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(*b*. Wallace, Nova Scotia, Canada, 12 March 1835; *d*. Washington, D.C., 11 July 1909), *astronomy*.

Simon Newcomb was the most honored American scientist of his time. During his lifetime his influence on professional astronomers and laymen was unparalleled, and it is still widely felt today. Having revolutionized the observational methods of the United States Naval Observatory, he reformed the entire theoretical and computational basis of the *American Ephemeris*. The planetary theories and astronomical constants that he derived are either still in official use or have been superseded only recently. Newcomb's discovery of the departure of the moon from its predicted position led to the investigations on the variations in the rate of rotation of the earth. These inquiries dominated dynamical astronomy during the first half of the twentieth century.

Though almost wholly of New England ancestry, Newcomb was born in Canada, the elder son of John Burton Newcomb, an itinerant country schoolteacher, and Emily Prince, daughter of a New Brunswick magistrate. Newcomb's early years were spent in various villages in Nova Scotia and Prince Edward Island. At the age of sixteen he was apprenticed to one Dr. Foshay, on the understanding that in return for schooling in "medical botany" he would serve as general assistant for five years. Dr. Foshay was a quack, and Newcomb ran away empty-handed, after serving two years. He walked most of the 120 miles to Calais, Maine, where he was befriended by a sea captain who agreed to let him work his passage to Salem, Massachusetts. There he was met by his father and they journeyed together to Maryland.

Newcomb obtained a teaching post at a country school at Massey's Cross Roads, Kent County, and a year later he moved to a school in nearby Sudlersville. In his spare time he taught himself mathematics, studying in particular Newton's *Principia*. In 1856 Newcomb became a private tutor nearer Washington and frequently traveled to the capital; he visited the library of the Smithsonian Institution and secured secretary Joseph Henry's permission to borrow the first volume of Bowditch's translation of Laplace's *Mécanique céleste*—a work that proved then to be somewhat beyond his mathematical powers. Soon afterward he met Henry, who suggested he seek employment at the Coast Survey. He was in turn recommended to the Nautical Almanac Office, then located in Cambridge, Massachusetts. Newcomb arrived there at the beginning of 1857 and a few weeks later was given a trial appointment as an astronomical computer. He also took the opportunity of studying mathematics under Benjamin Peirce at the Lawrence Scientific School of Harvard University and graduated the following year.

The outbreak of the Civil War in 1861 brought the resignations of several of the professors of mathematics attached to the United States Navy, and Newcomb was invited to fill a vacancy at the Naval Observatory. He was assigned to assist in observing the right ascensions of stars with the transit circle. He deplored the random observation of stars, as was customary, and was dismayed that there was no concerted action with the person observing declinations with the mural circle. In 1863 he was placed in charge of the mural circle, and he proposed to Superintendent Gilliss a plan, based largely on the practice at European observatories, whereby the right ascension and declination observations would be conducted more systematically. When a new transit circle was acquired in 1865 Newcomb initiated a four-year program of fundamental observations of stellar positions, involving both day and night measurements.

Newcomb had great respect, but no particular love, for observational work. While in Cambridge he had put the principles of the *Mécanique céleste* to good use and studied the secular variations in the motions of some of the minor planets. He showed that their orbits did not intersect and that there was no reason for accepting the then prevalent hypothesis that the minor planets were fragments of a larger planet that had exploded or been shattered by a collision.

After moving to Washington, Newcomb became especially interested in the motion of the moon and in the accuracy of Hansen's lunar tables. It soon became clear that the moon was starting to deviate from its predicted position. Hansen had fitted his theory to observations back to 1750, and in order to study the deviation it was desirable to make use of even earlier observations. Surmising that older records of occultations of stars by the moon existed in the archives of the Paris Observatory, Newcomb visited Paris during the siege of 1871 (departing only three weeks before the observatory found itself in the line of retreat of the Commune) and located a wealth of high-quality observations extending back to 1672. His analysis of these and other observations revealed that Hansen's tables were considerably in error prior to 1750. He suspected that the discrepancy was due to variations in the rate of rotation of the earth—and thus in the astronomical reckoning of time—but his attempt to verify this from observations of transits of Mercury was inconclusive (1882). Newcomb again took up the problem of the "fluctuation" in the motion of the moon during the final years of his life, and his exhaustive discussion of lunar observations from 720 B.C. to A.D. 1908 was completed only a month before his death. It remained for Brown, Innes, Spencer Jones, de Sitter, and others to prove that the cause of the fluctuation is indeed the irregular rotation of the earth.

