# Augustus De Morgan

Augustus De Morgan (June 27, 1806 – March 18, 1871) was a highly principled man, a lover of books, conundrums and witticisms, a prolific writer, a superb and effective teacher, and a mathematician of such diverse interests that he never pursued anything far enough to obtain results of the first rank. Had he confined himself to one area of research, he might have been a much greater mathematician but he would have been far less interesting.
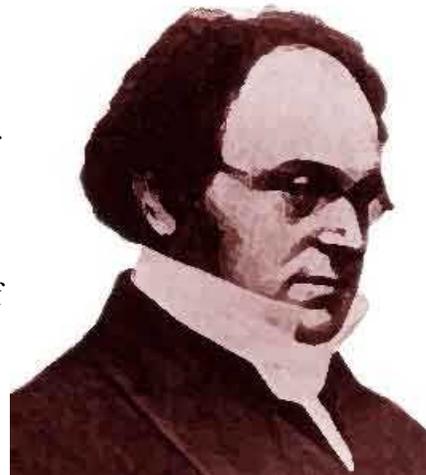
De Morgan's name is usually associated with his innovative efforts in symbolic logic. His most important work, *Formal Logic; or the Calculus of Inference, Necessary and Probable* (1847) was the first since medieval times to discuss the concept of the quantification of the predicate, thereby solving problems that were impossible in classical Aristotelian logic. He is known for the development of De Morgan's Laws, which played an important role in the study of set theory that became prominent after his death. De Morgan's work in symbolic logic greatly influenced Charles Babbage in his design of his Analytical Engine.

De Morgan made significant contributions to many fields of mathematics, including geometry, probability and differential equations, and to the chronicling of the history of mathematics. In 1838 he defined, perfected, and named the process of proof by "mathematical induction." He also developed a rule named for him for determining the convergence of a series, and introduced the modern notation for fractions using the slash (/) instead of the horizontal bar. He championed the adoption of a decimal coinage system of his design and prepared an almanac of all the full moons from 2000 BCE to 2000

CE.

De Morgan was born at Madura, in southern India, where his father, a lieutenant colonel, held various appointments with the East India Company. Shortly after birth Augustus lost the sight in his right eye, and about that time his father returned with his family to England. The combination of his disability and his lack of sociability prevented De Morgan from excelling at school. Though his maternal grandfather was an eminent mathematics teacher, Augustus's mathematical talents remained unnoticed until he was fourteen. He had a gift for drawing caricatures, and it was said that he read algebra "like a novel." He entered Trinity College, Cambridge in 1823, where he was greatly influenced by his teachers George Peacock and William Whewell, who became his life-long friends. De Morgan graduated four years later as Fourth Wrangler. Because he was born in India, he maintained that he was neither English, nor Scottish, nor Irish, but a Briton "unattached," the technical term used for undergraduates at Oxford or Cambridge, who were not members of a college. Although brought up in the Church of England, he objected to the theological test required for a M.A., and without a master's degree, he was not eligible for a Fellowship. He also rejected his parents' wish that he become a priest.

De Morgan traveled to London to enter Lincoln's Inn to study for the Bar, but found law unpalatable. At the age of 21, despite having no mathematical publications, on the strength of the strong recommendations of Peacock and Whewell he was unanimously elected to the chair of mathematics at the newly founded University of London. Afterwards known as University College, the institution was founded on principles that were in accord with De Morgan's religious independence. Always a champion of religious and intellectual tolerance, in 1831 he resigned his position after another professor was fired without explanation. De Morgan regained his position five years later when his replacement accidentally drowned, and held it until 1866 when once again he resigned over a matter of

abridgement of academic freedom. In the years 1831 to 1836 De Morgan produced much of his most significant writing on mathematical education. The *Quarterly Journal of Education* contained thirty of his pieces in its ten-volume existence.

In 1837 De Morgan married Sophia Elizabeth Frend, with whom he would have seven children. The next year, in his article "Induction" in the *Penny Cyclopedia* he put "mathematical induction," a process already in use, on a rigorous and clear basis. A highly lucid expositor, he wrote 712 articles for the *Penny Cyclopedia*, published by the Society for the Diffusion of Useful Knowledge (SDUK). His textbooks included *Elements of Arithmetic* (1830), *The Differential and Integral Calculus* (1836-1842), published by the SDUK in serial segments so that poorer subscribers could afford it, and *Trigonometry and Double Algebra* (1849), in which he gave a geometric interpretation of complex numbers.

De Morgan's most important results were in the areas of probability and mathematical logic. His theory of probability of life events was a boon to London insurance companies. In his most distinguished work *Formal Logic*, De Morgan added a new principle to Aristotelian logic. In the latter the premises "Some Musicians are Artists" and "Some Musicians are Bachelors", have no conclusion. Aristotelian logic says that the middle term "Musicians" must be used universally, that is "All Musicians" must occur. But De Morgan pointed out that from "Most Musicians are Artists" and "Most Musicians are Bachelors," one might conclude, "Some Artists are Bachelors." Besides his theory of syllogisms, De Morgan is widely known for the symbolic logic laws that are named for him: For any sets A and B, the complement of their union is the intersection of their complements and the complement of their intersection is the union of their complements. Symbolically the laws are given by: $(A \cup B)' = A' \cap B'$ and $(A \cap B)' = A' \cup B'$.

De Morgan wrote biographies of Newton and Halley and published *Arithmetical Books*, in which he described the work of more than fifteen hundred mathematicians and discussed the history of various mathematical ideas. De Morgan, who was an excellent teacher, felt that it was important for students to know the history of mathematics so that they might understand the development of the field. His wife, who wrote his biography, edited collection of paradoxes, puzzles, riddles, lore, odd opinions of the learned, and anecdotes that had appeared in his column in *The Athenaeum* periodical, publishing it as *Budget of Paradoxes*, which is also known as *The Encyclopedia of Eccentrics*. It is a delightful satire on some of the strangest people the world has ever known, including those who believed they had squared the circle, invented perpetual motion, demonstrated that the Earth is flat, proved that astronomers were wrong in claiming planetary orbits to be ellipses, refuted Newton's laws of motion. De Morgan took particular pleasure in describing the class of eccentrics and quacks, who insisted that they had found a solution to the problem of constructing a square equal in area to a given circle using only a straightedge and compass, even long after the construction had been proved impossible. De Morgan coined the phrase "morbus cyclometrius" – the circle squaring disease and "cyclometer" as his name for a circle-squarer. His favorite cyclometer was one James Smith of whom he wrote:

  "He is beyond a doubt the ablest at reasoning and the greatest hand at writing it, of all

  who have tried to attach their names to an error. Common cyclometers sink into puny

  orthodoxy by his side…. We can only say this: he is not mad. Madmen reason rightly upon

  wrong premises. Mr. Smith reasons wrongly upon no premises at all."

De Morgan never allowed his name to be forwarded for membership in the Royal Society, holding the opinion that it was too much affected by social influences to be an effective scientific institution, and

he also refused an honorary degree from the University of Edinburgh. His son George, who was a very able and promising mathematician, conceived the idea of founding a Mathematical Society in London, where mathematics papers would not only be received, as was the case of the Royal Society, but actually read and discussed. The first meeting was held in 1866 at University College, with Augustus as the first president, and George as the first secretary. This was the beginning of the London Mathematical Society. Two years later George died, and shortly after this the De Morgan's experienced another loss, in the death of a daughter. De Morgan's healthy rapidly declined and he died of nervous exhaustion at his home on March 18, 1871.

Quotation of the Day: "The moving power of mathematical invention is not reasoning but imagination." – Augustus De Morgan