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Babbage, Charles

(*b*. Walworth, Surrey, England, 26 December 1791; *d*. London, England, 18 October 1871)

mathematics, computing, statistics, economics, philosophy of science. For the original article on Babbage see *DSB*, vol. 1.

Babbage is generally remembered as the nineteenth-century prophet of the modern computer. He was a mathematician who designed two distinct types of mechanical computing devices that were rediscovered in the late 1930s, a time when American and European engineers were building electronic computing machines. Since that period, the story of Babbage served as a starting point for the computer age, the distant founder of a modern discipline. Many a discussion of the field began with a brief treatment of Babbage's computing engines. The London Science Museum constructed one of his computing machines from the original plans in order to demonstrate the validity of Babbage's ideas.

After the first major biography of Babbage appeared in 1982, scholars developed a broader understanding of Babbage that places his computing machines in the context of his other scientific work. Babbage explored a number of fields, including geology, chemistry, economics, electricity, actuarial mathematics, astronomy, statistics, and mechanical engineering. In probing these different areas, he developed three basic themes that served as his foundation stones for the practice of science. The first was the importance of analysis, the dissection of ideas into their fundamental components. The second was the value of symbolism, the tool for recording and manipulating ideas. The last is need for well, democratic institutions to support scientific research. These themes are best seen in his efforts to reform the English scientific community and his writings on industrial management but they are also found in his work on computing machines.

Education and Early Career. Babbage was born into a middle-class family with rising fortunes. His father was a London banker, who made enough money to be able to purchase an estate in the country. Though he was educated at minor regional schools, Babbage was prepared for the Cambridge University entrance exam by a scholar from Oxford. In this preparatory work Babbage demonstrated a substantial skill in mathematics and a firm interest in the mathematical writings of continental mathematicians represented by Leonhard Euler, Joseph-Louis Lagrange, and Pierre-Simon Laplace, a group that was often identified as the "analytical school."

Babbage entered Trinity College, Cambridge, in the fall of 1810. His first months at college were awkward as he struggled to find a place among the aristocratic students who had studied at England's public schools. He shunned the ordinary course of study at Cambridge, which was focused on the mathematical ideas of Isaac Newton, and spent hours studying the analytical mathematicians. In the spring of 1812 he fell into a group of like-minded students and formed an organization known as the Analytical Society. The leader of this group was John Herschel, son of the astronomer William Herschel.

For the rest of Babbage's life Herschel would be his best friend and closest confidant.

Over the next eighteen months Babbage and Herschel prepared a small volume of mathematical papers called the *Memoirs of the Analytical Society* (1813). After

Herschel graduated from college in May 1813, Babbage turned his attention from mathematics to chemistry. He created a small laboratory in his college rooms and started a program of experiments. Most of these experiments consisted of subjecting different substances to extremely high temperatures. His study was guided by England's premier chemist of the time, Smithson Tennant, who had just taken an appointment at Cambridge. Babbage's interest in the subject faded when his time at college came to an end, but he would later write that "I have never regretted the time I bestowed upon [chemistry] at the commencement of my career" (1864, p. 27).

In June 1814 Babbage left Cambridge with a bachelor's degree, married Georgiana Whitmore, and moved to London. For the next seven years he returned to mathematical work and published more than a dozen papers. Though he is usually associated with the traditional ideas of calculus—the analysis of motions and forces—Babbage actually devoted most of his energies to a branch of algebra called the calculus of functions. This branch looks at broad classes of mathematical functions and tries to determine the properties of those functions.

During his time in London, Babbage became interested in geology and astronomy. He also traveled to France in search of scientific books. While in Paris he was likely introduced to the work of Gaspard de Prony, who had completed a large set of logarithm and trigonometry tables. De Prony had been able to divide the labor of computing these tables among ninety assistants. This work impressed Babbage, and he would draw upon it when he returned to England.

The Difference Engine. In 1820 he became a founding member of the Astronomical Society, a group of businessmen who were interested in revising the *Royal Nautical Almanac*, the annual volume that was used by navigators and surveyors. This book gave lengthy tables that showed the positions of the heavenly bodies on every night of the year. It needed to be prepared years in advance and required a substantial amount of calculation.

In preparing some ancillary tables for the *Almanac*, Babbage conceived of a machine that might assist with the calculation. The machine would calculate polynomial interpolations; it would draw curves through points on a graph. Babbage called this machine the Difference Engine, because it used the method of finite differences to compute the interpolations. For this idea he received a gold medal from the Astronomical Society and a grant of funds from the British government to complete the machine.

