Alan Turing (1912-1954)

by **Ong Marc-us**

"It was a good thing the authorities hadn't known Turing was a homosexual during the war, because if they had, they would have fired him – and we would have lost."

Professor Jack Good, wartime colleague of Alan Turing[1]

INTRODUCTION

From famous innovators like Albert Einstein and the Wright Brothers, to inspirational leaders like Winston Churchill and JF Kennedy, the 20th century is certainly not short of influential people who have changed the lives of people all around the world. One such person, perhaps one of the more underappreciated figures in modern history, would be Alan Turing. Renowned for his ground breaking work in computer science, mathematics and cryptanalysis that greatly helped the Allies defeat Nazi Germany during World War II (WWII), Turing can also add one of the most important inventions in human history to his long list of achievements, the computer, which has revolutionised the way humans think, work and live.

EARLY LIFE

Alan Mathison Turing was born on 23rd June, 1912, in Maida Vale, London, England to parents Julius Mathison Turing, a member of the Indian Civil Service who served in the Madras Presidency, and Ethel Sara Stoney, who came from an Anglo-Irish family. As a result of his father's job, Turing, along with his elder brother, John, spent his early childhood with a retired Army couple in Hastings, a town on the south coast of England.

EDUCATION

At a tender age, Turing showed signs of intellectual genius far beyond his peers, even if they, along with his teachers, were not keen to respect it. In a time when appreciation for a more classic education such as business and literature was the norm in upper-middle class private schools, Turing's curiosity and passion for science and mathematics left him at odds with the education system when he was enrolled into Sherborne School at the age of 13. With his lukewarm performances in subjects like literature and history, and his flair and inclination for science and mathematics being cocooned, it was clearly difficult to imagine Turing having a significant impact on the world of science and technology.

Yet, the tenacity and drive to excel and pursue his passion that would become a hallmark of Turing during his later, more

successful years meant that the rigid education system left Turing undeterred to chase academic excellence in his chosen fields. Despite not having studied elementary calculus, Turing was still able to solve advanced mathematical problems beyond his years. At age 16, after being given a book on the theory of relativity by Albert Einstein, Turing not only comprehended Einstein's work, he enhanced and improved Einstein's questioning of Newton's Laws of Motion.

INFLUENCES

While his time at Sherborne School was not exactly productive, one of Turing's most important influences that piqued his interest for science and mathematics came in the form of a good friend whom he had met at Sherborne. It was in science classes that Turing met Christopher Morcom, another gifted student in science. Time in Sherborne was spent with Morcom, who has been said to be Turing's 'first love', on intellectual interactions over subjects like mathematics and astronomy.

It was thus unsurprising that the sudden death of Morcom to complications of bovine tuberculosis deeply affected Turing. No longer a man with religious beliefs, Turing became an atheist, believing more and more in scientific reasoning and spending more time exploring his passion for the sciences.

RISE TO PROMINENCE

Mathematics

While his role in cracking the German Enigma cipher machines that greatly aided Western allies defeat Nazi Germany in WWII and his subsequent development of the first computer are undoubtedly Turing's finest achievements, his earlier feats in mathematics and cryptanalyst cannot be overlooked too.

In 1931, Turing continued his education at the prestigious King's College, Cambridge. It was here that Turing's brilliance was becoming more evident. At the age of 22, after attaining first-class honours in mathematics, Turing wrote a dissertation that proved the central limit theorem. Although unaware that Finnish mathematician, Jarl Waldemar Lindeberg, had in fact proved this theorem in 1922, his work was rewarded when he was elected a fellow at King's College in 1936 after his graduation.[2]

1936

Unknown to many, the year 1936 was a crucial year for one of mankind's most important inventions, the computer. In response to the *Entscheidungsproblem* (decision problem) created by David Hilbert, a German mathematician in 1928, Turing published a monumental paper, *On Computable Numbers, with an Application to the Entscheidungsproblem.*[3] In his paper, Turing proved that there was no solution to the *Entscheidungsproblem* and presented a hypothetical machine (now known as the Turing Machine), that was capable of computing any conceivable mathematical computation if it could be represented by an algorithm. The concept of the computer and computation was based on this paper written by Turing and his Turing Machines now provide a fundamental study in the theory of computation.

