Sir GEORGE HOWARD DARWIN, 1845–1912.

By the death of Sir **George Howard Darwin**, which took place on December 7 last, the Society has lost an investigator of rare skill and untiring patience, whose work has done much to add lustre to a name already pre-eminent in the annals of British science.

Sir George, the second son of Charles Darwin, was born at Down, Kent, in the year 1845. Brought up amidst scientific surroundings from the start, he received his early education privately at the hands of Rev. Charles Pritchard, who afterwards became Savilian Professor of Astronomy in the University of Oxford. Among Pritchard's pupils at the time were numbered the sons of many of England's leading scientists, and many of these in turn have since won for themselves distinguished careers, no fewer than three having officiated in after years as Presidents of the British Association.

He gained an entrance scholarship and entered at Trinity College, Cambridge, in 1864, and graduated as Second Wrangler and Smith's Prizeman in the year 1868. The same year he was elected to a Fellowship at Trinity College. The Senior Wrangler of the year was Mr. Fletcher Moulton of St. John's (now Lord Justice of Appeal), who relates how he himself at first remained at Cambridge with the object of pursuing an academic career while Darwin proceeded to London to read with a prominent barrister with a view to adopting the bar as a profession. He was duly called but never practised, and a few years only elapsed before the positions were interchanged and Darwin once more returned to Cambridge, where the rest of his life was spent. There he devoted himself to the solution of those intricate problems, associated primarily with the unravelling of the early history of the Solar System, which form the subject of the four monumental volumes of 'Collected Papers' recently issued under his personal supervision by the Cambridge University Press.

This work had already made considerable progress when he was invited to occupy the Plumian Chair of Astronomy, which became vacant by the death of Challis in 1883, and in the following year he was re-elected to a professorship at Trinity, his previous tenure having expired by lapse of time in 1878. The same year he married Maud, daughter of Charles du Puy, of Philadelphia, and took up his abode at the pleasant home of Newnham Grange at the end of the "Backs," which will long be associated with kindly recollections by all whose privilege it was to visit there. He had two sons and two daughters. His elder son Charles followed in his father's footsteps by becoming a scholar of Trinity in 1905 and graduating as Fourth Wrangler in the Mathematical Tripos of 1909.

Darwin's earliest notable contribution to science was an investigation "On the Influence of Geological Changes on the Earth's Axis of Rotation" ('Phil.

Trans.,' 1877, Part I, vol. 167). At this time the opinion was frequently held by geologists that the wanderings of the pole in the Earth's figure caused by geological upheavals and subsidences, together with associated changes in the obliquity of the ecliptic and the consequent variation in the intensity of seasonal changes, could afford an adequate explanation of the glacial epochs, though the best physical opinion was opposed to this view.

Darwin attacked this problem in characteristic manner. Not content with the mere qualitative indications of analysis his aim was to subject the results which might arise therefrom to definite numerical tests, and though the vagueness of the geological evidence available was such as to preclude any great precision in the results, the conclusions arrived at are quantitatively such as to be "absolutely inconsistent with the sensational speculations as to the causes and effects of the glacial epoch which some geologists have permitted themselves to make."

This paper was referred by the Society to Sir William Thomson (Lord Kelvin), and in this manner was the means of bringing Darwin into association with him. The acquaintance thus formed ripened into a close and intimate friendship which lasted till Kelvin's death. Henceforth we find the well known inspiring influence of Lord Kelvin pervading Darwin's work, and important memoirs followed one another in quick succession.

The conclusions arrived at in the paper referred to above were based on the assumption that throughout geological history, apart from slow geological changes, the Earth would rotate sensibly as if it were rigid. It is shown that a departure from this hypothesis might possibly account for considerable excursions of the axis of rotation within the Earth itself, though these would be improbable, unless, indeed, geologists were prepared to abandon the view "that where the continents now stand they have always stood"; but no such effect is possible with respect to the direction of the Earth's axis in space. Thus the present condition of obliquity of the Earth's equator could in no way be accounted for as a result of geological change, and a further cause had to be sought. Darwin foresaw a possibility of obtaining an explanation in the frictional resistance to which the tidal oscillations of the mobile parts of a planet must be subject. The investigation of this hypothesis gave rise to a remarkable series of papers of far reaching consequence in theories of cosmogony and of the present constitution of the Earth.

