CHARLES HENRY BREWITT-TAYLOR, late Commissioner to the Chinese Customs service, died on 1938 March 4 at his residence, Cathay, Earlsferry, Fife, aged eighty years. He was born at Kingston, Sussex, 1857 December 11, and spent most of his active life in China. For many years he resided at Foochow and taught navigation and astronomy at the Imperial Arsenal there. During the hostilities of 1884–5 his house was wrecked in the bombardment by the French fleet. In 1891 he was appointed to the Imperial Maritime Customs, being afterwards attached to the Chinese Post Office; while Postmaster at Shanghai he was responsible for the building of the new Post Office. He was in Peking during the siege of the Legations in the Boxer rising of 1900, when his translation of a long Chinese novel was destroyed and had subsequently to be rewritten. He published a work on *Problems and Theorems in Navigation and Nautical Astronomy*, and edited and enlarged a second edition of F. Hirth's *Textbook of Modern Documentary Chinese*; in addition he made various translations from the Chinese, including the novel in two volumes mentioned above, entitled *San Kuo, or Romance of the Three Kingdoms*.

He married, first, Alice Mary Vale, who died in 1891, and by whom he had two sons, both of whom predeceased him, one being killed in the Great War; and secondly, Ann Michie, of Tientsin, who survives him with two daughters.

He was elected a Fellow of the Society on 1885 May 8.

ERNEST WILLIAM BROWN was born on 1866 November 29, in Hill, England, son of William and Emma Martin Brown. He had two sisters, one of whom survives him; his only brother died in infancy. His father was a well-to-do farmer.

During his school years at East Riding College, Hull, he showed such aptitude for mathematics that it was decided he should continue his training at Cambridge University, where he entered Christ's College. Brown's years at Cambridge were happy ones; he succeeded in finding the proper balance between the intellectual and the social side of college life. The one sport that he indulged in was rowing. The Christ's College Boat Club figured prominently among the treasured reminiscences of his college years.

Beyond question the Cambridge professor to whom he was attached more than to anyone else was G. H. Darwin. The attraction was mutual, and grew into a friendship that continued until Darwin's death in 1912. It was Darwin who suggested to him the study of Hill's papers on the lunar theory. This was in the summer of 1888, after Brown had spent a year of post-graduate study at Cambridge. At that time Darwin himself had not yet made a thorough study of Hill's researches.

It is not unusual that the recommendation to an advanced student of a subject for specialized study gives a young man a start on a successful scientific career in the suggested field, but Brown's case is one of the most striking on record. From the summer of 1888 on, until his death, he studied the lunar theory. For twenty years he gave very little thought to other research. During the remaining thirty years, although he had then broadened his field of activity, the Moon's motion remained his favourite subject, to which he returned again and again.

He remained in Cambridge, as fellow of Christ's College after 1889, and received his M.A. degree in 1891. In that year he went to the United States and became instructor in mathematics in Haverford College. His connections with his Alma Mater remained very intimate. A part of almost every summer was spent at Cambridge, frequently as guest at the Darwin residence, even long after Darwin's death. He received his Sc.D. degree in 1897, and became honorary fellow of Christ's College in 1911.

The study of the Moon's motion was not undertaken with the ambitious plan of creating a new and complete lunar theory. This plan grew gradually as he studied the entire field, and familiarized himself with the various methods that had been used or were available. Two methods attracted him particularly, Hill's and Delaunay's. He learned to know the value and the power of Hill's method by actual application and further developments. Beginning in 1891 he published a number of contributions in which he presented the theoretical developments required for evaluation of certain classes of terms in the Moon's motion and their numerical application.

The long period of preparation was followed by three years, 1895 to 1897, of astonishing productivity. In this short space of time he published (1) *Investigations in the Lunar Theory*, in which a complete plan was presented for the development of the solution of the "main problem"; (2) *An Introductory Treatise on the Lunar Theory*; (3) important theoretical papers including a theory of the secular accelerations in the Moon's motion; and (4) the first part of his *Theory of the Motion of the Moon.*

An Introductory Treatise on the Lunar Theory shows how completely he had absorbed the entire subject, the more remarkable if one considers that the author had not yet reached the age of thirty.

Brown himself considered his evaluation of the secular accelerations (1896–97) his favourite contribution to celestial mechanics. For this reason it deserves a somewhat detailed presentation.

