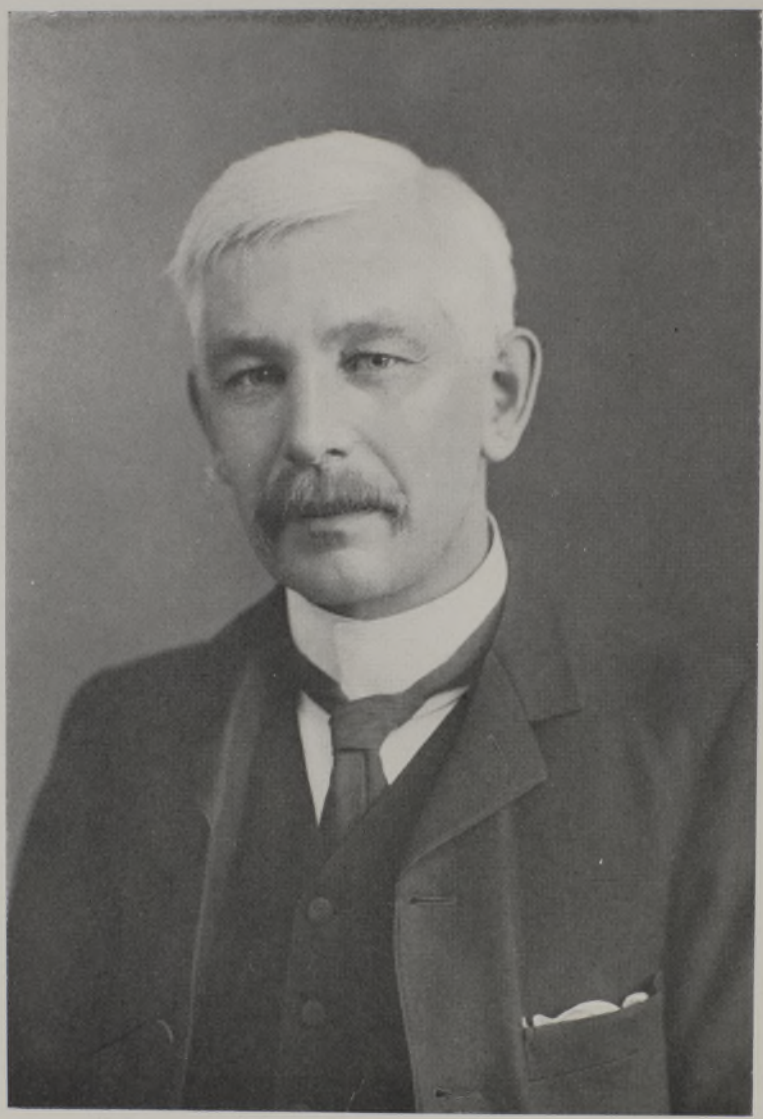

Charles Chree

CHARLES CHREE, 1860—1928.

Dr. CHARLES CHREE, the second son of the Rev. Charles Chree, D.D., was born at Lintrathen, Forfarshire, on May 5, 1860. He was educated at the Grammar School, Old Aberdeen, and at the University of Aberdeen. While at the University he did not specialise in science, but took a wide course and graduated in 1879, winning the gold medal awarded to the most distinguished graduate in arts of the year. He then went to Cambridge, where he graduated as Sixth Wrangler in 1883, being placed in the first division in Part II of the Mathematical Tripos, and in the first class in Part II of the Natural Science Tripos. He was elected to a Fellowship at King's College in 1885, which he held until he was appointed Superintendent of Kew Observatory in 1893.

During his stay in Cambridge, Chree devoted practically the whole of his time to mathematical physics. His first research, like so many more first researches of that period, was the development of a problem considered in Rayleigh's "Sound." Rayleigh had discussed the motion in a gas contained in a spherical or in a cylindrical envelope when the motion in the bounding surface is given; Chree considered certain simple forms of vibration when the solid boundary and the fluid are treated as one system. The result was presented to the Edinburgh Mathematical Society during the session 1885–86 in a paper entitled "On certain forms of Vibration." This was the first of about thirty papers written in Cambridge, mainly dealing with the mathematical theory of elasticity. Chree's contribution to the theory of elasticity alone would have given him a high place in the history of science, and it was mainly for this work that he received his F.R.S. in 1897, when his real life's work on terrestrial magnetism had hardly begun. In later life, Chree never lost his interest in this subject, and even after his removal to Kew, about fifteen papers on the subject appeared at irregular and increasing intervals. He also found his knowledge of the elasticity of solids of use to him in his later work, especially in connection with the effect of pressure on thermometers, the bending of magnetometer deflection bars, and the application of elastic solids to metrology.