In the first of these papers, which is of a preparatory character, "On the Bodily Tides of Viscous and Semi-elastic Spheroids, and on the Ocean Tides on a Yielding Nucleus" ('Phil. Trans.,' 1879, vol. 170), he adapts the analysis of Sir William Thomson, relating to the tidal deformations of an elastic sphere, to the case of a sphere composed of a viscous liquid or, more generally, of a material which partakes of the character either of a solid or a fluid according to the nature of the strain to which it is subjected. For momentary deformations it is assumed to be elastic in character, but the elasticity is considered as breaking down with continuation of the strain in such a manner that under very slow variations of the deforming forces it will behave sensibly as if it were a viscous liquid. The exact law assumed by Darwin was dictated rather by mathematical exigencies than by any experimental justification, but the evidence afforded by the flow of rocks under continuous stress indicates that it represents, at least in a rough manner, the mechanical properties which characterise the solid parts of the Earth.

The chief practical result of this paper is summed up by Darwin himself by saying that it is strongly confirmatory of the view already maintained by Kelvin that the existence of ocean tides, which would otherwise be largely masked by the yielding of the ocean bed to tidal deformation, points to a high effective rigidity of the Earth as a whole. Its value, however, lies further in the mathematical expressions derived for the reduction in amplitude and retardation in phase of the tides resulting from viscosity which form the starting point for the further investigations to which the author proceeded.

The retardation in phase or "lag" of the tide due to viscosity implies that a spheroid as tidally distorted will no longer present a symmetrical aspect as viewed from the disturbing body which generates the tides, as it would do if no such cause were operative. The attractive forces on the nearer and more distant parts will consequently form a non-equilibrating system with resultant couples tending to modify the state of rotation of the spheroid about its centre of gravity. The action of these couples, though exceedingly small, will be cumulative with lapse of time, and it is their cumulative effects over long intervals which form the subject of the next paper, "On the Precession of a Viscous Spheroid and on the Remote History of the Earth" ('Phil. Trans.,' 1879, vol. 170, Part II, pp. 447–530). The case of a single disturbing body (the Moon) is first considered, but it is shown that if there are two such bodies raising tidal disturbances (the Sun and Moon) the conditions will be materially modified from the superposed results of the two disturbances considered separately. Under certain conditions of viscosity and obliquity the obliquity of the ecliptic will increase, and under others it will diminish, but the analysis further yields "some remarkable results as to the dynamical stability or instability of the system . . . . for moderate degrees of viscosity, the position of zero obliquity is unstable, but there is a position of stability at a high obliquity. For large viscosities the position of zero obliquity becomes stable, and (except for a very close approximation to rigidity) there is an unstable position at a larger obliquity, and again a stable one at a still larger one."

The reactions of the tidal disturbing force on the motion of the Moon are next considered, and a relation derived connecting that portion of the apparent secular acceleration of Moon's mean motion, which cannot be otherwise accounted for by theory, with the heights and retardations of the several bodily tides in the Earth. Various hypotheses are discussed, but with the conclusion that insufficient evidence is available to form "any estimate having any pretension to accuracy . . . . as to the present rate of tidal friction."

But though the time scale involved must remain uncertain, the nature of the physical changes that are taking place at the present time is practically free from obscurity. These involve a gradual increase in the length of the day, of the month, and of the obliquity of the ecliptic, with a gradual recession of the Moon from the Earth. The most striking result is that these changes can be traced backwards in time until a state is reached when the Moon's centre would be at a distance of only about 6000 miles from the Earth's surface, while the day and month would be of equal duration, estimated at about 5 hours 36 minutes. The minimum time which can have elapsed since this condition obtained is further estimated at about 54 million years. This leads to the inevitable conclusion that the Moon and Earth at one time formed parts of a common mass and led to an inquiry as to how and why the planet broke up. The most probable hypothesis appeared to be that, in accordance with Laplace's nebular hypothesis, the planet, being partly or wholly fluid, contracted, and thus rotated faster and faster, until the ellipticity became so great that the equilibrium was unstable.