Though Babbage was quickly able to complete a prototype of his Difference Engine, he found that the full machine was considerably more complicated than he had anticipated. He spent seven years refining the design and developing new machining techniques. During this time he visited different English companies in order to learn how they engineered complicated machinery. He also became engaged in other activities. He became interested, for a time, in the new insurance industry. He wrote a treatise on the construction of mathematical tables. He experimented with electricity. He wrote papers on machinery and mechanical engineering. And he lobbied for an academic appointment at the new University of London.

In 1827 Babbage was confronted, in less than six months' time, by the deaths of a son, his father, and his wife. Abandoning his Difference Engine, still unfinished, he retreated to Europe. During his travels he was introduced to many of Europe's leading scientists and learned that he had been appointed to the Lucasian chair at Cambridge, the professorship that had once been held by Newton.

Babbage returned to England invigorated and filled with new ideas. He first became involved in the reform movement and stood for election to Parliament twice as a Liberal or Whig. He lost both times and turned from politics back to scientific projects. From the notes he made while visiting machine shops and factories he wrote a book titled *On the Economy of Machinery and Manufactures* (1832), which was probably his most influential work during his lifetime. It took the economic ideas of Adam Smith and updated them to the machinery age. The book showed not only how machines might be used in industry but how they might be used most economically.

Most of Babbage's economics ideas were based upon the division of labor. He recognized that the division of labor could be applied not only to physical tasks such as manufacturing but also to mental tasks such as the computation of a trigonometry table. Furthermore, he recognized that the division of labor allowed factory owners to reduce the cost of manufacturing by assigning each individual task to the least expensive laborer capable of handling that task. This insight became one of the foundations of industrial management.

As one of the country's leading experts on computation, Babbage was appointed to a committee reviewing the *Royal Nautical Almanac*. This group met in the offices of the Royal Astronomical Society and considered both the contents and means of producing the almanac. They recommended adding a substantial number of tables to the volume. They also urged that the British government use a more systematic form of management to compute the tables, though they stopped short of recommending that Babbage's machine be used for the calculations.

During this period Babbage also became interested in the organization of scientific societies. In particular he became a champion of the modern, self-organized scientific institution. In an 1830 pamphlet, *Reflections on the Decline of Science*, he argued that "science has long been neglected and declining in England" (p. i). England's major scientific society of the time, the Royal Society, was not entirely self-governed and had many members who were not scientists. Babbage, who had been a member of the Royal Society since his graduation from Cambridge, attempted to reform the society but found little assistance. Frustrated by the work, he and a small group of friends decided to found a new society, the British Association for the Advancement of Science, based on the principles of self-organization by scientists.

The Analytical Engine. In 1834, with his Difference Engine still unfinished, Babbage conceived a new, more general machine for the evaluation of functions. This machine resembled the modern computer in that it read operations from a string of punched cards and performed those operations on individual numbers. It also had a means of storing and retrieving numbers. He would name the new device the Analytical Engine after his interest in analytical mathematics. It was far more complicated than his Difference Engine, which could calculate only polynomials. It required him to prepare new designs, new plans, and new descriptions.

In his work on the Analytical Engine, Babbage was briefly assisted by Ada Lovelace, the daughter of the poet Lord Byron (George Gordon Byron). Lovelace played a key role that moved Babbage's idea beyond its inventor into the larger world: She translated and annotated a description of the Analytical Engine and wrote the instructions that would compute a set of values called Bernoulli numbers. In modern terminology the term *program* would be used to identify this set of instructions.

While Babbage was working on his design for his Analytical Engine he was also continuing to organize scientific institutions. He was a founding officer of the Royal Statistical Society. At the time, statistical science included most of the fields that have since devolved into social sciences: economics, sociology, psychology, and anthropology. Babbage was interested in the mathematical foundations of these fields and corresponded with most of the leading statisticians of the day, including the Belgian Adolphe Quetelet.

Though he worked on many different projects during the late 1830s, Babbage devoted most of his attention to his Analytical Engine. "My coach house was now converted to a forge," he wrote, "whilst my stables were transformed into a workshop" (1864, p. 27). He refined the design of the machine, carefully describing the motion of each part in a notation that he had devised. Through these years his ideas about calculation drew the attention of individuals both in England and in Europe. In 1840 Babbage discussed his Analytical Engine at a scientific conference in Turin, Italy, which proved to be one of the more gratifying moments in his life. Two years later his workshop was visited by Prince Albert, the husband of Queen Victoria.