While at Cambridge, Chree attended the Cavendish Laboratory and worked under J. J. Thomson. He first investigated the effect of an electric current on saturated solutions, and then experimented with liquid electrodes in vacuum tubes. This work appears to have been his only contribution to ordinary experimental physics, for after leaving Cambridge he did no further laboratory work.

Chree's skill with instruments was of a high order, but consisted chiefly in accurate and patient observations. He did not apply laboratory

methods to his work at Kew, and thirty years after he had been Superintendent, the laboratory equipment at the Observatory was ludicrously inadequate. The present writer remembers with amusement the list of apparatus prepared by Chree when asked to bring his laboratory equipment up to date; it included "four rings for a retort stand" and a "nest of four beakers."

In 1893, Chree left Cambridge on his appointment to the superintendentship of the Kew Observatory. At that time Kew Observatory was controlled by a committee of the Royal Society, but it was in a very precarious financial position. The use of the Observatory and grounds, with an endowment fund of £10,000 provided by Mr. John Peter Gassiot, F.R.S., had been made over to the Royal Society in 1871. In order to eke out the meagre income from the endowment, which was not sufficient to maintain the Observatory, the testing and calibration of scientific instruments of many kinds was undertaken for suitable fees. When Chree became superintendent, the work of the Observatory consisted of three main branches. In the first place, it was the central meteorological observatory of the Meteorological Office, and maintained a constant record, by means of self-recording instruments, of all the chief meteorological elements, and in addition regular eye observations were taken at fixed hours. The second branch of work consisted in maintaining a constant record of the three components of terrestrial magnetism and of the electrical potential gradient. These again were obtained by self-recording instruments, checked and standardised by regular eye observations. The third and largest branch of the work was the verification of instruments. The magnitude of the testing work can be judged by the fact that during the ten years 1886–95 188,279 instruments of various kinds were tested. The majority of these, it is true, were clinical thermometers, but large numbers of other instruments were examined, the annual average of the chief being: thermometers other than clinical, over 3,000; watches, 744; hydrometers, 367; sextants, 348; telescopes, 273; binoculars, 257; mercury barometers, 174; aneroid barometers, 102; and a large number of other instruments, including chronometers, magnetic instruments and ordinary meteorological instruments. When Chree took over charge the work was growing, so that the actual numbers he had to deal with must have been considerably larger than the averages just mentioned, and the total staff was only fifteen.

During his first few years at Kew Chree continued to write on the theory of elasticity, but his new work soon commenced to grip him. In the year after he went to Kew he published a "Note on the Relation between the Coefficients of Pressure in Thermometry," and in the following year a "Contribution to the Theory of the Robinson Cup-anemometer." In 1895 he wrote his first paper on terrestrial magnetism, which took the form of the Report made to the Ipswich meeting of the British Association Committee on

"Comparison and Reduction of Magnetic Observations." The Report dealt with the results from the Kew magnetographs during the five years 1890–94.

In this first paper Chree announced a discovery which proved to be one of his chief contributions to the science of terrestrial magnetism and a discovery which was to tinge the whole of his future work. Chree found that if he took the mean value of the horizontal magnetic force for each hour, starting at midnight and ending at midnight, for a number of "quiet" days, the average force for the second midnight was higher than that for the first midnight, and similar results in the case of other magnetic elements. The increase in horizontal force was so great that if it continued during all days at the same rate as it did during "quiet" days the annual secular variation would be 63 times as great as the observed secular variation. Chree drew two important conclusions from this result: (*a*) that "quiet" days were not typical of ordinary days, and (*b*) that it is absolutely necessary to allow for the non-cyclic change when discussing the cyclic variation of any periodic element. In the following year he again wrote the Report of the B.A. Committee, and developed the same line of thought, using data for six years instead of five.

