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Chris Pritchard, *A Common Family Weakness for Statistics: Essays on Francis Galton, George Darwin and the Normal Curve of Evolutionary Biology,* Mathematical Association, 2018, 127 pp, £9.00, ISBN 978-1-911616-03-0

George Darwin, born halfway through the nineteenth century into a family to whom the principle of evolution was key, at a time when the use of statistics to study such a concept was in its infancy, found a kindred spirit in Francis Galton, 23 years his senior, who was keen to harness statistics to aid the investigation of evolutionary matters.

George Darwin was the fifth child of Charles Darwin, the first proponent of evolution. He initially trained as a barrister and was finally an astronomer, becoming Plumian Professor of Astronomy and Experimental Philosophy at Cambridge University and President of the Royal Astronomical Society. In between he was a mathematician and scientist, graduating as Second Wrangler in the Mathematics Tripos in 1868 from Trinity College Cambridge.

Francis Galton was George Darwin's second cousin. He began his studies in medicine, turning after two years to mathematics at Trinity College Cambridge. He made important contributions in many fields of science, including meteorology, statistics, psychology, biology (the mechanism of heredity), and criminology (fingerprints). Galton was impressed by Charles Darwin's 'The Origin of Species', particularly the chapter on 'Variation under Domestication' concerning animal breeding. Galton devoted much of his life from then on to investigating variation in human populations, looking at both mental and physical characteristics. This led him to invent novel measures of traits and means of gathering measurements on a large scale, and to discovering new statistical methods for analysing the data.

In this book, Chris Pritchard brings together seven essays concerning Francis Galton's development of statistical techniques in the context of human variation and heredity, and the part played by his cousin George Darwin in fine-tuning Galton's work and bringing it into the public sphere, in a collaboration that took place in the early to mid-1870s. Galton provided the initiative, drive and most of the conceptual development, while Darwin contributed the tempering, mathematical correction and attention to detail, and the critical mediation with other experts. Pritchard reveals the nature and extent of George Darwin's assistance to Galton in giving rise to the concept of statistical regression. Charles Darwin provided the context in which Galton developed the theory of regression, that of evolutionary biology.

The normal curve is prominent in the statistics of Galton and the Darwins. Pritchard explains its origin in the previous century as a limiting form of the binomial distribution, and its subsequent development and uses, culminating in its place in the synthesis of probability theory and error theory.

The first essay concerns the role of Quetelet's analysis of the measurements of the chest girths of Scots militiamen and the heights of French conscripts in establishing in the mid-19th century what became the normal distribution as a model of the variability of human physical traits. Using binomial expansions and Pascal's triangle he demonstrated that empirical and theoretical results converge as the number of measurements increases, and that the precision of the results varies with the square root of that number. Quetelet derived a curve of possibility, effectively a normal curve, from these results. He perceived differences between a calculated mean and actual measurements not as errors, as his predecessors had done, but as natural deviations; these would be seen by his successors, including Galton, as variation. Pritchard is here setting the scene for what is to come.

The second essay looks at natural history, particularly how Quetelet's law of error, that had become the normal curve, can model the distribution of variation in the characters of species where there is little pressure to survive. Also addressed is the changing distribution of variation as species separate in the process of speciation, Charles Darwin arguing that as conditions change the symmetry of the distribution would be lost around the point at which species separate, while George, Galton and others showed how the symmetry would be restored. Galton applied Quetelet's error curve to analysing the distribution and inheritance of intelligence, supported by the Darwins. He considered not natural selection but class-driven and race-driven artificial selection as a threat to society. He suggested that the mental and physical attributes of our race are not symmetrically arranged, owing to differential birth rates, not fitting the normal curve but being skewed towards the lower talents. He invented the term 'Eugenics' and believed that marriage between families of high abilities should be encouraged, with incentives for them to have many children to perpetuate their good qualities.

The third essay describes Galton's quincunx, essentially a pin-board with a row of compartments at the bottom. It illustrated the cause of the curve of frequency, by demonstrating the connection between Bernouilli trials, the binomial law and the law of frequency. Lead shot is poured in at the top of the device, each descending shot being randomly deflected by successive pins before coming to rest in one of the compartments. The surface outline of the resulting columns of shot approximates to the Curve of Frequency. The greater the number of pins, and the greater the number and the smaller the diameter of the shot, the closer the outline of the columns becomes to the Normal Curve of Frequency. Pritchard argues in favour of the bagatelle as the basis of its design.

The subject of the fourth essay is the ogive, the cumulative frequency curve employed by Galton to visualise the method of ranks, which provided relative measurement in place of absolute measurement. It avoided taking direct measurements where this would cause social offence, or where no metric had been established such as when assessing intelligence. When developing the ogive Galton referred to Quetelet's use of cumulatives and ranks to analyse his measurements of Scots militiamen and French conscripts. Galton used the ogive in his research into the growth of the human form, comparing measurements of boys in rural and urban schools. The magnitudes of the quality under consideration are arranged on an evenly-spaced base and a 'curve of double curvature' drawn though their tops. Galton took the name of his curve from architecture, where such curves are called an 'ogive'. Galton used the ogive as both an empirical and a theoretical model, the former requiring no assumption that the data are distributed according to the law of frequency of error, while the latter depends upon that assumption.