In 1875 Newcomb was offered the directorship of the Harvard College Observatory, which he declined. In 1877 he was appointed superintendent of the Nautical Almanac Office, which had by then been transferred to Washington. After improving the efficiency with which the calculations for the *American Ephemeris* were made, he embarked on two ambitious projects: discussing the observations of the sun, moon, and planets obtained since 1750 at thirteen of the leading observatories throughout the world, and developing new theories and tables for the motions of these bodies. (He had published preliminary theories and tables for Uranus and Neptune several years earlier.) The project was clearly too much for one individual; and Newcomb thus went to considerable pains to obtain the best possible assistance. The most difficult part of the work, that of constructing the theories of Jupiter and Saturn, was entrusted to G. W. Hill. For these, Hansen's method was employed, and Newcomb subsequently regretted that he had not used the same method for the other planets; the use of Encke's method, although much more straightforward, introduced problems into the determination of the orbital constants that Newcomb was not able to solve. Most of the work was completed by 1895, although it was left for E. W. Brown to construct the lunar theory.

In the course of his work on planetary theory Newcomb devised a useful procedure for developing the "disturbing function" that gives the perturbative action of one planet on another. In the case of circular orbits it is usual to develop the reciprocal of the distance between the planets as a cosine series in multiples of the longitude difference between the planets, each term being multiplied by a "Laplace coefficient." Newcomb showed that the process could easily be extended to elliptical orbits by the introduction of quantities dependent upon the multiple of the mean longitude difference and differential operators that act on the Laplace coefficients. He tabulated these quantities, now commonly known as "Newcomb operators," out to those corresponding to the eighth power of the orbital eccentricities, although some of the final ones have been found to be incorrect.

During his early years at the Naval Observatory, Newcomb made an investigation of the solar parallax, principally from observations of Mars at its 1862 opposition. In 1870 he proposed the establishment of a committee to plan observations of the 1874 and 1882 transits of Venus, with a view to obtaining a more precise value of the solar parallax. The committee became the Transit of Venus Commission, and Newcomb was appointed secretary. The results from the 1874 transit were disappointing; and although he was very much in the minority, Newcomb seriously questioned the wisdom of dispatching expeditions to observe the 1882 transit. (He did, however, conduct an expedition to South Africa in 1882.) He felt that a better value of the parallax could be obtained from the velocity of light and the constant of aberration. Newcomb's investigation of the velocity of light, using mirrors at the Naval Observatory, the Washington Monument, and Fort Myer, Virginia, was essentially a refinement of Foucault's method. The value obtained was long the astronomical standard.

Newcomb's study of the transits of Mercury confirmed Leverrier's conclusion that the perihelion of Mercury is subject to an anomalous advance (now known to be due to relativity), and he sought vainly for an explanation. In the course of his work on the transits of Venus of 1761 and 1769 he resolved the doubts surrounding the 1769 observations of Maximilian Hell. The value for the mass of Jupiter which he determined from the observations of Polyhymnia has still not been significantly improved. Newcomb also established that the retrograde motion of the line of apsides of Saturn's satellite Hyperion is due to the resonant influence of Titan. He was able to show that the fourteen-month period found by Chandler in the variation of latitude is due to some lack of rigidity of the earth. He studied the zodiacal light, the distribution and motions of the stars, and solar radiation.

Around 1880 Newcomb founded the *Astronomical Papers Prepared for the Use of the American Ephemeris and Nautical Almanac* and the greater part of the above-mentioned researches was printed in the first seven volumes of this series. He also published a short account of his work on astronomical constants under the title *The Elements of the Four Inner Planets and the Fundamental Constants of Astronomy* (1895). At an international conference in Paris in 1896, it was agreed that from 1901 onwards, these constants (with only minor modifications) should be used in all the national ephemerides of the world. Newcomb was also charged with completing a catalogue of the positions and motions of the brighter stars and with making a new determination of the constant of precession. Completion of this work was complicated by his automatic retirement on his sixty-second birthday (1897), but arrangements were made for him to continue on a consulting basis.