Chree had at last found his life's work, and from now onwards the study of terrestrial magnetism was to become his main preoccupation. It is not possible to review here in any detail the eighty odd papers, monographs, and books which contain the contributions made by Chree to the study of terrestrial magnetism and the allied subject of atmospheric electricity, but it is not difficult to outline their chief contents.

In the early years of Kew Observatory funds were not available for a complete reduction of the magnetic traces, and attention was fixed on undisturbed days. Each month the Astronomer Royal chose five days which were conspicuously quiet and, as far as possible, spaced out equally over the month. It was thought that these days would be typical of all days if the latter could be freed from the effect of disturbances which were considered to be extraneous and casual occurrences. Reference has already been made to Chree's early discovery that in one particular at least—the non-cyclic effect—they were not representative. Still, as it was then impossible to measure all days, Chree's earlier work was devoted to discussing in detail the results obtained from the quiet days, the traces of which were measured as a matter of routine. In 1903 he published in the 'Phil. Trans.' his first analysis of the results obtained from the quiet day records at Kew during the 11 years 1890 to 1900, and this was followed in the following year by a similar but less extensive analysis from the records of the Falmouth Observatory. These two papers laid the foundation of our knowledge of the normal régime of terrestrial magnetism on "quiet" days in the British Isles. It is impossible to summarize them, and it must suffice to say that they included investigations

of the annual and daily variation and the relationship of magnetic phenomena to sunspots and meteorological conditions.

In 1908, Chree obtained a grant from the Government Grant Committee of the Royal Society to pay for the reduction of the traces for all days during the same 11-year period. The records thus extended were subject to the same detailed investigation, and the results discussed in three papers published in the 'Phil. Trans.' for 1908, 1910 and 1916. It is impossible to over estimate the importance of these five papers, for they are the only general discussion of magnetic conditions in the British Isles and they are an unfailing mine of data and information. They may be said to contain the climatology of terrestrial magnetism in the British Isles, all other papers dealing simply with magnetic weather.

That there is an intimate connection between sunspots and terrestrial magnetism had long been known. About the middle of the nineteenth century it was discovered by Sabine, Lamont and Wolf that the daily range of magnetic declination increases with an increase in the number of sunspots. In the general discussions described above, Chree had shown that a similar relationship extended also to the other magnetic elements. The relationship, however, was only of a statistical nature and the direct effect of individual sunspots on terrestrial magnetism had not been definitely demonstrated, although a number of coincidences between great solar activity and large magnetic storms had been recorded. In 1912 and 1913 Chree published in the 'Phil. Trans.' two important papers on "Some Phenomena of Sunspots and of Terrestrial Magnetism at Kew Observatory," in which he made a very successful attempt to obtain some definite information regarding the relationship which exists between sunspots and terrestrial magnetism. Arrhenius had suggested that the magnetic disturbance effects visible on the earth are due to the discharge from the sun of electrified particles which probably take some 48 hours to travel to the earth. Chree wished to investigate this suggestion by finding the average magnetic conditions before and after the appearance of spots on the sun. For this purpose he chose the five days from each month having the largest sunspot areas as determined at Greenwich, then he tabulated the magnetic data (H range) for the fifteen days before and fifteen days after the day of large sunspot area, and found that "while in the average year there is a clear association of H ranges with sunspot area some days previously, the relation is either of a somewhat complex character, or else is liable to be much overshadowed in individual years by other influences."

Another matter which Chree investigated in these papers was the suggested tendency for magnetic storms to recur at intervals of 27 days, *i.e.*, the average period of rotation of the sun. Dr. Ad. Schmidt, of Potsdam, had stated that a large proportion of magnetic storms of the very largest kind are separated by intervals which are multiples of 29·97 days, and Mr. E. W. Maunder claimed