The tentative theory put forward by Darwin, however, differs from the nebular hypothesis of Laplace in the suggestion that instability might set in by the rupture of the body into two parts rather than by the casting off of a ring of matter, somewhat analogous to the ring of Saturn, to be afterwards consolidated into the form of a satellite.

The mathematical investigation of this hypothesis forms a subject to which Darwin frequently reverted later, but for the time he devoted himself to following up more minutely the motions which would ensue after the supposed planet, which originally consisted of the existing Earth and Moon in combination, had become detached into two separate masses. In the final section of a paper "On the Secular Changes in the Elements of the Orbit of a Satellite revolving about a Tidally Distorted Planet" ('Phil. Trans.,' 1880, vol. 171), Darwin summarises the results derived in this and preceding memoirs. Various factors ignored in the earlier investigations, such as the eccentricity and inclination of the lunar orbit, the distribution of heat generated by tidal friction and the effects of inertia, were duly considered and a complete history traced of the evolution resulting from tidal friction of a system originating as two detached masses nearly in contact with one another and rotating nearly as though they were parts of one rigid body. Starting with the numerical data suggested by the Earth-Moon system, "it is only necessary to postulate a sufficient lapse of time, and that there is not enough matter diffused through space to resist materially the motions of the Moon and Earth," when "a system would necessarily be developed which would bear a strong resemblance to our own." "A theory, reposing on *veræ causæ*, which brings into quantitative correlation the lengths of the present day and month, the obliquity of the ecliptic, and the inclination and eccentricity of the lunar orbit, must, I think, have strong claims to acceptance."

Confirmation of the theory is sought and found, in part at least, in the case of other members of the solar system which are found to represent various stages in the process of evolution indicated by the analysis.

The application of the theory of tidal friction to the evolution of the Solar System and of planetary sub-systems other than the Earth-Moon System is, however, reconsidered later, "On the Tidal Friction of a Planet attended by Several Satellites, and on the Evolution of the Solar System" ('Phil. Trans.,' 1882, vol. 172). The conclusions drawn in this paper are that the Earth-Moon system forms a unique example within the Solar System of its particular mode of evolution. While tidal friction may perhaps be invoked to throw light on the distribution of the satellites among the several planets, it is very improbable that it has figured as the dominant cause of change in any of the other planetary systems or in the Solar System itself.

These researches were followed by a further application of Lord Kelvin's analysis of the strain in an elastic sphere to the determination of the strength of the materials of which the Earth must be built so as to prevent the continents from sinking and the sea-bed from rising—"On the Stresses caused in the Interior of the Earth by the Weight of Continents and Mountains" ('Phil. Trans.,' 1882, vol. 173). In this paper it is conclusively shown that the surface inequalities of the Earth's surface must give rise to enormous stress even at considerable depths comparable with the dimensions of the globe itself, and the continued resistance to this stress must imply a strength of material at least equivalent to that of granite. If this resistance is located in the surface layers only a still higher and almost inconceivable degree of strength will be indicated. Thus additional evidence is afforded by the dimensions of superficial inequalities of the Earth's crust of the solid structure of the Earth advocated by Lord Kelvin.

Simultaneously with the above researches we find Darwin, in conjunction with his brother, Mr. Horace Darwin, conducting experiments, in accordance with a suggestion of Lord Kelvin, for the purpose of directly measuring the deflections of the plumb-line due to the disturbing action of the Moon. The experiments failed in their purpose, not from want of delicacy of the apparatus used, but from the existence of more pronounced disturbing influences at the time but little understood, but which nowadays form the subject of continued observation by seismologists. The experiments afford an early contribution to the scientific study of these seismic disturbances; the separation of the lunar disturbances from them has since been successfully accomplished by Hecker.

The application of the theoretical researches on tidal friction to the consideration of the present structure of the Earth demanded observational data to be derived from existing knowledge of ocean tides. As the principal tides might be expected to depart far from the equilibrium law, and an adequate dynamical theory, on account of the complex distribution of the ocean, appeared to be far beyond the posssibilities of mathematical analysis, such evidence as was required had to be sought in the separation from the records of tidal observation of the tides of long period which might be expected to follow more closely the equilibrium law. This separation required a close and delicate analysis.