Turing would spend the next two years studying mathematics and cryptology at Princeton University in the United States, where he graduated with a Ph.D. in 1938. On his return to England, Turing held a part-time position at the Government Code and Cypher School (GC&CS), a British code-breaking organisation. It was here that Turing would firmly establish himself as one of the world's greatest minds for his work at GC&CS.[4]

SIGNIFICANT ACHIEVEMENTS

WWII: Cracking the Enigma

With the outbreak of WWII, GC&CS was relocated to Bletchley

Park, Buckinghamshire. This was Turing's second home, as he and a group of cryptanalysts spent months trying to break the Enigma, the German electro-mechanical cipher machines used by the Nazis to encipher and decipher secret messages. The Enigma used systems known as rotors to set keys for each message transmitted. Breaking these key-systems would mean being able to decipher these messages.

The Enigma was an incredibly complex cipher machine that many deemed impossible to break. It was only through poor operational procedures and mistakes that enabled Turing and other Allied cryptologists to succeed in cracking the Enigma.

1938: The bombe

While working at GC&CS, Turing focused his efforts on the cryptanalysis of the Enigma.[5] Although Polish cryptologists had initially broken German military messages enciphered on the Enigma in 1932, by 1938, additional complexity was repeatedly added to the Enigma machines, making decryption an increasingly arduous task.

Drawing on the works of Polish cryptologist, Marian Rejewski, who created the *Bomba*, a machine designed to crack the Enigma enciphering machine, Turing identified that the most feasible way to crack the Enigma was to build an electromechanical machine that used crib-based decryption. This was dissimilar to the Polish *Bomba*, which depended on an insecure indicator procedure that the Germans changed in December 1938, limiting the Poles to reading only a small minority of messages. Turing, along with mathematician and cryptanalyst Gordon Welchman, began building the *bombe*, to crack the Enigma.[6]

1940-41: Frustrations with the *bombe*

The first bombe was installed on 18th March, 1940. The *bombe* used crib-based decryption suggested by Turing, searching for possible correct settings used by the Enigma to encrypt a message. As most possible settings would cause contradictions, the *bombe* would detect such contradictions, discard them and move on to the next possible setting. This left few settings to be investigated and translated in detail, making efforts to decrypt messages futile as Turing and his team did not have enough *bombe* machines and people to successfully translate these settings.

Towards the end of 1941, Turing and his team, which comprised of cryptologists Gordon Welchman, Hugh Alexander and Stuart Milner-Barry were at crossroads with the *bombe*.[7] The decryption system used by Turing and his team were effective in decrypting German messages, albeit in small quantities. To have a significant impact to aid Allied forces, more people and more bombe machines were needed to decrypt settings and hence messages. The constant adjustments made by the Germans to the Enigma machine added to the level of complexity and difficulty of Turing's task. Having taken the proper military channels to seek for more funds and manpower to operate the bombe, only to have these pleas fall on deaf ears, Turing and his team wrote to then Prime Minister of Britain, Winston Churchill, seeking help for their cause by explaining that their small requirements, in comparison to those needed by Allied troops should their task of breaking the Enigma messages not be fulfilled, were critical and significant in saving both men and money to win the war.

According to Andrew Hodges, a biographer of Turing, the team's letter greatly impressed upon Churchill to supervise his subordinates to give Turing and his team all the support possible. This would prove hugely beneficial to Turing and his team's work on the Enigma.

1941-42: German Naval Enigma and its impact on the Battle of the Atlantic

The Battle of the Atlantic was the longest running military battle of WWII, lasting from the beginning of the war in 1939 to Germany's defeat in 1945, with its climax from mid-1940 to 1943. The Battle was fundamentally an Allied Naval blockade of Germany and Germany's subsequent counter-blockade. Essentially, this battle comprised of the German Navy, known as the *Kriegsmarine*, and elements of the *Luftwaffe*, the German Air Force, against Allied forces and merchant shipping.

