Augustus DE MORGAN
b. 27 June 1806 - d. 18 March 1871

Summary. De Morgan is chiefly remembered today for his work in algebra and logic. He also made noteworthy contributions to probability theory, most especially concerning its use in actuarial mathematics. He headed the British logical probabilistic tradition, exemplified by Boole, Jevons and Venn.

De Morgan was born in Madurai, southern India. Raised and educated in southwest England, he entered Trinity College Cambridge, at the early age of sixteen, in February 1823. Graduating in 1827, he applied for the mathematics chair at the newly-established and explicitly secular University College London. At 21, with no teaching experience whatsoever, he was the youngest of thirty-one candidates. Nevertheless, he was unanimously elected founding professor of mathematics on 23 February 1828, giving his first lecture on 5 November that year.

All did not go smoothly, however, and when, in 1831, a fellow professor was unfairly dismissed, De Morgan promptly resigned in protest. Five years later, however, following the accidental death of his successor, De Morgan immediately offered himself as a temporary replacement. He was to remain for thirty more years.

As professor of mathematics, De Morgan taught everything from elementary arithmetic and the first book of Euclid's *Elements* to the calculus of variations in an intensive two-year programme of study. While his course was almost entirely 'pure', a few items of applied mathematics were included. For example, in his highest class he would introduce the use of probability in error theory. Briefly stated, this assumes that in good observational experiments, any errors will be very small, so that one can be certain that all results will be contained within a boundary of, say, $\pm E$

Let the law of probability of error be expressed by there being the chance $\varphi x.dx$ that, in an observation about to be made, the error shall be between x and $x + dx$. Then, to express the above certainty, we have

$$\int_{-E}^{E} \varphi x.dx = 1.$$

As with much of the material in his highest class, De Morgan's teaching of the theory of errors of observation was heavily influenced by the work of

Gauss (q.v.) a few decades before. Moreover, the main topics covered by De Morgan's lecture notes in this area, such as the weight of observations and the method of least squares, were all introduced by Gauss in his *Theoria motus corporum celestium* (1809) and *Theoria combinationis observationum erroribus minimis obnoxiæ* (1823).

Other remarks from various works reveal that his students were exposed to other aspects of probability theory by their professor. In an article on Buffon's (q.v.) needle experiment, De Morgan reveals that "a pupil of mine made 600 trials with a rod of the length between the seams and got $\pi = 3.137$". Isaac Todhunter, one of De Morgan's students in the 1840s, wrote a standard history of the subject in 1865 in which he provided strong evidence of the encouragement he received from his former teacher during its preparation. In the opening preface, "sincere thanks" are expressed to De Morgan "for the kind interest in which he has taken in my work, for the loan of scarce books, and for the suggestion of valuable references".

De Morgan was, throughout his career, a prolific writer, publishing 18 books and over 160 papers on many subjects. His research is primarily remembered today for its contribution to the development of modern symbolic algebra and logic, encouraging William Rowan Hamilton with his work on quaternions and George Boole in his algebraic logic. Indeed, De Morgan's major achievement lies in his recognition of the connection between the two disciplines. As he later characteristically put it:

> We know that mathematicians care no more for logic than logicians for mathematics. The two eyes of exact science are mathematics and logic: the mathematical sect puts out the logical eye, the logical sect puts out the mathematical eye; each believing that it sees better with one eye than with two.

He published two books and four papers based on his research into logic, of which the fourth is now regarded as his most original contribution. In it, he introduced the logic of relations which, although his work in this area was left unfinished, substantially increased the scope of the subject. Less enduring perhaps were his attempts to invent a suitable notation for his symbolic logic which were superseded by Boole's more algebraic approach. An illustration of this is provided by the fact that the famous De Morgan's Laws are far more familiar to us in their modern Boolean formulation:

$$(A \cup B)^c = A^c \cap B^c, \ (A \cap B)^c = A^c \cup B^c.$$

Perhaps De Morgan's best known work is a book entitled *A Budget of Paradoxes*. This is a collection of humorous writings and reviews compiled posthumously by his widow Sophia (a woman of no small intellect herself, although she was not a mathematician). De Morgan was a keen bibliophile, accumulating over 3000 mathematical volumes by his death, and the *Budget* consists of accounts of many of these works together with various anecdotes and witty verses, of which the following is perhaps his most famous:

> Great fleas have little fleas, upon their backs to bite 'em,
> And little fleas have lesser fleas, and so *ad infinitum.*

De Morgan was a man of many eccentricities. When asked his age, he reportedly declared: "I was x years old in the year x^2." In 1859, when offered an honorary law doctorate by Edinburgh University, he declined it, saying that he "did not feel like an LL.D." He also refused to allow himself to be proposed as a Fellow of the Royal Society. "Whether I could have been a Fellow," he later said, "I cannot know; as the gentleman said who was asked if he could play the violin, I never tried."