The theory underlying this analysis had been already laid down by Laplace, who had shown how the disturbing force may be analysed into various simple harmonic constituents, each of which will generate a tide of the same period as the disturbing force, the determination of the amplitude and phase of which, though not yielding to theory, can be effected for each port by direct observation.

The practical application of this theory to the discussion of tidal observations by means of harmonic analysis had been suggested by Lord Kelvin, and reports on the subject had been drawn up by him and presented to the British Association in 1868, 1870, 1871, 1872, and 1876. The whole subject was, however, in need of co-ordination and revision, and for this purpose a committee, consisting of Prof. Adams and Darwin, was appointed in 1882. The work of this committee devolved principally on Darwin, who, however, acknowledges the great benefit derived from the advice received from Adams from time to time. The output of this committee consists of a series of reports, dealing in a most thorough and complete manner with the co-ordination of the various existing methods of discussion of tidal observations, the derivation of harmonic constants with the highest degree of precision of which the observations permit, and the utilisation of these constants for the formation of tide tables. The schemes put forward by Darwin in these reports, of which a further account is given at length in the article "Tides," written by him for the 'Encyclopædia Britannica' in 1888, have since been practically universally adopted.

Following on this, we find Darwin turning his attention back to the problems arising in connection with the genesis of the Moon, in accordance with the indications previously arrived at from the theory of tidal friction. It appeared to be of interest to trace back the changes which would result in the figures of the Earth and Moon, owing to their mutual attraction, as they approached one another. The analysis is confined to the consideration of two bodies supposed constituted of homogeneous liquid. At considerable distances the solution of the problem thus presented is that of the equilibrium theory of the tides, but, as the masses are brought nearer and nearer together, the approximations available for the latter problem cease to be sufficient. Here, as elsewhere, when the methods of analysis could no longer yield algebraic results, Darwin boldly proceeds to replace his symbols by numerical quantities, and thereby succeeds in tracing, with considerable approximation, the forms which such figures would assume when the two masses are nearly in contact. He even carries the investigation farther, to a stage when the two masses in part overlap. The forms obtained in this case can only be regarded as satisfying the analytical, and not the true physical conditions of the problem, as, of course, two different portions of matter cannot occupy the same space. They, however, suggest that, by a very slight modification of the conditions, a new form could be found, which would fulfil all the conditions, in which the two detached masses are united into a single mass, whose shape has been variously described as resembling that of an hour-glass, a dumb-bell, or a pear. This confirms the suggestion previously made that the origin of the Moon was to be sought in the rupture of the parent planet into two parts, but the theory was destined to receive a still more striking confirmation from another source.

While Darwin was still at work on the subject, there appeared the great memoir by M. Poincaré, "Sur l'équilibre d'une masse fluide animée d'un mouvement de rotation" ('Acta Math.,' vol. 7).

The figures of equilibrium known as Maclaurin's spheroid and Jacobi's ellipsoid were already familiar to mathematicians, though the conditions of stability, at least of the latter form, were not established. By means of analysis of a masterly character, Poincaré succeeded in enunciating and applying to this problem the principle of exchange of stabilities. This principle may be briefly indicated as follows: Imagine a dynamical system such as a rotating liquid planet to be undergoing evolutionary change such as would result from a gradual condensation of its mass through cooling. Whatever be the varying element to which the evolutionary changes may be referred, it may be possible to define certain relatively simple modes of motion, the features associated with which will, however, undergo continuous evolution. If the existence of such modes has been established, M. Poincaré shows that the investigation of their persistence or "stability" may be made to depend on the evaluation of certain related quantities which he defines as coefficients of stability. The latter quantities will be subject to evolutionary change, and it may happen that in the course of such change one or more of them assumes a zero value. Poincaré shows that such an occurrence indicates that the particular mode of motion under consideration coalesces at this stage with some other mode which likewise has a vanishing coefficient of stability. Either mode will, as a rule, be possible before the change, but whereas one will be stable the other will be unstable. The same will be true after the change, but there will be an interchange of stabilities, whereby that which was previously stable will become unstable, and *vice versâ*. An illustration of this principle was found in the case of the spheroids of Maclaurin and the ellipsoids of Jacobi. The former in the earlier stages of evolution will represent a stable condition, but as the ellipticity of surface increases a stage is reached where it ceases to be stable and becomes unstable. At this stage it is found to coalesce with Jacobi's form which involves in its further development an ellipsoid with three unequal axes. Poincaré shows that the latter form possesses in its earlier stages the requisite elements of stability, but that these in their turn disappear in the later developments. In accordance with the principle of exchange of stabilities laid down by him, the loss of stability will occur at a stage where there is coalescence with another form of figure, to which the stability will be transferred, and this form he shows at its origin resembles the pear which had already been indicated by Darwin's investigation. The supposed pear-shaped figure was thus arrived at by two entirely different methods of research, that of Poincaré tracing the processes of evolution forwards and that of Darwin proceeding backwards in time.

