Max Newman: Topologist, Codebreaker, and Pioneer of Computing

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Maxwell Herman Alexander Newman

Max Newman was one of the most influential figures in the early history of British computing. He worked in the field for more than a decade beginning at Cambridge before World War II, continuing at Bletchley Park during hostilities, and finishing in the peacetime setting of Manchester in the mid-late 1940s. Newman's deeply ingrained habit of understating his own contribution and stressing the accomplishments of others goes some way toward explaining why historians of computing have generally paid only superficial attention to this remarkable man who is, in consequence, principally remembered for his work as a mathematician and topologist.

Early days

Max was the only child of Hermann Alexander Neumann and his wife Sarah (née Pike). Hermann was a German Jewish immigrant from Bromberg[1] who moved to London in 1881 with his parents and sister when he was 15 years old. In 1896, he married Sarah Pike, a 26-year-old schoolteacher and, in February of the following year, Max was born. The family lived in the London suburb of East Dulwich until the outbreak of World War I, when such domestic tranquility as may have existed was shattered by the internment of Max's father as an enemy alien.[2] Hermann, who had lived in England for 33 of his 48 years, was understandably disgusted at his treatment and returned to Germany immediately upon his release. Little is known of Max's relationship with his father but in 1916, Max broke with the past, changed his surname, and was henceforward called Newman.[3]

As a schoolboy at the City of London School, Max demonstrated a great aptitude for classics and also mathematics where he was fortunate enough to come under the influence of a particularly stimulating teacher, F.W. Hill.[4] Hill had formerly been a fellow of St. John's College, Cambridge, and it was to this college that Max in turn gained a scholarship, commencing his studies in 1915. Newman made a very promising start, winning several prizes at the end of his first year and obtaining a First Class in Part 1 of the Mathematical Tripos.[5] Newman spent the next three years away from Cambridge doing war-related work. Initially, Newman took up a teaching post at Archbishop Holgate's School in York. The onerous nature of the work was humorously described by Max in a 1917 letter to Harold Jeffreys:

> The most striking impression one receives at an institution like this is the lack of occupation for one's spare time. After rising at 7 and breakfasting we pray and hymnsing from 8.30 to 9, teach from 9 to 12.15, eat from 12.30 to 12.35, watch children eating (and eating (and eating)) from 12.35 to 1. Teach from 1.30 to 4, eat and let eat from 4.30 to 5. Prep from 6 to 9. Sup from 9 to 9.30. After this there is absolutely nothing to do except mark the books we have collected during the day (and I have never had more than two hundred so far), prepare the (seven) lessons for the next day and make up one's register, though occasionally the Head helps us to pass the time by chatting genially on King's (Chapel of), cabbages (price of), and shawms[6] (strings of) from 12 to 2 (ante meridian).[7]

There was, all too soon, the prospect of something much worse. The battlefields of Europe were providing a more or less insatiable demand for young men and on 9 February

Background of Maxwell H. A. Newman

Born 7 Feb. 1897, Chelsea, London, England. Died 22 Feb. 1984, Cambridge, England. **Education:** City of London School, 1908–1915; St. John's College, Cambridge (mathematics), 1915–1916 and 1919–1921; **Professional experience:** National Service: army paymaster and school teacher, 1916–1919; Cambridge University: fellow of St. John's College, 1923–1945 (honorary fellow 1973–1984); lecturer in mathematics, 1927–1945; Government Code & Cipher School, Bletchley Park, 1942–1945; University of Manchester: Fielden Professor of Mathematics, 1945–1964; Australian National University: visiting professor, 1964–1965; University of Warwick: visiting professor, 1964–1969; Michigan State University: visiting professor, 1964–1969; University of Wisconsin, Madison: visiting professor, 1965–1966; University of Utah: visiting professor, 1965–1966; Rice University, Texas: visiting professor, 1965–1966; University of Illinois: George A. Miller Visiting Professor, 1969–1970. **Honors and awards:** Fellow of the Royal Society, 1939; president of the London Mathematical Society, 1949–1951; Royal Society Sylvester Medal, 1958; speaker at International Congress of Mathematicians, 1962; London Mathematical Society De Morgan Medal, 1962; D.Sc. University of Hull, 1968.

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1918, Max received a letter asking him to report, a fortnight later, to the Cambridge Recruiting Office. Doubtless fearful of what the future might hold, Newman declared himself a conscientious objector, asking for exemption from military service but "not refusing Work of National importance."[8] Newman was spared any direct role in the fighting and was instead assigned to a position in the Army Pay Corps.