The theoretical determination of the secular accelerations, produced by the secular diminution of the eccentricity of the Earth's orbit, had been among the most difficult and laborious parts of the lunar theory. Newcomb, in 1895, showed that the derivation could be rendered a relatively simple matter by making use of a remarkable theorem that may be stated as follows: If the Delaunay variables L, G, H of the "main problem" are expressed in terms of the constants n, e, γ, e', the variations of n, e, γ can be obtained from those in e' by the relation

$$\delta L = \delta G = \delta H = 0,$$

where

$$\delta = \delta n \frac{\partial}{\partial n} + \delta e \frac{\partial}{\partial e} + \delta\gamma \frac{\partial}{\partial \gamma} + \delta e' \frac{\partial}{\partial e'}.$$

If π_1, θ_1 are the mean motions of the perigee and node, similarly expressed in terms of n, e, γ, e', the secular accelerations are obtained from

$$\int \delta n dt, \qquad \int \delta \pi_1 dt, \qquad \int \delta\theta_1 dt.$$

Newcomb's evaluation still suffered from the slow convergence of Delaunay's developments. On that account his result for the secular acceleration in the Moon's mean longitude was uncertain to about one-twentieth of its amount. Brown showed that a new theorem, related to Newcomb's, could be used to obtain the three secular accelerations each to one three-hundredth part, not including the uncertainty present in $\delta e'$ on account of the uncertainties in the planetary masses.

The fundamental relation, in which the unimportant terms depending on $(a/a')^2$ are ignored, is :

$$(L-G)\delta\frac{\partial\pi_1}{\partial\alpha}+(G-H)\delta\frac{\partial\theta_1}{\partial\alpha}=-\frac{3}{2}(E+M)\delta\frac{\partial}{\partial\alpha}\left(\frac{1}{r}\right)_0,$$

in which $\alpha=n$, e, γ successively, and $(1/r)_0$ is the constant part of the final trigonometric development of $1/r$. The symbol δ has the same meaning as in Newcomb's theorem. As a special case, since $(1/r)_0$ does not contain the first powers of e^2, γ^2, the part of δn that depends on n'/n and $\delta e'$ only is obtained from

$$\frac{\partial^2}{\partial n^2}\left(\frac{1}{r}\right)_0\delta n=-\frac{\partial^2}{\partial n\partial e'}\left(\frac{1}{r}\right)_0\delta e'.$$

The numerical work was carried out with a judicious use of both Delaunay's expressions and the results obtained in his own theory in which the Moon's mean motion had received a numerical value.

The systematic development of the lunar theory began in 1895. The entire plan had been so well prepared that the work could proceed without serious interruptions by unforeseen difficulties. The results were published in five parts in the *Memoirs of the Royal Astronomical Society*, 1897 to 1908. The fourth part, 1905, concluded with a tabulation of the final coefficients of the solution of the "main problem." Both as to completeness and accuracy Brown's solution surpassed those of his predecessors in a remarkable degree. Few terms having coefficients in longitude and in latitude exceeding ″·001 were not obtained, and in the great majority of terms the uncertainty did not exceed ″·001. In Hansen's theory some coefficients were in error by some tenths of a second of arc ; Delaunay's theory, on account of the slow convergence peculiar to his development, contained a few terms that were in error by as much as a whole second of arc.

Brown was always ready to give Hill a proper share of the credit for his solution of the main problem. It would be unfair, however, to consider his work merely a routine application of Hill's methods. This would have been impossible for a man of his character. He could use ideas of others, but would rarely apply them without important modifications. As a rule such modifications would be designed to shorten the work. This is very particularly true of the modifications to Hill's plan in the elaboration of the lunar theory. The study of this theory is complicated by the numerous devices and changes in procedure introduced for this purpose. The entire work had been completed with the aid of only one computer, Mr. Ira I. Sterner, A.M.

A difficult task remained after the work on the main problem had been completed, namely, the evaluation of the effects upon the Moon's motion due to the attractions of the planets and the deviations from sphericity of the Earth and the Moon. In 1878 Newcomb published his comparison of observations of occultations with Hansen's theory, extending backward to 1620 the period during which the Moon's motion was known with a fair degree of accuracy. This established more firmly than before the fact that large unexplained differences remained between Hansen's theory and observations. The question whether these differences could be ascribed to imperfections of the gravitational theory thus became one of the most pressing problems in gravitational astronomy, a problem that could be solved only by a reliable determination of the planetary perturbations in the Moon's motion. Brown's evaluation of these perturbations provided the answer, and established beyond reasonable doubt that the Moon's observed motion cannot be accounted for by gravitational theory alone. The fifth and final part of this theory, published in 1908, contained his results. The direct planetary perturbations had been published separately in more detail as an "Essay which obtained the Adams Prize in the University of Cambridge for the year 1907." This fifth part of the lunar theory is, in many respects, Brown's most original work. No other problem in celestial mechanics requires a more careful handling of the equations of motion and of the complicated developments. Brown's ability in treating such a problem has never been equalled. The planetary perturbations on the Moon had been developed fifteen years earlier by Radau and, just when Brown finished his work, a memoir by Newcomb appeared which contained a solution of the same problem. Later Brown published a comparison of the three results, leaving very few of the differences unexplained.