The chain of evidence was all but complete; it remained, however, to consider whether the pear-shaped figure indicated by Poincaré, stable in its earlier forms, could retain its stability throughout the sequence of changes necessary to fill the gap between these forms and the forms found by Darwin.

In later years Darwin devoted much time to the consideration of this problem. Undeterred by the formidable analysis which had to be faced, he proceeded to adapt the intricate theory of Ellipsoidal Harmonics to a form in which it would admit of numerical application, and his paper on "Ellipsoid Harmonic Analysis" ('Phil. Trans.,' A, 1901, vol. 197), apart from the application for which it was designed, in itself forms a valuable contribution to this particular branch of analysis. With the aid of these preliminary investigations he succeeded in tracing with greater accuracy the form of the pear-shaped figure as established by Poincaré, "On the Pear-shaped Figure of Equilibrium of a Rotating Mass of Liquid" ('Phil. Trans.,' A, 1901, vol. 198), and, as he considered, in establishing its stability, at least in its earlier forms. Some doubt, however, is expressed as to the conclusiveness of the argument employed, as simultaneous investigations by M. Liapounoff pointed to an opposite conclusion. Darwin again reverts to this point in a further paper "On the Figure and Stability of a Liquid Satellite" ('Phil. Trans.,' A, 1906, vol. 206), in which is considered the stability of two isolated liquid masses in the stage at which they are in close proximity, *i.e.*, the condition which would obtain, in the Earth-Moon System, shortly after the Moon had been severed from the Earth. The ellipsoidal harmonic analysis previously developed is then applied to the determination of the approximately ellipsoidal forms which had been indicated by Roche. The conclusions arrived at seem to point, though not conclusively, to instability at the stage of incipient rupture, but in contradistinction to this are quoted the results obtained by Jeans, who considered the analogous problems of the equilibrium and rotation of infinite rotating cylinders of liquid. This problem is the two-dimensional analogue of the problems considered by Darwin and Poincaré, but involves far greater simplicity of the conditions. Jeans finds solutions of his problem strictly analogous to the spheroids of Maclaurin, the ellipsoids of Jacobi, and the pear of Poincaré, and is able to follow the development of the latter until the neck joining the two parts has become quite thin. He is able to establish conclusively that the pear is stable in its early stages, while there is no evidence of any break in the stability up to the stage when it divides itself into two parts.

Reference must now be made to Darwin's work on the subject of "Periodic Orbits." Though no published work on this subject appeared before the year 1897, the memoir which then appeared contained the substance of work which had occupied him for some years previously, the continuation of which only ceased with his death. The work had its origin in the beautiful memoirs of Mr. G. W. Hill on the Lunar Theory. The usual method of procedure in discussing "the problem of three bodies" is to base the solution on the "problem of two bodies," *i.e.,* on the theory of elliptic motion, and then to calculate by successive approximations the small disturbances resulting from the presence of a third body. Hill was the first to show that certain special solutions of a simple character could be derived which presented marked superiority over the elliptic orbits previously used as a starting point for more exact investigation. As applied to the Lunar Problem he succeeded in determining by analytical methods a solution in which all those inequalities (the variational inequalities) dependent on the ratios of the mean motions of the Sun and Moon, but independent of the eccentricity and inclination of the lunar orbit and of the Sun's parallax, are taken into account at the outset. Owing to the slow convergence of the series involved, the analytical methods fail when the ratio of the month to the year is increased much beyond the value which actually holds, but Hill showed that in such cases the special solutions could still be derived by a method of numerical quadrature.

