materials. His chief difficulties were with regard to quality of solution, dust, and uniformity of setting. The first he overcame by making his own materials, and the others by the simple but ingenious device of setting the films under cover in partial vacuum. For his work in this connection he was awarded the Wilde Premium for Original Research. An interesting application of these replicas was his method of projection in natural colours, by means of three replicas adjusted to diffract the proper colour sensations to the eye. This he demonstrated very successfully at the Dover meeting of the British Association.

An excellent instance of his thoroughness and originality is provided by his attack on the difficult problem of producing diffraction gratings with all the light in one spectrum, instead of being distributed over many orders and a bright central image useless for spectrum work. Rowland indeed had investigated the subject and proved that the problem devolved on the shape of the groove cut by the diamond point, but we have no knowledge of any grating having been definitely made on these lines, although several chance rulings have very nearly fulfilled the condition. Thorp attacked the problem, calculated the shape of the point he wanted, made it, and actually produced a grating by stamping this tool in a metallic surface, the replicas from which were very nearly perfect in the desired property.

His latest desire was to make a ruling machine for himself, and this he devised on quite an original plan, his aim being to eliminate the difficulties which have always arisen in connection with screw-driven machines. In principle his idea was to drive the ruling point by a mercury clepsydra, furnished by a steel cylinder with micrometer valve of the most perfect finish he could command. The machine was well on the way to realisation when he was compelled to give up active work.

He accompanied the Eclipse expeditions to Algiers in 1900, and to Burgos in 1905.

Regarding his personality it is difficult to speak in words. All who knew him were impressed with his delightful companionship, modesty of manner, and constant readiness to help in whatever he was able.

His death occurred at Prestatyn, North Wales, on Saturday, 1914 June 13; he leaves a widow and three sons.

He was elected a Fellow of the Society 1902 April 11.

C. P. B.

Seth Carlo Chandler was born at Boston (Mass.) on 1846 September 17, the son of Seth Carlo and Mary (Cheever) Chandler. He was educated in the English High School at Boston, and became an actuary with the Continental Life Insurance Co., taking up his residence in New York. On 1870 October 20 he married Miss Caroline M. Herman of Boston, who, with six daughters, survives him. In 1877 he returned to Boston as consulting actuary for the Union Mutual Life Insurance Co. He moved to

Cambridge (Mass.) in 1881, and to Wellesley Hills (Mass.) in 1904. His business ability was considerable, and his advice carried great weight in the business world. Even in the sad years when his private correspondence, including astronomical matters, was absolutely neglected, his business duties, particularly those relating to many trusteeships which he held, were punctually discharged. He took great interest in buying and putting in order, twenty-five years ago, his grandfather's birthplace, a farm in the central part of Vermont. At times his health suffered from the nervous energy with which he worked, but it had much improved of late years, and his death (on 1913 December 31), after an attack of pneumonia lasting five days only, came as a severe shock to his family and friends.

Chandler's interest in astronomy began at school, where in his last year (1861) he made some calculations for Prof. B. Peirce. He then worked for some time with Dr. B. A. Gould as private assistant, thus laying the foundations of a lifelong friendship. Gould was at this time developing the longitude determinations of the U.S. Coast Survey, and Chandler joined the Survey in 1864; but he declined an invitation in 1868 to accompany Gould to Cordoba, Argentina, and became an actuary, as above mentioned. His astronomical work was resumed when he removed to Cambridge in 1881, and worked for a few years at the Harvard Observatory. His first success was the construction of a new instrument for fundamental observations, the Almucantar, so called because, being floated at a definite angle to the vertical, the telescope sweeps a horizontal circle (for which the Arab name is Al Mucantar). His first trial instrument was of only $1\frac{3}{4}$-inch aperture and 25 inches focal length; but the results obtained with it were of such surprising accuracy that a larger instrument was speedily made, a full description of which (and of the observations extending over a period of thirteen months) forms vol. xvii. of the *Annals of Harvard College Observatory*. These observations led directly to his second success. A curious systematic error was shown by them, one possible explanation of which was that the latitude was slowly changing. Such a hypothesis seemed, however, at that time to have been put out of court; for, on the strength of an investigation by Euler, it was supposed that the position of the Earth's axis could only vary in a period of about 10 months, and all attempts to detect a sensible coefficient for this variation had failed. Hence Chandler felt it more probable that the explanation lay in some other direction. But a few years later Dr. Küstner of Berlin published some observations made just at about the same time as Chandler's (1884–85) fully confirming the hypothetical change of latitude. Chandler thereupon resolved to discuss the matter apart from any prejudice due to Euler's theoretical result, and he soon found, from the discussion of many sets of observations, that there was a variation of latitude, not in 10 months but in 14 months. The discrepancy was disconcerting to the mathematicians, but Newcomb put his finger on its source by pointing out that Euler's investigation treated the Earth as a rigid body, and that, if allowance were made for elasticity, the period of 10 months would be lengthened. The change to 14 months might thus be regarded as a measure of the Earth's departure from rigidity, and this is now the accepted view. Meanwhile Chandler went steadily ahead with the discussion of huge masses of observations, from modern times back to those of Bradley. He paid a new tribute to Bradley as a wonderful observer (*A.J.*, 513): incidentally he rehabilitated the good fame of Pond, who had been rather under a cloud (*A.J.*, 313), and carried his good offices to our Royal Observatory further by explaining (*A.J.*, 511, and *Mon. Not.*, lxii. p. 122) the behaviour of Airy's Reflex Zenith Tube, which had been a standing puzzle since its erection with high hopes in 1852.

