006, p. 381

[60] Copeland 2006, p. 72


[108] Leavitt 2007, p. 280


[114] The petition was only open to UK citizens.


[120] Bill (http://services.parliament.uk/bills/2012-13/152615/turingstatutorypardon.html)

[121] http://www.synth.co.uk/images/paolozzi2.html


References

• O’Connell, H; Fitzgerald, M (2003), "Did Alan Turing have Asperger's syndrome?'", *Irish Journal of Psychological Medicine* (Irish Institute of Psychological Medicine) 20: 28–31, ISSN 0790-9667
• O'Connor, John J.; Robertson, Edmund F., "Alan Mathison Turing" (http://www-history.mcs.st-andrews.ac.uk/Biographies/Turing.html), *MacTutor History of Mathematics archive*, University of St Andrews.

Further reading

• Alan Turing (http://genealogy.math.ndsu.nodak.edu/id.php?id=8014) at the Mathematics Genealogy Project
• Gray, Paul (29 March 1999), "Computer Scientist: Alan Turing" (http://www.time.com/time/magazine/article/0,9171,990624,00.html). *TIME*.

**External links**

• Alan Turing (http://www.rkbexplorer.com/explorer/#display=person-{http://dblp.rkbexplorer.com/id/people-a27f18ebafc0d76ddb05173ce7b9873d-e0b388b7c1e0985b1371d73ee1fae8b5}) RKBExplorer
• Alan Turing Year (http://www.turingcentenary.eu/)
• CiE 2012: Turing Centenary Conference (http://cie2012.eu/)
• Visual Turing (http://www.visualturing.org/)
• Turing Machine calculators (http://www.wolframalpha.com/examples/TuringMachines.html) at Wolfram Alpha
• 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 (http://www.alanturing.net/) by Jack Copeland
• The Turing Archive (http://www.turingarchive.org/) – contains scans of some unpublished documents and material from the Kings College, Cambridge archive
• Sherborne School Archives (http://www.sherborne.org/school/School_Archives/) – holds papers relating to Alan Turing's time at Sherborne School
• Alan Turing plaques (http://openplaques.org/people/368) recorded on openplaques.org
• Turing's treatise on Enigma (The Prof's Book) (http://cryptocellar.org/Turing/)

**Papers**

• An extensive list of Turing's papers, reports and lectures, plus translated versions and collections (http://bibnetwiki.org/wiki/Category:Alan_M._Turing_Paper) BibNetWiki
• List of publications (http://academic.research.microsoft.com/Author/2612734) from Microsoft Academic Search.
• Turing, Alan (October 1950), "Computing Machinery and Intelligence" (http://loebner.net/Prizef/TuringArticle.html), *Mind LIX* (236): 433–460, doi:10.1093/mind/LIX.236.433, ISSN 0026-4423, retrieved 2008-08-18
• 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 Alan Turing and John von Neumann
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