Newcomb was instrumental in securing from Alvan Clark and Sons a twenty-six-inch refractor for the Naval Observatory, and with it he made measurements of the satellites of Uranus and Neptune. He was also prominently involved in negotiations with the Clarks for a thirty-inch refractor for the Pulkovo Observatory and in the establishment of the Lick Observatory.

In addition to his many scientific papers Newcomb wrote *A Compendium of Spherical Astronomy* (1906). It was intended to be the first of a series of texts, and it is regrettable that he never produced any further volumes. He wrote popular works on astronomy as well as three novels, some mathematical texts, several papers on economics, psychical research, and rainmaking, and one on the "flying machine" (in which his gift of foresight completely failed him: his view that man would never fly brought him into direct conflict with the astrophysicist Samuel Pierpont Langley).

Newcomb was a member or foreign associate of the national academies or astronomical societies of seventeen countries, and he received honorary degrees from as many universities. He was one of the first lecturers at the Johns Hopkins University and became a professor there in 1884; he was awarded the Sylvester prize in 1901. Among his other awards were the Copley Medal of the Royal Society, the Gold Medal of the Royal Astronomical Society, and the (first) Bruce Medal of the Astronomical Society of the Pacific. In 1863 he married Mary Caroline Hassler. He retired from the navy with the rank of captain and was promoted to rear admiral (retired) in 1906. Newcomb was buried with military honors in Arlington National Cemetery; President Taft and the representatives of several foreign governments attended the funeral.

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Lexis, Wilhelm - Encyclopedia of Mathematics

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Wilhelm LEXIS

b. 17 July 1837 - d. 24 August 1914

Summary. In a hostile germanic environment Lexis established statistics as a highly mathematical subject based on the probability calculus, by means of his dispersion theory.

Wilhelm Lexis, the son of a physician, was born in Eschweiler near Aachen, in Germany. He studied at the University of Bonn from 1855, first devoting himself to law, and later to mathematics and the natural sciences. He was awarded his doctorate in philosophy in 1859 for a thesis on analytical mechanics. For some time, he taught secondary school mathematics at the Bonn Gymnasium. He also held a job in the Bunsen chemical laboratory in Heidelberg.

Lexis' departure for Paris in 1861 marked a turning point in his career. It was there that he developed his interest in the social sciences and political economy, as well as familiarizing himself with the works of Quetelet (q.v.). His first major work, published in Bonn in 1870, was a detailed study of the evolution of France's foreign trade after the restoration of the monarchy (*Die Ausfuhrprämien im Zusammenhang mit der Tarifgeschichte* und Handelsentwicklung Frankreichs seit der Restauration*). In it* Lexis stressed the importance of basing economic theories on quantitative data, while not hesitating to make use of mathematics.

The Franco-Prussian war of 1870-71 forced him to return to Germany. While editing the *Amtliche Nachrichten für Elass-Lothringen* at Hagenau, then the seat of the general government of Alsace-Lorraine, he befriended Friedrich Althof, who was to become director of higher education in the Prussian Ministry of Education and Culture. This friendship was at the basis of Lexis' active participation in the exchange of ideas and reforms of German universities.

In the autumn of 1872, he was very appropriately appointed as professor extraordinarius (Associate Professor) in political economy at the newly created University of Strasbourg, then one semester old, where Althof was also teaching. It was in the same year that he took part in the formation of the Verein für Sozialpolitik, a movement of university members (the Kathedersozialisten), an offshoot of the historical school whose aim was the promotion of social politics. It was in the Alsatian capital that he wrote his impressive introduction to the theory of statistical demography, *Einleitung in die Theorie* der Bevölkerungsstatistik*, published in 1875*.