George Darwin assisted Galton's development of the ogive both through his own mathematical expertise and through his contacts, most notably his Trinity College colleague and friend J.W.L. Glaisher, an accomplished error theorist, who explained the analytical form of the ogive and showed how it could be expressed as a mathematical function. Pritchard recounts some of Glaisher's life and mathematical achievements and those of other mathematicians and their development of the error function, which I found somewhat distracting from Galton's work.

The fifth essay concerns an encounter between Francis Galton and John Venn. We are treated to a short life history of both John Venn and his father Henry, again diverting from the main account. John Venn was considered the leading philosopher of probability in Britain. Pritchard explains Venn's objective, relative frequency view of probability based on observations, as opposed to others' view of probability as depending on judgement and degrees of belief. In the second edition of Venn's book 'The Logic of Chance', following his meeting with Galton, he discussed the 'nature and physical origin of the Laws of Error', and explained the 'logical principles underlying the method of Least Squares'. He mentions variation in nature and speciation, a subject dear to both Darwins. Immediately prior to the meeting with Venn George Darwin was looking at how statistical arguments could be used fruitfully, and he promoted the relative sterility of the infirm in order to redress the imbalance in birth rates across the social, and hence intellectual, strata of British society. With cousins as his parents, he conducted a statistical treatment of the occurrence and effects of cousin marriages.

Galton was moving away from Quetelet's application of probability to error theory, beginning to focus more fully on natural variation within populations. Whilst the primary influence was certainly Charles Darwin, his encounters with Venn and his writings increased Galton's understanding that the frequentist position was consistent with the concept of variation, whilst the alternative was consistent with the concept of error.

The sixth essay discusses the influence that Galton's statistics had on George Darwin. George, as Charles Darwin's son, was familiar with the theory of evolution and its importance in the emerging understanding of inheritance. George actively supported Galton in the development of regression as a statistical concept in relation to inheritance.

George Darwin wrote to Galton that 'we have a common family weakness for Statistics'. The reader is shown how Francis and George are related as second cousins by descent from Erasmus Darwin. Following a British Association meeting where Galton spoke on meteorology George and Francis began to correspond on problem solving and refinement, such that Francis was receiving considerable assistance from George in developing his statistical methods when he was revealing the method of ranks and the concept of regression. Under Galton's influence George undertook research into statistics, heredity and eugenics.

Pritchard describes the influences of other mathematicians and philosophers on Galton's theory of probabilities, his method of ranks and his use of the ogive. Many were introduced to him by George Darwin, including William Stanley Jevons, who linked psychological state and economic activity in attempting to measure unquantifiable psychological characters such as pleasure, pain and emotion.

Galton's substantial experiments on inheritance in plants, in the form of sweet pea trials, are described, which led him towards developing regression analysis. Galton relied heavily upon George Darwin and to some extent Charles to help him write up his results for publication, and also to prepare a lecture at the Royal Institution, supported by his quincunx as a visual aid, in which he explained how the processes of variation and reversion to type are governed by the normal law and how they counter each other to produce stability.

The seventh essay looks at the contributions made by other mathematicians to extending Galtonian statistics once George Darwin had moved on to astronomy in the late 1870s. W.F.R. Weldon, a young zoologist, was much influenced by Galton's 'Natural Inheritance'. Citing Galton's seminal paper on correlation in man, Weldon applied the method to wild species. Francis Ysidro Edgeworth shared Galton's belief in the inheritance of intelligence and extended the reasoning to high moral fibre and common contentment. They agreed that the influence of those with little ability to experience happiness might be reduced by artificial selection, e.g. by seeking refuge in celibate monasteries or sisterhoods. Galton's influence is seen in Edgeworth's papers on statistical methods, especially correlation. Edgeworth borrowed Galton's quincunx for his demonstrations in a lecture on correlation.

Galton was impressed by Charles Darwin's notion of the indivisible transmission unit and recognised the possibility of constructing a statistical theory of inheritance from these building blocks.

Richard Pendlebury, Donald McAlister, Karl Pearson and many others are cited as inheriting Galton's statistics, being influenced by his ideas and often receiving his help and advice. Pendlebury refined Glaisher's definitions of the error function, erf x, which is the mathematical form of Galton's ogive, later Pearson's cumulative frequency curve. At Galton's bidding McAlister formulated what became known as the lognormal distribution. Pearson followed up Weldon's studies with his important paper 'Contributions to the Mathematical Theory of Evolution'.

I found this book a readable, informative, meticulously referenced and enjoyable account of the mathematical relationship between the cousins Francis Galton and George Darwin. The author explains the mathematics and statistics clearly and thoroughly. There is some overlap of the chapters, but this is due to their origin as individual essays and does not detract from the whole.

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