At the end of the war Newman elected to undertake a second period of teaching, this time at the Chigwell School in Essex. He returned to Cambridge to continue his studies in October 1919, and graduated in 1921 as a wrangler[9] in Part II of the Mathematical Tripos, with distinction in Schedule B.[10]

His next challenge was to study for a college fellowship, and in pursuit of this aim Max spent 1922–1923 in Vienna where he was joined by a number of people including his lifelong friends Lionel Penrose and Margaret Leathes.[11] The dissertation that Newman produced in 1923 in support of his fellowship may particularly interest historians of computing as it shows a nascent curiosity about the impact mechanized calculation might have in the mathematical sciences. Universal computing machines were still some way off but Newman discusses the use of "symbolic machines" for making predictions in physics.

Newman's career made smooth progress. He was elected a fellow of St. John's College in November 1923 and, in 1927, was appointed as a lecturer in mathematics.

Solving major problems in minor steps

Max took full part in college life, which was much to his taste, and formed a number of lifelong friendships as well as a wide circle of acquaintances. Among the most important members of his set were J.H.C. (Henry) Whitehead and P.M.S. (Patrick) Blackett.

In 1934 Max announced his intention to marry, much to the surprise of most of his friends. His bride-to-be was Lyn Irvine,[12] a friend of some years' standing and the daughter of a minister of the Church of Scotland. The wedding took place at the end of 1934, and early the following year, the couple took up residence a few miles south of Cambridge at Cross Farm. In the years that followed they had two sons.

Over the next two decades Newman applied himself to mathematics, setting out to tackle combinatorial topology, which no one else in Britain had attempted at that time. Characteristically, his approach was to build on the work of the major pioneers in the field, proceeding incrementally in simple steps. The result was a collection of important papers and theories that continue to be of interest to topologists.

As mathematician Dame Mary Cartwright put it:

> His early work on Combinatory Topology has exercised a decisive influence on the development of that subject. At a time when the study of manifolds was based on a number of different combinatory concepts, he established a simple combinatory system of simplicial complexes with an equivalence relation based on elementary moves. He proved that it is as powerful as some other systems with more complex foundations. … He has proved two important results about fixed points. The first was an early inroad on Hilbert's Fifth Problem, in which he proved that abelian continuous groups do not have arbitrarily small subgroups, the second was a simplified proof of a difficult fixed point theorem of Cartwright and Littlewood arising in the study of differential equations … [13]

On only one occasion did Newman break with his usual habit by attempting to solve a major problem in a single grand leap. From September 1937 through March 1938, Max was at Princeton working in what appear to have been ideal conditions, according to his wife Lyn:

> Max has no job here. He simply sits at home doing anything he likes. That is what the Institute of Advanced Studies exists for. They know Mathematicians can be trusted to like doing Mathematics better than anything else. He has taken a little rest from his book and is doing some pet problem at the moment. He goes to a couple of seminars in the week and has tea most days with his brother Mathematicians at the Institute.[14]

The "pet problem" occupying Newman's mind was nothing less than the Poincaré Conjecture. Max presented a proof of this notoriously difficult theorem to an audience of mathematical glitterati in the course of a five-hour talk spread over four days. The flaw in Newman's reasoning was not immediately noticed but on discovering the problem some months later Max was devastated.

Origins of modern computing in pre-war Cambridge

If modern computing may be said to have begun with A.M. Turing, then its roots can be traced back through Newman to a talk David

Hilbert gave at the Sorbonne at the turn of the century. Hilbert proposed 23 "future problems" that effectively formed the agenda for mathematics research in the 20th century. Hilbert's 10th problem was, essentially, this: could there exist, at least in principle, a definite method or process involving a finite number of steps, by which the validity of any given first-order logic statement might be decided?

Turing first encountered Hilbert's so-called *Entscheidungsproblem* around the spring of 1935 when he was a student on Newman's Part III Foundations of Mathematics course. As Newman was later to recall:

> I believe it all started because he attended a lecture of mine on foundations of mathematics and logic in which I had mentioned … that what is meant by saying that the process is constructive is that it's purely … mechanical … and I may even have said a machine can do it. But he took the notion … and did produce this extraordinary definition of a perfectly general, … computable, function thus giving the first idea really of a perfectly general computing machine.[15]

In the middle of April 1936, Turing presented Newman with a draft of his breathtakingly original answer to the *Entscheidungsproblem*.[16] At the heart of Turing's paper was an idealized description of a person carrying out numerical computation that, following Church,[17] we have come to call a "Turing machine." All modern computers are instantiations of Turing machines in consequence of which Turing's paper is often claimed to be the single most important in the history of computing.