The *Kriegsmarine*, unlike the *Heer* (German Army) and the *Luftwaffe*, used much more secure operating procedures while using the Enigma to encipher radio messages.[8] The Enigma machines used by the *Kriegsmarine* used three rotors from a set of eight, unlike the *Heer* and the *Luftwaffe*, which used three rotors from a set of five that was easier for Turing and his team to decipher. The rotors and its key settings to encipher messages were changed every other day, making it more difficult for cryptologists to decipher and translate messages.

Turing and his team attempted to understand the wiring of these naval Enigma machines. With help from the Royal Navy, where HMS *Gleaner* destroyed *U-33* in February 1941, and members of the destroyer, HMS *Bulldog* seized cryptologic material such as Enigma keys, Turing and his team were able to utilise the bombes to decipher and translate German messages until the Enigma keys ran out. By this time, Turing and his team were familiar with how to decipher German messages.[9]

As a result of this breakthrough, by the end of 1941, merchant ship losses were reduced by two-thirds. The intelligence provided by Turing and his team allowed the British to plot positions of U-boat patrol lines of the *Kriegsmarine* and the convoy lines around them.

However, in 1942, the *Kriegsmarine* switched U-boats to a new Enigma key. This was a blow to Turing and his team, as they were unable to break the new keys and as a result, the Royal Navy was unable to identify the U-boat patrol lines. On 30th October, 1942, crewmen from the HMS *Petard* recovered Enigma information from a German submarine, *U-559*. Turing and his team finally had the information to break these new Enigma keys. By the end of 1942, Turing and his team were able to once again provide the Allies with information on U-boat patrol lines, leading to shipping losses being reduced again.[10]

Turing's efforts to crack the Enigma and design the *bombe* machines were quintessential to Allied efforts to combat Nazi Germany. Most people, including then Prime Minister of Britain, Winston Churchill, believe that his work shortened the war by at least two years.

WORKS AFTER WWII

With the end of WWII, Turing moved to Hampton, London, where he worked at the National Physical Laboratory (NPL). Some of his most significant achievements there include designing the first stored-programme computer, which he presented in 1946 and his work on the design of the Automatic Computing Engine (ACE). Although a complete version of Turing's ACE was never built, his legacy in building and designing the computer is evident, as his concept has been an influence for other computers like the English Electric DEUCE and the American Bendix G-15.

Turing took up the position of Reader of the Mathematics Department at the University of Manchester in 1948. Subsequently, he assumed the position of Deputy Director of the Computing Laboratory at the same university.

It was during this time that Turing published a paper on artificial intelligence, *Computer machinery and intelligence,* in which Turing suggested a test, now widely known as the Turing test that would test a computer's intelligence and ability to 'think'.[11] Turing is widely regarded as the founding father of artificial intelligence because of these works.

Later troubles

It was known to those around him that Turing was homosexual back in 1940, which led to the breaking of his engagement to his fiancée, Joan Clarke, a fellow mathematician and cryptanalyst at Bletchley Park. However, in the 1950s, homosexuality was illegal in Britain. Turing was charged with gross indecency in 1952 after he admitted to being in a sexual relationship with a 19 year-old, Arnold Murray, who broke into Turing's house during a break-in.

Turing's conviction barred him from continuing his cryptographic work at the GC&CE, which had become the Government Communications Headquarters (GCHQ) in 1946, ultimately preventing the world from benefiting from more works from Turing.[12]

Turing died on 7th June, 1954. The cause of his death is widely attributed to cyanide poisoning, but many alternative theories have surfaced in the years since his passing. In 2009, after a petition that garnered more than 30,000 signatures, then British Prime Minister Gordon Brown apologised for Turing's prosecution as a homosexual, describing the treatment of Turing as 'appalling'.[13]

Recognition and Tributes

After WWII, Turing was awarded the OBE (Order of the British Empire) in 1945 for his wartime efforts. Among a glittering list of tributes in recognition of his remarkable achievements, a statue of Turing was unveiled at Bletchley Park, Buckinghamshire in June 2007 in recognition of his contributions. Turing was also named the second-most significant alumnus in Princeton University's history. Turing has also been recognized in a variety of ways in Manchester, where he spent his last few years, with a road and bridge named after him. In 1999, Times listed him as one of its "*100 Most Important People of the 20th Century*".[14]

Since 1966, the Association of Computing Machinery (ACM) has given out the Turing Award, widely known as the computing equivalent of the Nobel Prize, for outstanding contributions to computing.