By then he had already left Strasbourg for Dorpat, but not without recognition by award of Doctor rerum politicorum honoris causa in 1874. In Dorpat (now Tartu in Estonia), a town in the Russian Empire where the language of university instruction was German till 1895, he held the Chair as full professor in Geography, Ethnography and Statistics. He spent only two years there, returning to the banks of the Rhine as Chair of Political Economy at the University of Freiburg im Breisgau from 1876 to 1884. This was undoubtedly his most productive period. His publications of the time, most of them appearing in *Jahrbücher für Nationalökonomie und* Statistik*, of which he was chief editor beginning from 1891*, propelled him to the front rank in the field of theoretical statistics, and revealed him as the leader of a group working on the application of the calculus of probabilities to statistical data.

Lexis simultaneously continued his research in political economy, editing the first German encyclopedia of economic and social sciences *Handwörterbuch der Staatswissenschaften*. He was particularly expert in the field of finance, publishing his *Erörterungen* über die Währungsfragen*, among other works in 1881*.

In 1884, he resigned his Chair in Freiburg for the Chair of Statistics (*Staatswissenschaften*) at the University of Breslau (now Wroclaw in Poland). Finally, in 1887, he moved to Göttingen where he held the Chair of Statistics until his death, a few days after the start of the First World War. Bortkiewicz (q.v.) was his student in Göttingen in 1892. In 1895, Lexis founded the first actuarial institute in Germany (*Königliches Seminar für Versicherungswissenschaften*), which trained its candidates in both political economy and mathematics. His scholarship in both fields allowed him to manage its direction, and to provide part of the teaching in economics and statistics, while G. Bohlmann took charge of the teaching of mathematics.

Lexis left his mark on the history of statistics through his pioneering work on dispersion, which led on to the analysis of variance. Lexis' plan was to measure and compare the fluctuations for different statistical time series. In a sense, he followed Quetelet in applying urn models to statistical series. But by stressing fluctuations, he corrected Quetelet's work, which aimed to set every series within a unique "normal" model by assuming quite erroneously their homogeneity and stability. Similarly, using a binomial urn model to represent the annual number of male births, he derived a dispersion coefficient QQ (in homage to Quetelet) which is the ratio of the empirical variance of the series considered to the assumed theoretical variance. An analogous coefficient of divergence had been independently constructed by the French actuary Emile Dormoy in 1874. In the ideal case, Lexis refers to a ``normal" dispersion when the fluctuations are purely due to chance, and the coefficient is equal to 1. But in most cases the coefficient is different from 1, and thus differs from the binomial model. The fluctuations then indicate a ``physical" rather than a chance component. Lexis classified these dispersions into two categories, ``hypernormal" and ``hyponormal" according as to whether Q>1Q>1 or Q<1Q<1. He also showed that series of social data usually have a hypernormal dispersion.

His studies on the ratio of sexes at birth, his stability theory of statistical series with his famous QQ coefficient of dispersion were re-examined in his large treatise entitled "Abhandlungen zur Theorie der Bevölkerungs- und Moralstatistik*(1903). In a review of it*, Bortkiewicz in 1904 concludes that ``(Lexis) has known how to clarify and synthesize the most general problems of moral and demographic statistics, insofar as their conditions, methods and tasks are concerned; he has also shown that if this science has had to renounce its status as ``social physics" to which Quetelet tried to raise it, it remains nevertheless far more than the simple social accounting which some modern, and excessively timid, practitioners of the discipline would have us believe."

Lexis' coefficient foreshadowed the statistics of K.Pearson (q.v.) and R.A. Fisher (q.v.), in particular χ2χ2 for the analysis of variance. However, it suffered from certain weaknesses which his more mathematical and younger contemporaries did not fail to point out and attempt to correct, among them Chuprov (q.v.), Markov (q.v.) and Bortkiewicz. In publications up to the period between the two World Wars, the Continental School of mathematical statistics tended to follow the dispersion theory of Lexis, but both eventually gave way together to the Anglo-Saxon developments in this area. Lexis' statistical views, however, did not disappear from view as they had the dubious distinction of being singled out for attack on their reactionary and bourgeois nature within the Soviet Union, by guardians of ideology such as Yastremsky.

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How to Cite This Entry:
Lexis, Wilhelm. *Encyclopedia of Mathematics*. URL:
http://www.encyclopediaofmath.org/index.php?title=Lexis,_Wilhelm&oldid=39224