The initial object of Darwin's research was to apply Hill's method of investigation to cases which departed somewhat widely from the traditional cases dealt with in the lunar and planetary theories, and where strictly analytical methods were of little avail. He therefore adopts the method of numerical quadratures from the outset. The problem which he set himself was to trace out the possible paths of a small body (or satellite) moving in the plane of the circular orbit of a planet (Jove) round the Sun; from among such possible paths he then sought to pick out, by trial and error, the particular ones which fulfilled the condition of Hill's lunar orbit, viz., that after the lapse of a certain interval the conditions which obtained at the commencement of the interval would be exactly reproduced, so that the solution obtained would be "periodic" in character. Thus, it would only be necessary to investigate the features pertaining to a single period to obtain a knowledge of the motion of the satellite for all time.

In order to emphasise the phenomena of perturbation, Darwin started with a case where the mass of the planet was considerable compared with that of the Sun. The actual numerical value adopted for the ratio of the masses of the planet and Sun was 1 : 10, and this was adhered to throughout. The differential equations of motion admit of one integral, Jacobi's integral, which introduces an arbitrary constant (C), the constant of relative energy. It was found convenient to classify the orbits in accordance with the value of this constant.

Following Hill, Darwin shows that for large values of C, the orbits described will all be contained either within a closed curve surrounding the planet, within a similar closed curve surrounding the Sun, or outside a closed curve which surrounds both of the former. The three cases correspond with the lunar theory, planetary theory as applied to an inferior planet, and planetary theory as applied to a superior planet.

For smaller values of C, however, the different branches of these limiting curves unite, and passages are opened up through which a satellite may be transferred from one of the spaces to another. The great point of interest was to investigate the features associated with such a transference, and consequently the investigation was limited to the smaller values of C which would permit of this possibility. Even with the further limitation that "simply" periodic orbits alone (*i.e.*, those which repeat themselves after a single revolution round the Sun, or primary) were considered, the amount of work required was found to be prodigious. The interest in the subject was sustained by the continued surprises which the results yielded, and he was thus induced to continue computing more and yet more orbits whose forms appeared to be typical. Many of these were of a highly complex character, the arithmetical determination in such cases being almost always highly evasive.

Not content with merely indicating the forms of these orbits, he set himself in every case the still more difficult task of discussing their stability. In order that a satellite may describe a periodic orbit it must satisfy ideal initial conditions, any departure from which will cause it to describe initially a closely adjacent orbit. For certain orbits the disturbed orbit will oscillate in relation to the periodic orbit in a period which is associated only with the properties of the latter orbit, and is independent of the nature of the disturbance, provided only the latter be small. This was the case with Hill's variational orbit, but in other instances an alternative presents itself in which the quantity, which figures analytically as the period of the disturbance, presents itself as an imaginary or complex quantity. In such a case the amplitude of the oscillations will increase with greater or less rapidity, and the disturbed orbit will soon cease to follow even approximately the course of the periodic orbit. In the latter case the periodic orbit is said to be unstable.

The problem of determining the periods of the small oscillatory disturbances, whether of real or imaginary period, is identical with that dealt with by Hill in his determination of the motion of the lunar perigee. Darwin at first followed Hill's methods, in which the solution is derived by the reduction of a determinant of infinite order, but later an alternative method depending on quadratures was devised. But whichever plan was used the computations were found to be exceedingly laborious, and for orbits with sharp flexures almost intractable. Nevertheless, in almost every case he is able to arrive at a definite conclusion as to the stability or otherwise of the orbits traced.