From the moment Newman saw Turing's solution, he took him under his wing. Newman canvassed successfully for "On Computable Numbers" to be published by the London Mathematical Society and, simultaneously, enlisted Alonzo Church's assistance in arranging for Turing to spend some time studying in Princeton.

Cambridge in the late 1930s and early 1940s seems to have provided particularly fertile soil for computing pioneers, and Newman played a part in the education of most of them. In addition to Alan Turing and his exact contemporary Maurice Wilkes, other students of Newman's included Tom Kilburn, Geoff Tootill, and David Rees.

A Colossal contribution: Bletchley Park, 1942–1945

On 16 March 1939, as war was breaking out across Europe, Newman was awarded a fellowship of the Royal Society. However, there was little opportunity to use this as a springboard for further work in mathematics. The outbreak of hostilities took one colleague after another out of academic life into war work, leaving Newman—whose young family had evacuated to the US—increasingly isolated and gradually disillusioned with life at Cambridge, and at the suggestion of Blackett, he accepted a post at Bletchley Park. Neither of them could have had the least inkling that Newman had embarked on a course that was to completely alter the future direction of his career. Max was initially appointed as a cryptanalyst working on "Fish"[18] traffic as part of John Tiltman's group. The type of transmission that attracted the greatest interest was known as "Tunny" and carried messages between the very highest ranks of the German command. Manual methods utilizing statistical techniques had been devised for breaking into the code, but the sheer volume of traffic being intercepted was beginning to overwhelm the human resources available.

Newman was able to make a vital contribution. He believed it was possible to mechanize the attack on Tunny and successfully lobbied to test his conviction by developing an electromechanical code-breaking machine that came to be known as the "Heath Robinson." Newman was placed in charge of the development, and a cryptanalyst, two engineers, and 16 Wrens were placed at his disposal.

He ran his section "The Newmanry" with patriarchal authority but in a democratic spirit, encouraging his staff to speak up if they thought him mistaken. Having something of the force of nature about him and possessed of considerable intellectual daring, he demanded, and generally got, the impossible both of events and people. Donald Michie recalls that Newman proceeded with "vigour and certitude, seemingly as a vehicle without reverse gear."[19] Under his leadership originality flourished. The successes of his team, in which he took great pleasure, were not the result of detailed micromanagement but came about by finding people in whom he could place his trust and allowing them to work according to their own judgment. This freed Newman to concentrate on the larger managerial and organizational issues in the service of which he displayed an "unerring sense of direction in a broader-brush landscape of which [his staff] often had no inkling. Over time his persistence towards a perceived goal would fructify in a stunning coup."[19]

An illustrative example of Newman's democratic approach to management was his famous "Tea Party" book,

> in which anyone was encouraged to write anything—mainly technical schemes, analyses and suggestions. Additionally one was free to make the entry "There will be a Tea Party on ... at ... ," and the discussions then occurring at the said meeting were minuted, including decisions and action items with report-back dates. If [Newman] were out of town, or for any other reason, unable to attend, he simply had to read the new stuff and abide by it ....[19]

Although tolerant of debate, Newman was certainly quite prepared to put an end to discussion when it had served its purpose and he had settled on his course.

> People who incline on occasion to be peremptory usually cover up thereby some inner lack of confidence. In Max's case the reverse was true. His confidence in his own judgment (including his judgment of his own strengths and weaknesses) was serene. ... Max Newman was an Olympian.[19]

The Heath Robinson proved fairly unreliable but the results it achieved were sufficiently impressive for approval to be given to develop a more sophisticated machine—the Colossus. A great deal has been written about this device—the world's first digital electronic computing device. It is sufficient to note that, had Newman done nothing else in his career, he would have been assured of a place among the most important pioneers of early British computing.

The Colossus had a profound effect on Newman's future career. He saw at once, as few others did, the impact that computing would come to have on mathematics and resolved to establish a computer-building project as soon as the war was over. The mathematics department at Cambridge was not the right environment for this, and he began to look around for a more favorable setting. With Blackett's help and encouragement, Max was appointed to the Fielden Chair of Pure Mathematics at Manchester University, the post having become vacant when Louis Mordell moved in the opposite direction to take up the Sadleirian Chair. Newman had two clear goals in mind: to establish a first-rate department that could stand comparison with the best in the country and to build a computer. At Bletchley, Max was surrounded by people who could help him achieve both objectives.

