and tactoids. Tactoids, however, look very different from spindles under polarized light; they grow in an entirely different manner, and they never have asters associated with them.

Mr. F. C. Grigg demonstrated sections through the embryo sac of *Lilium* in which the nucleus had been driven to one end of the cell by moderate centrifugal force.

1816

OBITUARIES

Dr. P. H. Cowell, F.R.S.

PHILIP HERBERT COWELL, who died on June 6 last in his seventy-ninth year, was educated at Eton, where his mathematical ability attracted attention. From there he went to Trinity College, Cambridge, in 1889 with an entrance scholarship. He was Senior Wrangler in 1892, and it was said of him—as of other outstanding mathematicians—that he gained more than twice as many marks as his nearest competitor. His astronomical leanings were shown by the award of the Sheepshanks Exhibition and the Isaac Newton Studentship. Like the late Prof. E. W. Brown, who was four years his senior, he undertook research on the motion of the moon, employing the method which was devised but not developed by G. W. Hill. For this work, involving the inclinational terms in the moon's motion, he was elected a fellow of his College in 1894.

In 1896 Cowell was appointed to the newly created post of a second chief assistant at the Royal Observatory, Greenwich. It was soon found that he had neither the taste nor the aptitude for devising or even using instruments; but he excelled in all matters relating to reducing observations and analysing them. At that time the difference between the observations of the moon and Hansen's theory was increasing, and the long series of Greenwich observations gave Cowell an excellent opportunity of comparing the coefficients of the periodic terms with those derived from theory. For the shorter period terms he used the observations from 1847 to 1901, while for those of longer period he used observations back to 1750. His discussion showed essential agreement between the observed and the computed coefficients for all the short-period terms, whether they arise from solar or planetary action or the distribution of matter in the non-spherical earth.

Cowell then went on to discuss the light thrown on the long-scale motion of the sun and moon by ancient eclipses, a subject which has fascinated astronomers for two centuries. To explain the observations he introduced a secular acceleration of the moon of 10·9″, which agrees closely with that found by others; but he found another term which he identified first of all as an acceleration in the motion of the node but attributed later to an acceleration of the sun. In this view he differed from Prof. Newcomb, who placed less reliance on results derived from ancient observations, the interpretation of which may be uncertain.

The work by which Cowell is probably best known was done in co-operation with, and at the instigation of, the late Dr. A. C. D. Crommelin. This concerns the calculation of the orbit of Halley's Comet and that of Jupiter's eighth satellite. In 1907 Cowell and Crommelin undertook the process of computing the motion of Halley's Comet between 1759 and 1910. The elements derived from the observations made at the return of the comet in 1835 could not be used to predict the motion to 1910 without deriving the mean motion from the period 1759–1835, taking account of all the perturbations between 1759 and 1910.

While the calculations connected with Halley's Comet were still being carried out, the discovery of a moving object near Jupiter in 1908 presented new problems to the Greenwich astronomers. After the fact had been established by Dr. Crommelin that this was a satellite of Jupiter, it was clear that the solar perturbations could amount to 10 per cent of Jupiter's attraction, and no theory was available which could take account of these analytically. Cowell decided to apply the method of mechanical quadrature to compute the motion direct from the differential equations in rectangular co-ordinates. Although this merely involved the application of formulæ known from the time of Newton, it had not been thought of before. It had always been found possible to take account of most of the gravitational forces analytically and so get an approximate orbit, the action of the remaining forces producing perturbations to motion in the orbit. Cowell was probably led to his decision by the experience he had had of the need to 'rectify' frequently the basic eclipse in which Halley's Comet was assumed to move.

The success of this simple solution for the gravitational problem in the case of the eighth satellite of Jupiter led Cowell and Crommelin to compute the motion of Halley's Comet between 1759 and 1910 by the same method. Before the end of 1908 they had predicted the time of perihelion as 1910 April 16·61, later corrected to April 17·01. The actual time proved to be 2·68 days later. A final revision indicated that errors of computation and application of the attraction of known bodies could not account for more than a fraction of a day.

In 1910 Cowell was appointed superintendent of the Nautical Almanac Office. He re-organised the work of that establishment and effected a very considerable saving in the cost of the calculations; such success, as might have been expected, did not bring him any benefit. During the final illness of Sir Robert Ball, Cowell undertook lecturing at Cambridge, and it was confidently expected by his friends that he would be elected to a professorship at Cambridge. This was not to be, and Cowell continued to direct the work of the Nautical Almanac Office until 1930, when he retired to live quietly at Aldeburgh in Suffolk.

Cowell was a great organiser of computing and was himself a very rapid and accurate computer. However, he never used a calculating machine, doing all his arithmetic by hand. It is one of the freaks of development that he should originate the direct calculation of orbital motion from the differential equations—by formulæ very suitable for use in machines and now being exploited in the United States and elsewhere.

For his lunar work Cowell was elected a fellow of the Royal Society in 1906, and for that and his later work he was awarded the Gold Medal of the Royal Astronomical Society and an honorary D.Sc. of Oxford. After 1914 he never attended scientific meetings; but he continued to go to Cambridge for Commemoration at Trinity College. He was indeed warmly attached to his College, to which he made a number of bequests. In 1901 he married Phyllis, daughter of Holroyd Chaplin; she died in 1924.

J. JACKSON