The construction of new lunar tables was undertaken as soon as the theory had been completed. Brown had been connected with Haverford College since 1891, first as instructor and since 1893 as professor of mathematics. In 1907 he became professor of mathematics in Yale University, just when it became desirable to find ways and means for the construction of the tables. An agreement was made by which Yale University undertook the cost of their calculation, printing, and publication. This involved a sum of some thirty-four thousand dollars.

As with his work on the theory, he did not start the definitive calculations for the tables without an exhaustive study of the problem before him. It is not likely that he had, at that time, more than a superficial knowledge of the construction of astronomical tables. When he had completed the task he had made some very real contributions to the subject. The excellence of the tables is, to a large extent, due to the efficient assistance rendered by Dr. H. B. Hedrick who was employed as chief computer for nine years. Hedrick had been connected with the Nautical Almanac office in Washington for twenty-four years, and possessed exceptional qualities as computer in the highest sense.

The most ingenious new feature of the tables is the arrangement of the single-entry tables. Here the improvement over Hansen's form of tabulation is extraordinary. The tables cover less space than in Hansen's case, and are more convenient to use. This is especially due to their being completely re-entrant, *i.e.* after the value of the argument for a certain instant has been found, the values for succeeding half-day intervals for a whole year can be found without recomputation of the argument or change of the interpolating factor.

The monumental *Tables of the Motion of the Moon* were published by the Yale University Press in 1919; they had been printed at the Cambridge University Press. The three volumes, containing some 660 pages of tables and explanation of their use, set a standard of perfection for works of this nature that will not easily be surpassed.

The numerical values for the constants used in the tables had been obtained from a comparison with the Greenwich observations in the years 1750 to 1900. This mass of some 20,000 observations had been prepared and analysed by Cowell, a continuation and extension of an undertaking started by Airy. The accuracy of the constants is, therefore, primarily due to Cowell's admirable analysis. An interesting confirmation was obtained in 1932 by Spencer Jones who, in a revision of Newcomb's occultation work, made an independent determination of the constants from totally different material, and derived results that are in excellent agreement with Brown's values.

The new tables have been used for the calculation of the Moon's place in most national ephemerides since 1923. The great improvement over Hansen, especially in the short-period terms, is immediately apparent from the small range of the residuals from observations in any one year. The new theory did not, however, account for the large fluctuations in the Moon's mean longitude that had puzzled Newcomb; a "great empirical term" was introduced with coefficient $10''\cdot71$ and period 257 years in order to eliminate the major part of the fluctuations during the past few centuries. Newcomb had seen very clearly that the discrepancy in the Moon's motion might be due to irregularities in the rate of rotation of the Earth. In that case similar fluctuations should be present in the observed mean longitudes of other bodies in the solar system. Newcomb concentrated upon transits of Mercury and found some indication of agreement with the Moon, but not enough to be quite convinced of its reality. Brown gave much thought to this problem, especially after 1913. Finally, in 1926, he published his well-known paper: "The Evidence for Changes in the Rate of Rotation of the Earth and their Geophysical Consequences," in which he accepted the explanation that the fluctuations in the Moon's mean longitude, including the great empirical term, were caused by irregular changes in the Earth's rate of rotation. His argument was that no external cause had been found for such effects in the Moon's motion, and that the explanation was supported by a general similarity between the residuals in the Sun's longitude and those exhibited by the Moon. The principal value of this paper was the clear exposition of the entire problem. Other astronomers had helped to clear the ground for Brown's contribution. Especially noteworthy was Innes's discussion in 1925, in which he concluded, mainly from a study of transits of

Mercury: "When allowance is made for the variability of the rotation of the Earth, the Moon's motion will probably be found to be purely gravitational. The inclusion of empirical terms confuses." Neither Innes's nor Brown's exposition could be considered a complete proof of the irregular variability of the Earth's rotation. This required the more thorough quantitative analysis of all relevant observational data which was subsequently made by other astronomers, mainly by de Sitter and by Spencer Jones, and which proved that the problem was more complicated than Innes or Brown had assumed.