Newman's contribution to computing: Manchester in the postwar period

Max, in a clear declaration of intent, brought with him Jack Good and David Rees.[20] Both had been at Cambridge before the war, and as part of Newman's section at BP, they had experience working on Colossus. With Blackett's assistance, a substantial grant was secured from the Royal Society for the purpose of developing a computer. The only piece of the puzzle which was missing was a lead engineer. Max was not the only person looking for a top-flight engineer; the National Physical Laboratory (NPL) was also planning to build a computer and "Good circuit" men, Newman wrote to von Neumann, were "both rare and not procurable when found."[21]

Thus it was that, at war's end, F.C. (Freddie) Williams found himself in the fortunate position of being a man much in demand. It must have been quite a disappointment to the NPL when, in late 1946, Williams was offered and accepted the Edward Stocks Massey chair of Electro-Technics at the University of Manchester.[22] Blackett and Newman, who had earlier discussed with I.J. Good the possibility of hiring Williams,[23] were both on the appointments panel.

Having secured the support of the university, obtained funding from the Royal Society, and assembled a first-rate team of mathematicians and engineers, Newman now had all elements of his computer-building plan in place. Adopting the approach he had used so effectively at Bletchley Park, Newman set his people loose on the detailed work while he concentrated on orchestrating the endeavor. The result was success beyond all expectation. By the middle of 1948 the SSEM (Small Scale Electronic Machine) was up and running. Although little more than a proof of concept, it was still the world's first working digital electronic stored program computer. The Manchester team had indisputably achieved a major coup.

Newman's direct involvement with computing activity was, however, coming to an end. Like Blackett, Newman was opposed to the inevitable use of the Manchester computer in the development of nuclear weapons, and as the government took an ever closer interest in the Manchester computer, Max stepped back to leave further development to the engineers.

Max retired in 1964 but continued to be active in topology and two years later pro-

For Further Reading

A. Hodges, *Alan Turing: The Enigma,* Vantage, 1992.

L. Irvine, *So Much Love, So Little Money,* Faber, 1957.

W. Newman, ''Married to a Mathematician: Lyn Newman's Life in Letters,'' *The Eagle*, St. John's College, Cambridge, 2002, pp. 47–55.

W. Newman, ''Max Newman: Mathematician, Codebreaker and Computer Pioneer,'' in J. Copeland, ed., *Colossus: The First Electronic Computer*, Oxford Univ. Press, 2006, pp. 176–188.

S. Wylie, revised by I.J. Good, ''Newman [formerly Neumann], Maxwell Herman Alexander (1897−1984), mathematician,'' *Oxford Dictionary of National Biography*, vol. 40, Oxford Univ. Press, 2004, pp. 656–658.

duced an engulfing theorem for topological manifolds. Until 1970, he taught in a succession of visiting professorships; mostly in the US. In May 1973, his wife Lyn died and later the same year he married Margaret Penrose. Together they enjoyed a happy and contented life surrounded by their children and much occupied with travel, music, and entertaining. Max died in 1984 at age 89.

Newman was a deeply cultured man with an inquiring mind whose interests ranged over a broad canvas. His influence on the first generation of British computer scientists was incalculable, and his early appreciation of the importance of computing was probably matched only by that of Alan Turing. The vision and leadership he showed at Bletchley Park during World War II and his single-minded determination to mechanize the British code-breaking efforts not only had an appreciable impact on the outcome of the conflict but also created a computing legacy that he was determined to carry into the postwar situation. Such was the deftness by which he accomplished the transfer of knowledge that some of those who gained most from his understanding were more or less unaware of the singular contribution made to their own success by this remarkable man.

I am content to leave the last word to Mary Cartwright, who in presenting Newman with the 1962 De Morgan Medal said of him:

> Newman is a scholar of mathematics with a fine sense of the directions in which important advances are to be expected. It was, for instance, at least in part as a result of his interest and advocacy that Manchester University acquired one of the first general purpose computers. He has also contributed greatly to mathematics as an expositor. … Whether in writing or in speaking he has a distinction and clarity of language that few can rival and all must admire.[24]

