Alan Turing

English Mathematician, Computer Scientist, and Codebreaker

23 June 1912 - 7 June 1954

Overview

Alan Mathison Turing was an English mathematician, computer scientist, logician, cryptanalyst, philosopher, and theoretical biologist who fundamentally shaped the modern world. He is widely considered to be the father of theoretical computer science, providing a formalization of the concepts of algorithm and computation with the Turing machine, which can be considered a model of a general-purpose computer.

Born in London, Turing was raised in southern England and educated at Sherborne School before attending King's College, Cambridge, where he received first-class honours in mathematics. In 1938, he earned a doctorate from Princeton University. During World War II, Turing worked for the Government Code and Cypher School at Bletchley Park, Britain's codebreaking centre that produced Ultra intelligence. He led Hut 8, the section responsible for German naval cryptanalysis, and his work is estimated to have shortened the war by more than two years.

The cognitive scientist Douglas Hofstadter summarized Turing's extraordinary impact:

> *"Atheist, homosexual, eccentric, marathon-running mathematician, A. M. Turing was in large part responsible not only for the concept of computers, incisive theorems about their powers, and a clear vision of the possibility of computer minds, but also for the cracking of German ciphers during the Second World War. It is fair to say we owe much to Alan Turing for the fact that we are not under Nazi rule today."*

Early Life and Education

Family Background

Turing was born in Maida Vale, London, while his father, Julius Mathison Turing, was on leave from his position with the Indian Civil Service of the British Raj government. His mother was Ethel Sara Turing (nee Stoney), daughter of the chief engineer of the Madras Railways. The Turings were a Scottish family of merchants that included a baronet, while the Stoneys were Protestant Anglo-Irish gentry. Turing's parents traveled between Britain and India, leaving Alan and his elder brother John to stay with foster families in England.

Education

From his earliest years, Turing exhibited an unusual fascination with science and mathematics. His headmistress at St Michael's primary school recognized his talent, noting that she "had clever boys and hardworking boys, but Alan is a genius." At Hazelhurst Preparatory School and later at Sherborne School, his natural inclination towards mathematics and science did not always earn him respect from teachers who emphasized the classics. His headmaster wrote: "If he is to be solely a Scientific Specialist, he is wasting his time at a public school."

Despite this, Turing continued to show remarkable ability in the studies he loved, solving advanced mathematical problems in 1927 without having studied even elementary calculus. At age 16, he encountered Einstein's work; not only did he grasp it, but he managed to deduce Einstein's questioning of Newton's laws of motion from a text in which this was never made explicit. The first day of term at Sherborne coincided with the 1926 General Strike, but Turing was so determined to attend that he rode his bicycle unaccompanied 60 miles from Southampton.

Christopher Morcom

At Sherborne, Turing formed a significant friendship with fellow pupil Christopher Morcom, who has been described as Turing's first love. Their relationship provided inspiration for Turing's future endeavours, but it was cut short by Morcom's death in February 1930 from tuberculosis. The event caused Turing great sorrow. He coped with his grief by working harder on the scientific topics they had shared. In a letter to Morcom's mother, he wrote: "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."

Cambridge and Princeton

After Sherborne, Turing earned a scholarship to King's College, Cambridge, where he studied from 1931 to 1934 and was awarded first-class honours in mathematics. His dissertation proved a version of the central limit theorem, and in 1935 he was elected a Fellow of King's College at the remarkably young age of 22. From 1936 to 1938, Turing studied under Alonzo Church at Princeton University, where he earned his PhD with a dissertation introducing the concept of ordinal logic and relative computing with oracles.

The Foundations of Computer Science

On Computable Numbers

Between 1935 and 1936, Turing worked on the decidability of mathematical problems, building on Godel's incompleteness theorems. In May 1936, he delivered his groundbreaking 36-page paper "On Computable Numbers, with an Application to the Entscheidungsproblem." This paper has been called "easily the most influential math paper in history."

In this work, Turing reformulated Kurt Godel's 1931 results on the limits of proof and computation, replacing Godel's universal arithmetic-based formal language with simple hypothetical devices that became known as Turing machines. He proved that his "universal computing machine" would be capable of performing any conceivable mathematical computation if it were representable as an algorithm. He then demonstrated that certain problems are fundamentally undecidable by showing that the halting problem for Turing machines is undecidable: it is not possible to decide algorithmically whether a Turing machine will ever halt.

The Universal Machine

The paper also introduced the 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. This concept is fundamental to modern computing - every general-purpose computer is essentially a physical realization of Turing's universal machine. John von Neumann acknowledged that the central concept of the modern computer was due to Turing's paper. According to the Church-Turing thesis, Turing machines are capable of computing anything that is computable. To this day, Turing machines remain a central object of study in the theory of computation.

Codebreaking at Bletchley Park

The Enigma Challenge

During World War II, Turing was a leading participant in breaking German ciphers at Bletchley Park. The historian and wartime codebreaker Asa Briggs said: "You needed exceptional talent, you needed genius at Bletchley and Turing's was that genius." From September 1938, Turing worked part-time with the Government Code and Cypher School (GC&CS;), concentrating on cryptanalysis of the Enigma cipher machine used by Nazi Germany. On 4 September 1939, the day after the UK declared war, Turing reported to Bletchley Park.