In 2014, a historical thriller film *The Imitation Game* starring Benedict Cumberbatch and Keira Knightley was based on a biography of Turing, *Alan Turing: The Enigma*, by Andrew Hodges.[15] The film was a critical and box-office success, with many acclaimed magazines and newspapers like *The New York Observer* and *The Independent* giving it rave reviews.

CONCLUSION

With the 20th century filled with innovators and inspiring people with notable contributions such as Enrico Fermi, Albert Einstein, Alexander Fleming and the like, one could be forgiven for not adding Turing's name to this list. Yet, his pioneering works in the invention of the computer and artificial intelligence, and his wartime efforts at Bletchley Park have ensured that his name will forever be etched in the minds of people forever. Time Magazine sums up Alan Turing's contributions to the world rather aptly: "*The fact remains that everyone who taps a keyboard, opening a spreadsheet or a word-processing programme, is working on an incarnation of a Turing machine.*"[16]

It is hard to imagine what could have been of Alan Turing's life and the accomplishments he could have achieved had he lived a longer life. What is certain is that his legacy will truly be a long

lasting and defining one for years to come.

ENDNOTES

1. Brainy Quotes, "Alan Turing Quotes", http://www.brainyquote.com/quotes/authors/a/alan_turing.html#DyKoDMRfrgMF0ToK.99
2. Andrew Hodges, *Alan Turing: The Enigma*, (London: Burnett Books, 1983).
3. Ibid.
4. Jack B. Coperland, *Colossus: The secrets of Bletchley Park's code-breaking computers*, (Oxford University Press, 2006).
5. Michael Smith, *Station X: The Codebreakers of Bletchley Park*, (London: Pan McMillan Ltd, 1998, 2007).
6. Gordon Welchman, *The Hut Six story: Breaking the Enigma codes*, (Cleobury Mortimer, England: M&M Baldwin, 1982, 1997).
7. J. N. Wenger; H. T. Engstrom; R. I. Meader, *History of The Bombe Project: Memorandum for the Director of Naval Communications*, The Mariner's Museum, 1998.
8. Hugh Sebag-Montefiore, *Enigma: The Battle for the Code* (Cassell Military Paperbacks ed.), London: Weidenfeld & Nicolson, 2004.
9. Alexander, C. Hugh O'D. (c. 1945). "Cryptographic History of Work on the German Naval Enigma". *The National Archives*, Kew, Reference HW 25/1, 1945.
10. A.P. Mahon, (1945). "The History of Hut Eight 1939–1945". *UK National Archives Reference HW 25/2*, 1945.
11. Jack B. Coperland (n.d.). "Enigma" In *The Essential Turing: Seminal Writings in Computing, Logic, Philosophy, Artificial Intelligence, and Artificial Life plus The Secrets of Enigma (2004 ed.)*.
12. Alan Turing: a short biography http://www.turing.org.uk/bio/part1.html
13. Caroline Davis, "PM's apology to codebreaker Alan Turing: We were inhumane, *The Guardian*, http://www.theguardian.com/world/2009/sep/11/pm-apology-to-alan-turing
14. Alan Turing's World http://historysheroes.e2bn.org/hero/world/91
15. Charles Mcgrath, "The Riddle Who Unlocked the Enigma: The Imitation Game dramatizes the story of Alan Turing", *The New York Times*, http://www.nytimes.com/2014/11/02/movies/the-imitation-game-dramatizes-the-story-of-alan-turing.html?_r=0
16. Paul Gray, "Alan Turing – Time 100 People of the Century". *Time Magazine*. http://content.time.com/time/magazine/article/0,9171,990624,00.html