Acknowledgments

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References and notes

1. Today, the city is known as Bydgoszcz and is located in northern Poland.
2. Some 30,000 mainly long-term residents were similarly interned, the main discernable effect of which appears to have been the breakup of families and the disruption of social networks.
3. Max's mother also changed her name in 1920.
4. Frederick William Hill of St. John's College, Cambridge, was 3rd Wrangler in the 1886 Mathematics Tripos Pt II, and obtained a 1st Class degree in 1887.
5. In medieval times, the Cambridge degree examination in mathematics took the form of a three-cornered syllogistic disputation between the candidate and an examiner, with the Dean acting as a buffer between the contestants and a ''friend'' for the student. All parties were seated on three-legged stools in recollection of which the examination in mathematics is called a ''Tripos.'' For a longer discussion see L. Roth, ''Old Cambridge Days,'' *The Am. Mathematical Monthly*, vol. 78, no. 3, 1971, pp. 223-236.
6. *Shawm* is the name of a whole family of double-reed woodwind instruments that flourished throughout the middle ages and Renaissance, only to be replaced by the Baroque oboe. Newman's parenthetic reference draws on Arthur Clement Hilton's parody of Lewis Carroll's ''The Walrus and The Carpenter.'' Hilton's version, which is reprinted in E.E. Kellett, *A Book of Cambridge Verse*, Cambridge Univ. Press, 1911, runs as follows: ''The time has come,'' the Vulture said, ''To talk of many things, Of Accidence and Adjectives, And names of Jewish kings, How many notes a sackbut has, And whether shawms have strings.''
7. Newman writing to Harold Jeffreys, box 1, folder 1, item 4, The Newman Digital Archive, the History of Computing Group, Portsmouth, and St. John's College, Cambridge. Facsimile available at http://www.tech.port.ac.uk/staffweb/andersod/Newman/Newman.php?Show=Home.php.

8. Newman writing to Harold Jeffreys, box 1, folder 1, item 5, The Newman Digital Archive, the History of Computing Group, Portsmouth, and St. John's College, Cambridge. Facsimile available at http://www.tech.port.ac.uk/staffweb/andersod/Newman/Newman.php?Show=Home.php.
9. At the university of Cambridge, a *wrangler* is a student who has completed the third year (called Part II) of the Mathematical Tripos with first-class honors.
10. Schedule B was an optional examination based on advanced courses and was the equivalent of today's Part III.
11. Margaret married Lionel Penrose in 1928, and following his death in 1973, she became Max's second wife.
12. Lyn Irvine is a fascinating character in her own right. For a description of her early life see L. Irvine, *So Much Love, So Little Money*, Faber, 1957, and for a fascinating account of her marriage to Max seen through the prism of her correspondence see W. Newman, ''Married to a Mathematician: Lyn Newman's Life in Letters,'' *The Eagle*, St. John's College, Cambridge, 2002, pp. 47-55.
13. M.L. Cartwright, ''Presentation of the De Morgan Medal to Professor M H A Newman,'' *J. London Mathematical Soc.*, vol. 38, 1963, pp. 129-130.
14. Lyn Newman, writing to her parents in November 1937, papers of Lyn Newman, St. John's College Library, box 5.
15. C.R. Evans and interviewer, ''Pioneers of Computing 15: M.H.A. Newman,'' audio recording, Science Museum London, 1976; C.D.P. Anderson, transcription, 1998.
16. A.M. Turing, ''On Computable Numbers, with an Application to the Entscheidungsproblem,'' *Proc. London Mathematical Soc.*, series 2, 42, London Mathematical Soc.,1936–1937, pp. 230-265.
17. A. Church, review author of A.M. Turing's ''On Computable Numbers, with an Application to the Entscheidungsproblem,'' *J. Symbolic Logic*, vol. 2, no. 1, 1937, pp. 42-43.
18. This derives from the name which the Germans gave to one of their cipher systems: *Sägefisch*, (Sawfish).
19. D. Michie, personal communication,12 February 2001.
20. Alan Turing joined Newman's department in autumn 1948.
21. Newman to J. von Neumann, 8 February 1946, box 6, folder 2, item 2, The Newman Digital Archive, the History of Computing Group, and St. John's College, Cambridge.
22. Williams brought with him Tom Kilburn, a very able young engineer who, as is well known, was to play a crucial role in the development of the Manchester computer.
23. I.J. Good to S.H. Lavington, 7 April 1976, NAHC/MUC/2/A4, National Archive of the History of Computing. Newman had also discussed the vacancy with Williams during the summer of 1946.
24. M.L. Cartwright, ''Presentation of the De Morgan Medal to Professor M H A Newman,'' *J. London Mathematical Soc.*, vol. 38, 1963, p. 130.

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