A few words may be quoted from *Mon. Not.*, lxii. p. 123:—

"It is certainly a comfort that the perplexing enigma connected with the Reflex Zenith Tube has finally found its answer, and that the patience of the astronomers who executed this laborious series meets at last an adequate reward of useful result. . . . It scarcely needs to be suggested that [the work] ought properly to extend to all the stars, passing the Greenwich Zenith, bright enough for reflection-observations on a dark sky. This would determine both the aberration and latitude variation, which is not possible with a single star."

In the light of these remarks of Dr. Chandler, observations with the instrument were resumed at Greenwich, and a large number of stars put on the programme. In 1911 Prof. Eddington discussed the results of eight years' work. He found several sources of instrumental error, and it seemed desirable to change the form of instrument. But Chandler's criticisms had the valuable result of recalling attention to this important investigation.

In all these cases and many others, Chandler showed how the new hypothesis of a variation of latitude would make crooked paths straight. But, meanwhile, he was not without troubles in his own investigations. The period of 14 months detected in 1885 seemed to be replaced in Bradley's time by one of 12 months. The mathematicians again refused to countenance this change. Undismayed, Chandler continued "deliberately to put aside all teachings of theory, because it seemed high time that the facts should be examined by a purely inductive process," and he ultimately found the means of reconciling observation with theory in the existence of two periods superimposed, an annual and a 14 months' term, one of which gradually overtakes the other. Later he was led to suggest also a 13 months' term (*A.J.*, 522), and again a 15 months' term (*A.J.*, 523). Further observations will probably show that while the first supposition of an annual term and a 14 months' term is a good first approximation, the details are less suitable for definite statement as yet. A fuller account of this latitude investigation will be found in the President's Address on presenting our Medal to Dr. Chandler in 1896. But the original series of papers in the *Astronomical Journal*, following one another with marvellous rapidity, and yet each representing a great mass of work, are well worth reading by those interested. Incidentally the constant of aberration came under investigation, and Chandler put the value high, say at $20''\cdot52$ (*A.J.*, 529). He was much distressed at the adoption in the Ephemerides, from 1901 onwards, of the value $20''\cdot47$ to accord with the parallax of $8''\cdot80$, declaring that a discrepancy which was probably significant was being unnecessarily obscured. His work on the subject of latitude variation did not, however, end with this series of published papers: he had pursued the matter so much further as to satisfy himself that he had obtained a definitive solution, and it only remained to prepare it for publication. This at any rate he stated to the present writer in 1910. But the serious and continued illness of one of his daughters, who had taken a special interest in his astronomical work, seemed to have paralysed his astronomical energies. His correspondence, outside business matters, as above remarked, lay untouched; the *Astronomical Journal*, of which he had undertaken the editorship, sometimes ceased to appear for protracted intervals; and the investigation of polar motion never appeared. Chandler's papers have been placed in the able hands of Mr. Benjamin Boss, and it is possible that there are sufficient indications of what was in his mind to guide an editor. For the present we have only this hope.

The mere mention of the *Astronomical Journal* suffices to remind us of another side of Chandler's work, as also of close ties of friendship. The editorship of various journals has had remarkable influences in astronomy. Prof. E. C. Pickering has more than once remarked that the Astronomical and Astrophysical Society of America originated in the gathering of the editors of the *Astrophysical Journal*. The *Astronomical Journal* cemented close friendships among its editors. Founded by Gould in 1849, it ran through six volumes of twenty-four numbers each, and then ceased abruptly in 1861 with the American Civil War. Chandler's name does not appear in these first six volumes: he was only a schoolboy. But when, on Gould's return to the States, the Journal was restarted in its old shape in 1886, Chandler contributed no less than twenty papers to the first volume. They are chiefly on comets and variables. He was an enthusiastic computer of cometary orbits, and towards the end of this first volume is an account of the "Science Observer Code" which was instituted to give telegraphic information of the orbit and ephemeris of a new comet as soon as possible. Apparently John Ritchie had started the idea in 1879, but Chandler must have entered into it very early, and the code published in the *Science Observer* (vol. iii., 1881 Aug. 1) bore the joint names. In the second volume of the revived Journal appears Chandler's First Catalogue of Variable Stars, as also two papers on those periodic departures from a uniform period to which he paid such unremitting attention in later years. His First Catalogue was followed by supplements, and in course of time by a Second (*A.J.*, 300), a Third (*A.J.*, 379) and a Revised Third (*A.J.*, 553) Catalogue; each representing great labour. There came a time when he felt unequal to further work in this field, and it was handed over to a German Committee. But Chandler's Catalogues form a landmark in the history of the subject.