Through 1842 the British government had supported the development of Babbage's computing machines and had given him fifteen thousand pounds to help pay for materials and the salary of a skilled machinist. However, the government had become impatient with Babbage's progress. In twenty years of work he had failed to complete a full, working machine. In the fall of that year the chancellor of the exchequer informed him that the government would no longer provide him with funds. Babbage appealed to the prime minister, but he was unable to change the decision.

Babbage was angered by the action of the British government and was particularly stung by a report from the astronomer royal, George Airy, who wrote, "I believe the machine to be useless, and that the sooner it is abandoned, the better it will be for all parties" (George Airy to Henry Goulburn, September 16, 1842, Papers of the Royal Greenwich Observatory, Cambridge University). For the next twenty-five years Babbage would devote himself to erasing that verdict and establishing the value of his ideas. However, Airy probably made the correct judgment for the time. Babbage's calculators would have had limited application. Within the nineteenth-century scientific community only astronomers might regularly have found a use for one of Babbage's machines, and none of them could have kept it fully occupied.

In 1854 Babbage's ideas came to the attention of George and Edvard Scheutz, a father and son from Sweden. After reading a description of the Difference Engine, they designed and built their own version. This machine was smaller and lighter than the engine conceived by Babbage. They used gears and levers that would have been suitable for the mechanism of a clock. In contrast, Babbage used technology that would have been appropriate for a steam engine. Babbage's engine, if completed, would have filled a room. The Scheutz engine sat nicely on a table and looked like a complicated music box.

Babbage was pleased with Scheutz engine and praised it publicly. The machine was purchased by the Dudley Observatory in Albany, New York, and was given its test, in 1858, by the staff of the *American Nautical Almanac*. The Americans used it to compute part of an astronomical table that showed the position of the planet Mars. Though they ultimately completed the task, they found the machine difficult to set up and more trouble than it was worth. "The result thus far," wrote one member of the staff, "has not been such as to demonstrate to my satisfaction that any considerable portion of the *Almanac* can be computed more economically by this machine" (*U.S. Naval Observatory Annual Report for 1858*, p. 7).

Later Years. At this time Babbage began to withdraw from scientific work. One author speculates that Babbage had a problem with his eyes that made it hard for him to work and exacerbated his difficult personality. Increasingly he turned to problems that were trivial and not worthy of his talents. He designed a system for coastal navigation and worked on minor problems of machining. However, he did complete a new, refined design for his Difference Engine and continued to promote his ideas on computation.

Babbage remained a key member of the scientific community. He knew Charles Darwin and had a brief correspondence with George Boole. Yet during the last years of his life he continued to return to his computing engines. In 1861 he wrote an autobiography, which is largely a defense of his ideas on computing machines. He also returned to his Analytical Engine, looking at calculations and seeing how he might do them with his machine. For the most part he went over old ground. He looked at different mathematical expressions and tried to write code for them. Only a few times did he begin to wander into fields that would really show the power of the computer, but he never pursued these ideas very far. He died in 1871 with his machines still unfinished.

In 1879 the British Association for the Advancement of Science considered the possibility of building an Analytical Engine from Babbage's plans but concluded that such a project was beyond their ability and resources. A decade later Babbage's son, Henry Prevost Babbage, constructed part of the machine, the section involved with the actual computation. The younger Babbage also collected and published his father's papers on calculating machines.

A practical Difference Engine was demonstrated by the *Royal Nautical Almanac* in the 1920s. The superintendent of the *Almanac*, L. J. Comrie, discovered a commercial bookkeeping machine that had a structure similar to that of Babbage's original computing machine. It can "be called a modern Babbage machine," Comrie wrote, for "it does all that Babbage intended his difference engine to do and more" (Comrie, 1936, p. 94). Comrie showed how this machine could be used to compute some of the *Almanac*'s tables. The *Almanac* staff made regular use of this machine until it was replaced with an electronic computer in the 1950s.

Babbage is connected to the modern computer through the work of Howard Aiken, a Harvard University graduate student who built a computing machine in the early 1940s. Aiken discovered Babbage's papers and a model of his computing machine while he was designing his own device. Aiken quickly grasped what Babbage had accomplished and identified him as one of the founders of the field of computation, "a radical inventor," according to Aiken's biographer, "who was not fully appreciated by his contemporaries" (quoted in Cohen, 1999, p. 72).

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