The last major event of his career was his term as first president of the London Mathematical Society (LMS), founded in 1865. Due no doubt to his reputation and influence, membership of the new society rose steadily from the outset, and, to this day, the Society commemorates its founding president with the conferment of the De Morgan Medal, awarded every three years for outstanding mathematical achievement.

De Morgan's long association with University College ended soon after the foundation of the LMS, occasioned by another matter of principle, this time over adherence to the college's policy of religious neutrality. For De Morgan, the council's refusal to appoint a candidate to the vacant chair of philosophy on the grounds of his being a controversial Unitarian minister was a betrayal of its founding principles. He resigned his professorship on 10 November 1866, giving his last lecture in the summer of 1867. He never returned, explaining that, as far as he was concerned, "our old College no longer exists". He died four years later.

Although in comparison to his output in other areas De Morgan's work on probability was small, it is not insignificant. His chief works are a book-length article for the *Encyclopædia Metropolitana* in 1837, and a volume entitled *An Essay on Probabilities*, published in 1838. These two works, though bearing similar titles, were vastly different in content. The first was, in the author's

words: "A Mathematical Treatise on the Theory of Probabilities; containing such development of the application of Mathematics to the said Theory as shall to him (the Author) seem fit, and in particular such a view of the higher parts of the subject as laid down by Laplace in his work entitled *Théorie des Probabilités*, as can be contained in a reasonable compass, regard being had to the extent and character of the Mathematical portions of the said work." In a contemporary review of Laplace's (q.v.) *Théorie*, De Morgan described it as

> the Mont Blanc of mathematical analysis; but the mountain has this advantage over the book, that there are guides always ready near the former, whereas the student has been left to his own method of encountering the latter.

De Morgan's own treatise, while it contained no original results, was nevertheless the first major exposition of the subject to be published in Britain, and as such, it constituted the first major work on modern probability theory to appear in the English language.

The second work was concerned with actuarial mathematics, and in particular, to the application of probability to problems in insurance. In the early 19th century, the actuarial profession was still in its infancy. Consequently, able mathematicians with an understanding of actuarial methods, had the potential to follow very lucrative careers in the insurance business. De Morgan therefore ensured an increased revenue by acting as a free-lance consultant to a variety of companies; in fact his last major mathematical undertaking was a large calculation for the Alliance Insurance Company in 1867. We are told that as an actuary "he occupied the first place, though he was not directly associated with any particular office; but his opinion was sought for by professional actuaries on all sides, on the more difficult questions connected with the theory of probabilities, as applied to life-contingencies". His book on the subject, being the first of its kind, remained highly regarded in insurance literature for well over a generation.

As such it was far less technically demanding than the former work. However, the publishers of the *Encyclopædia Metropolitana* did not see this distinction and threatened legal action, accusing De Morgan of having broken the terms of his contract with the *Encyclopædia* by publishing what they claimed "might be deemed a second edition of the treatise". De Morgan, who was apparently more amused than irritated by this, later published a

small pamphlet in which he ridiculed the publishers for "throwing away good grumbling upon nothing at all" through their inability to see the very obvious difference between a work requiring a thorough knowledge of integral calculus and a popular essay needing only decimal fractions.

Curiously, another elementary work on probability with which De Morgan was associated had nothing to do with him at all. This was an anonymous book titled *On Probability*. The book, authored by the British mathematicians Sir John Lubbock and John Drinkwater-Bethune, was published in 1830, seven years before De Morgan's first major work on probability; yet he was frequently credited as the author, despite his frequent disclaimers. As he later wrote: "nothing could drive out of people's heads that it was written by me. I do not know how many denials I have made ... and I am not sure that I have succeeded in establishing the truth, even now."

In statistics, De Morgan was less active. He does not appear to have joined the Statistical Society (founded in 1834), and his biographer tells us that when "the International Statistical Congress was held in London in 1860, ... he joined a Committee for the inspection, I think, of Scientific Instruments, but he did not give much work to this." Nevertheless, his work does evince a knowledge and appreciation of statistical methods. This is particularly evident in his *Essay*, which, in a number of places, contains analysis of data from various publications, including a couple of then-recent works by Quetelet (q.v.).

De Morgan's contributions, then, to probability theory in Britain were twofold. Firstly, he provided the British with the first full treatment of Laplacean probability theory in their own language, showing himself to be one of the few mainstream British proponents of the subject during the mid-19th century; and secondly, by advocating its practical utility in the growing field of insurance he helped establish it as the basis of modern actuarial methods, which it has remained ever since.

References

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