From 1926 on Brown gave much attention to comparisons of observations of the Moon with the tables. This led to his occultation campaign, supported by many astronomers all over the world. These discussions meant a great deal to him: they kept him occupied at times when his failing health did not permit him to do more strenuous work.

He found several opportunities to apply his knowledge of the theory of the Moon's motion to the study of related problems. After a discussion with Jackson, who had developed a plan to apply Delaunay's theory to the motion of the eighth satellite of Jupiter, Brown took up this problem. He overcame the extremely slow convergence by ingenious extrapolations, but was apparently not satisfied with the results. Soon afterwards he began an entirely numerical development of the theory by a totally different method.

During the last three years of his life the main problem of the lunar theory again held his almost exclusive attention. In this period he treated the stellar case of the problem of three bodies, and followed with the greatest interest the numerical verification of the solar perturbations in the Moon's motion by his former pupil, Dr. W. J. Eckert, who had undertaken this work at Brown's suggestion.

He ventured but rarely outside of the realm of celestial mechanics. Next to the lunar theory he was attracted primarily to the problems of planetary motion. Until 1908, when he finished the lunar theory, his explorations in this field had always been closely connected with the study of the Moon's motion. From then on they became independent. A theoretical study of the motion of bodies near the Lagrangian triangular points was later followed by a general theory applicable to all planets of the Trojan Group, and particularly to orbits with large amplitudes of libration. Soon after his earlier work on this problem (1910) he began a more general study of resonance in planetary motion. This problem, related to that of the gaps in the ring of asteroids, had been treated on numerous previous occasions by many mathematical astronomers. Brown's contributions had many original features; he was probably the first to see clearly that "the calculus of probabilities is more likely to lead to further information than the logical processes of analysis."

The more abstract phases of celestial mechanics could hold his attention for limited times only. Gradually he became more particularly interested in the study of practical methods for planetary theories. In this connection he dealt extensively with the development of the disturbing function. This led eventually to the construction of the *Tables for the Development of the Disturbing Function* (1933).

He concentrated upon two different forms of planetary theories: the variation of arbitrary constants, and a method in which a modified true orbital longitude is used as independent variable. In the former he limited himself mainly to the indication of abbreviated methods and to the computation of the most important terms of higher order due to the presence of small divisors. His true-longitude method is a modification of Laplace's method. It is not an easy matter to judge its value. Brown used it himself in its original form in the theory of the Trojan Group because it offered some advantages in obtaining the intermediate orbit. Later he decided that for the Trojan Group the method of the variation of arbitrary constants is superior. He used it again in the theory of the eighth satellite of Jupiter. In the introduction to the second part of this theory he wrote: "The method has given rise to complications which make the developments of the terms of higher order difficult to follow, requiring great care if errors are to be avoided." A complete application to an ordinary planetary theory has not yet been made.

In the treatise *Planetary Theory* (1933), written in collaboration with Dr. C. A. Shook, a coherent presentation is given of most of his contributions to celestial mechanics that are not related to the lunar theory.

Striking features of all his published work are the clearness of presentation, the orderly development of the subject, and the excellent command of the English language. This suggests that he could have been a great teacher. He was, in fact, able to present a difficult subject to any audience with perfect lucidity. However, he never permitted himself to become fond of teaching, although he fulfilled his teaching duties conscientiously. He taught various subjects in pure and applied mathematics, in later years only dynamics and celestial mechanics.

Brown's high standing among scientists was recognized early. He became a member of numerous honorary societies and received the highest distinctions. At the very early age of thirty-one he was elected Fellow of the Royal Society; he received the Royal Medal of the Society in 1914. In 1907 the Royal Astronomical Society awarded him the Gold Medal for his researches in the lunar theory. Then followed the Pontécoulant Prize of the Paris Academy of Sciences in 1910, and the Bruce Medal of the Astronomical Society of the Pacific in 1920. After he had become an American citizen he was elected member of the National Academy of Sciences. The Watson Medal, presented to him by the Academy in 1937, was among his most cherished honours: perhaps because it was awarded specifically not for his lunar theory but for his other contributions to celestial mechanics.

He was never married and made his home with his unmarried younger sister, who predeceased him by about two years. No man could ever have asked for a more devoted companion than he had in his sister; she seemed to concern herself exclusively with his comfort. He was an accomplished piano player, fond of music. He played a good game of chess and read widely. His literary taste changed with his age from a fondness for English