On Gould's death in 1897, Chandler took over the editorship of the Journal, as an act of piety to his lost friend. Gould left a small endowment for it, which Chandler often supplemented from his private means; for a journal of that kind is somewhat of a luxury. After his activities suffered the blow above mentioned, he handed over the editorship to another close friend, Lewis Boss, whose papers on the places of fundamental stars had illuminated the pages as brightly as Chandler's on variation of latitude. Although the Journal again lost its editor in 1912, it is still in the capable hands of his son.

It would unduly prolong this notice to follow the whole of Chandler's work: but mention must be made of his identification of Comet *d* 1889 with Lexell's Comet of 1770; and of his recovery of the little planet Eros from plates taken previous to its discovery in 1898. Orbits of DQ (or "Pluto," as some called it at first), computed from the plates of 1898, suffered from uncertainty as to the mean motion, which rendered the position in 1894 too vague to identify the object. Chandler had the happy thought of searching the plates of 1896, when the planet was very faint; he succeeded in finding it, and, with an improved mean motion, quickly traced it on the 1894 plates. His delight in this success does not appear in the sober statement (in *A.J.*, 452); but it bubbles over in a letter to the present writer, dated on Christmas day 1898, equal appreciation being shown of Boss's recent paper on the southern zone $-20°$ (*A.J.*, 448–50). The successful outcome of a piece of work was a very keen pleasure to him; and in pursuit of it he often worked under an obvious stress of excitement, one familiar feature of which was that he could not wait to write down the logarithms of a pair of numbers to be multiplied, but added them in his head and found the product directly.

This keenness in delight, and also in impatience, was characteristic of him throughout. He loved the music of certain composers—Beethoven, Gounod, and Verdi; but could hardly stay in the room if Debussy, or even Brahms, were played. He read very fast, and could read anything except the modern novel. He spent much time in Vermont, designing and constructing beautiful little sailing boats of novel type, and claimed that long before a certain "America Cup" defender was launched, he had sailed her exact model in his little pond. He was well versed in the lore of magic and was himself a good conjurer; but the real object of these pursuits was the confounding of those who showed leanings to spiritualistic beliefs. One of his idiosyncrasies is made plain by the following remark: "I used to say that it was a mark of aristocracy not to own an automobile; it is more than that now: it is a mark of respectability."

Chandler was elected a Foreign Associate of this Society in

1889 Nov. 8. In 1895 he received the Watson Medal of the National Academy of Sciences, and in 1896 our Gold Medal. He received the degree of LL.D. from De Pauw in 1891. He was a member of the U.S. National Academy; and a Fellow of the American Association, of which he was Vice-President in 1886.

For a great many years he was an influential member of the Bache Fund Committee of the National Academy, and of the Gould Fund Committee of the American Academy.

H. H. T.

Nils Christoffer Dunér was born at Billeberga, a village in South Sweden, on 1839 May 21. He entered the University of Lund in 1855, and took the degree of Doctor of Philosophy in 1862. His connection with the Lund Observatory began in 1858, and he became a member of the regular staff of that institution in 1864. He remained at Lund until 1888, when he was appointed director of the Observatory, and Professor of Astronomy in the University of Upsala. After his retirement in 1909 he continued to reside at Upsala until September last, when he removed to Stockholm. He died at Stockholm on 1914 November 10, soon after his return from a journey to Helgum in North Sweden, where he went to observe the total eclipse of the Sun in August.

Dunér was an active and distinguished worker in many departments of astronomy. During the period 1867 to 1875, with the 10-inch refractor at Lund, he made 2679 measures of double stars, the results of which were published in his well-known memoir, *Mesures micrométriques d'étoiles doubles faites à l'Observatoire de Lund* (1876). This work at once placed Dunér in the front rank of double-star observers and computers.

In 1878 Dunér was attracted by the subject of stellar spectra, and notwithstanding the moderate aperture of the Lund refractor, he made a particularly valuable series of observations of the red stars, most of which are faint. His classical memoir, *Sur les étoiles à spectres de la troisième classe* (1884), gives details of the visual spectra of 352 stars, of which 297 belong to Vogel's Type III. *a* (Secchi's Type III.) and 55 to Class III. *b* (Secchi's Type IV.), the former being characterised by bands now known to be due to titanium oxide, and the latter by bands of carbon and cyanogen. The relative positions of these two classes of stars in the scheme of celestial evolution is still a subject of discussion. Spectra intermediate between the two classes are not clearly represented in the heavens, and Dunér himself adopted Vogel's view, that they represent alternative and not successive forms following the decline of stars of the solar or second type. Dunér's observations were discussed in great detail by Sir Norman Lockyer in his *Meteoritic Hypothesis*, where it is argued that there must be stars of increasing as well as of decreasing temperature, and that the true place of the third-type stars is on the ascending arm of the "temperature curve," while the fourth-type stars occupy the lowest division of the descending branch, in direct succession to