The subject of these investigations was dealt with simultaneously by Poincaré in his volumes dealing with "Les Nouvelles Méthodes de la Mécanique Céleste." Both authors derived their inspiration from Hill's work, but the methods of treatment differ as widely as do their respective methods of treatment of the problem of the figures of equilibrium of rotating fluid. Poincaré's method consists in a discussion of the analytical

For the Royal Society he frequently served on Committees and officiated as a referee for numerous papers. He was President of the Royal Astronomical Society in the year 1889–1900, when it devolved on him to deliver an appreciative address on delivering the Gold Medal of the Society to his famous co-worker Poincaré. This address has been referred to by those who were privileged to hear it as one of the most inspiring that has ever been heard from that Chair on a similar occasion.

An event of great importance in his life was the occasion on which he was invited to occupy the Presidential Chair of the British Association in 1905, on the occasion of its visit to South Africa. The task was an exceptionally difficult one, involving, besides the delivery of two formal addresses at the two more important centres visited, innumerable minor speeches at almost every place of call *en route;* in each one of which he was exceedingly happy in adapting himself to the occasion. He took no small share in the preliminary organisation for the journey of the Society, and it was largely due to his personality and tact in adjusting minor differences that the arrangements proved so efficient and frictionless in actual operation. His Presidential Address on this occasion deals with a remarkable analogy between the subjects of his own investigations and collateral investigations in biological and political science. On his return to England he received the well-deserved honour of a K.C.B. at the hands of His Majesty.

In 1897 he was invited to America to deliver a course of lectures at Boston and chose as his subject "The Tides." These lectures formed the nucleus of a volume published by him in 1898 under the title of 'The Tides and Kindred Phenomena of the Solar System,' in which a semi-popular account is given of many of his important researches. The book met with a hearty reception and has since passed through many editions and been translated into many foreign languages.

He was nominated as a member of the Meteorological Council soon after his return to Cambridge, and continued to serve as a representative of the Royal Society on the Treasury Committee which superseded that Council a few years ago.

He was appointed by the Foreign Office as the first British representative on the International Geodetic Association, a position which involved him in extensive correspondence with the various geodetic organisations throughout the British Dominions. The choice is admitted by all to have proved an exceedingly happy one, and his services were duly acknowledged by the Association itself when they accepted the invitation, conveyed by him, to hold their triennial meeting in England in 1909, and nominated him as President for the occasion.

He took a leading part in the organisation of the meeting of the fifth International Congress of Mathematicians, which was held at Cambridge on August 22–28 of last year, and, in spite of failing health at the time, fulfilled the duties of the presidency with notable success. The symptoms were, unfortunately, to prove fatal, and, after a protracted illness, he passed peacefully away on December 7 last, to the great sorrow of all who were privileged to know him.

He was a corresponding member of many learned Societies, both in Europe and America, and many honours were conferred on him, in appreciation of his scientific work. The Gold Medal of the Royal Astronomical Society was awarded to him in 1892, and a Royal Medal on the nomination of the Royal Society in 1884, while, shortly before his death, he had the gratification of receiving the greatest mark of distinction which the Society can confer, by the award of the Copley Medal in the year 1911, and in 1912 the Victoria Medal of the Royal Geographical Society.

In private life his characteristic energy showed itself in a multitude of ways, such as in the mass of miscellaneous knowledge he had acquired from books, and in his facility in languages. As a trifling instance may be mentioned his acquaintance with heraldry, in which he had grounded himself as a little boy at Down, daily poring over the abstruse works of Guillim and Edmondson. The careful drawings made from these books doubtless trained his powers of draughtsmanship, which in later life were shown in his illustrations of some of his father's works.*

The same trait might be illustrated in many ways, *e.g.* in the zeal with which as a boy he collected lepidoptera, or the vigour with which as a young man he mastered the difficult game of tennis, just failing, however, to represent his University against Oxford; or again, near the end of his life, in his patient attempt to become an archer. The holidays of life, and especially the pleasures and amusements of his wife and children, were shared by him, and organised with a happy and rapid effectiveness.

Here, and indeed in every relation of life, his energy was coloured and made lovable by that simple sweet open nature which endeared him to so many.

S. S. H.

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* He is mentioned in the 'Fertilisation of Orchids' as having solved the problem of the Musk Orchis (*Herminium monorchis*).