The Bombe

Within weeks of arriving, Turing had specified the bombe, an electromechanical machine that could break Enigma more effectively than the Polish bomba kryptologiczna from which its name derived. With an enhancement by mathematician Gordon Welchman, the bombe became one of the primary tools used to attack Enigma-enciphered messages. The bombe searched for possible correct settings by performing chains of logical deductions, ruling out settings that led to contradictions. More than two hundred bombes were in operation by the war's end.

Hut 8 and Naval Enigma

Turing led Hut 8, responsible for German naval cryptanalysis. He decided to tackle this problem "because no one else was doing anything about it and I could have it to myself." He made five major cryptanalytical advances: the bombe specification; deducing the German navy's indicator procedure; developing Banburismus, a statistical technique for efficient bombe use; developing Turingery for the Lorenz cipher; and creating Delilah, a portable secure voice scrambler.

> *His colleague Hugh Alexander wrote: "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... if anyone was indispensable to Hut 8, it was Turing."*

Impact on the War

In late 1941, frustrated by lack of resources, Turing and three colleagues wrote directly to Winston Churchill. The Prime Minister responded with a memo: "ACTION THIS DAY. Make sure they have all they want on extreme priority and report to me that this has been done." Official war historian Harry Hinsley estimated that the codebreaking work shortened the war in Europe by more than two years. Turing was appointed OBE in 1946 by King George VI for his wartime services, though his work remained classified for many years.

Post-War Computing and Artificial Intelligence

Early Computers

After the war, Turing worked at the National Physical Laboratory, designing the Automatic Computing Engine (ACE), one of the first detailed designs for a stored-program computer. His paper, presented in February 1946, predated von Neumann's incomplete report on the EDVAC but was much more detailed. In 1948, he joined the University of Manchester's Computing Machine Laboratory, where he worked on software for the Manchester Mark 1 and wrote its first Programmer's Manual.

The Turing Test

In his seminal 1950 paper "Computing Machinery and Intelligence," Turing addressed the question of artificial intelligence, proposing what became known as the Turing test. He suggested that if a machine could converse so naturally that an interrogator could not distinguish it from a human, it could be said to exhibit intelligence. Rather than building a program to simulate the adult mind, he suggested simulating a child's mind and subjecting it to education. This remains a significant contribution to the debate regarding AI, continuing after more than seventy years. A reversed form of the Turing test - the CAPTCHA - is widely used on the Internet today.

Mathematical Biology

In 1951, Turing turned to mathematical biology, publishing his masterpiece "The Chemical Basis of Morphogenesis" in January 1952. He proposed that reaction-diffusion systems - chemicals reacting with each other and diffusing across space - could account for pattern formation in biological organisms. Using systems of partial differential equations, he showed how autocatalytic reactions with inhibitors could create patterns: spots on a leopard, stripes on a zebra, spirals in sunflowers.

Though published before the structure of DNA was understood, Turing's work remains relevant and is considered seminal in mathematical biology. It has explained spots and stripes on animal fur, feather and hair follicle growth, lung branching patterns, and even organ asymmetry. A 2023 study with chia seeds became the first to experimentally verify Turing's model with living vegetation.

Personal Life and Death

In 1941, Turing proposed marriage to his Hut 8 colleague Joan Clarke, a fellow mathematician. After admitting his homosexuality to his fiancee, who was reportedly "unfazed," Turing decided he could not go through with the marriage. In 1952, he began a relationship with Arnold Murray. When Turing's house was burgled and he reported the crime, he acknowledged the relationship. Homosexual acts being illegal, both men were charged with "gross indecency." Turing was convicted and chose chemical castration over imprisonment, receiving hormone injections for one year. His security clearance was revoked.

On 8 June 1954, Turing was found dead at his home in Wilmslow, aged 41, from cyanide poisoning. A half-eaten apple lay beside his bed. The inquest ruled suicide, though philosopher Jack Copeland has suggested accidental inhalation from electroplating equipment. Turing had shown no signs of despondency and had made a list of tasks for after the holiday weekend. His mother never accepted the suicide verdict.

Legacy and Recognition

In 2009, Prime Minister Gordon Brown issued an official apology for Turing's treatment: "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." Queen Elizabeth II granted a royal pardon in 2013 - only the fourth since World War II. The "Alan Turing law" (2017) subsequently pardoned approximately 75,000 men convicted under historical anti-homosexuality legislation.

Today, the Turing Award, often called the "Nobel Prize of computing," is named in his honor. His portrait appears on the Bank of England 50 pound note (2021). A 2019 BBC audience vote named him the greatest scientist of the 20th century. Most importantly, the theoretical foundations he laid continue to underpin all of computer science and remain central to ongoing research in artificial intelligence worldwide.

Summary prepared from Wikipedia article on Alan Turing

Source: https://en.wikipedia.org/wiki/Alan_Turing