to have demonstrated a period of 27·275 days in the magnetic storms recorded at Greenwich from 1848 to 1903. Chree, however, was not satisfied with the evidence in either case and set out to investigate the problem by an entirely different method. Instead of investigating "magnetic storms," Chree selected the five days of largest H range in each month as the point from which to start, and then by the simple method of calculating the mean magnetic character of days before and after these selected days he was able to show that the days round about 27 days after his selected disturbed day were on the average more disturbed than the average day, and that the 27th day was more highly disturbed than its neighbours. In this way Chree was able to demonstrate clearly "that if any day were considerably more disturbed than the average day of the month, then the day 27 days subsequent to it was likely to be also more disturbed than usual." In the second of the two papers on sunspots and terrestrial magnetism he carried the investigation further and showed the converse also to be true; so that the above quotation is equally true if the words "more disturbed" are replaced by "less disturbed." There can be little doubt that this demonstration of the 27-day pulse in magnetic phenomena gave Chree great pleasure and that it is amongst the best and most valuable parts of his work. Chree returned to this problem later, and the last paper of his to appear in the 'Phil. Trans.' is one on the same subject, written in conjunction with Mr. J. M. Stagg, which was published as recently as August 3, 1927.

Chree was naturally very pleased whenever a practical application could be found for the work to which he was so devoted. Underground surveying is still largely carried on by means of the magnetic needle, and to meet the wishes of the mine surveyors he commenced, in March, 1918, to publish monthly in the technical mining press the daily values of the declination at Kew and Eskdalemuir, so that the surveyors could apply corrections to their observations and discard observations taken on magnetically disturbed days. At about the same time he read a paper before the Institution of Mining Engineers on "Terrestrial Magnetism in Relation to Mine Surveying," which gave rise to an interesting discussion on the whole question of magnetic surveying in mines. One of the points brought out in the discussion was our want of knowledge of the relationship between the magnetic changes on the surface and at the bottom of a mine. A few years later an opportunity offered to investigate this point, and under the direction of Chree Mr. R. E. Watson, an assistant at Kew Observatory, established two self-recording magnetometers, one on the surface and the other in a gallery of a mine 1,800 ft. below the surface. The chief conclusion obtained from the work was that "for practical purposes, the differences between the magnetic declination changes underground and at the surface are negligible, except perhaps on days of very large disturbance."

Important as Chree's work has been on terrestrial magnetism in the British

Isles, it is questionable whether it is not surpassed in importance by his work on the magnetic conditions in the Antarctic. Chree has discussed the observations made on four expeditions to the Antarctic: (*a*) the "Southern Cross" Expedition, 1899, under Borchgrevink; (*b*) the National Antarctic Expedition, 1901–1904, under Captain R. F. Scott, R.N.; (*c*) the British Antarctic Expedition, 1910–1913, Scott's last expedition; and (*d*) the Australian Antarctic Expedition, 1911–1914, under Mawson. In addition, Chree personally trained the observers of the first three expeditions. The first expedition did not carry self-recording instruments and made only a few observations; so that Chree's discussion was not long but it was remarkably thorough. The three later expeditions used self-recording instruments and obtained records of three elements for two years in each case. In the case of Scott's two expeditions, the records were measured and reduced at Kew and Chree discussed them in addition to his normal work. In the case of Mawson's expedition, the traces were measured in Australia and Chree discussed the values supplied to him. It is necessary to examine the three volumes containing Chree's discussions of these records to realize the magnitude and importance of his work. It is true that no one else has ever had the opportunity to investigate such a mass of entirely new data; but it is impossible to imagine that anyone else could have extracted so completely the scientific information contained in such unpromising material. I welcome this opportunity of placing on record the sincere gratitude of all the magnetic observers on these expeditions to Dr. Chree for ensuring that every observation we made, often at some personal discomfort, has been put to the greatest possible use.

It has only been possible to touch on the main features of Chree's scientific work, but it must not be thought that because he devoted so much of his time to terrestrial magnetism he was at all narrow. He wrote on a number of subjects not mentioned here and he kept well abreast of the rapid developments of general physics. It is a great misfortune that Chree wrote his papers on terrestrial magnetism in a style which makes them difficult for the specialist to read and quite impossible for the average physicist. Most of his papers are discussions of the statistics derived from almost endless measurements of the magnetometer curves. These statistics had to be arranged, rearranged and compared in order to bring out different aspects of the problems under discussion. Chree himself had an uncanny facility for interpreting a line of figures without plotting them on a curve and failed to realize that other people had not this facility. In consequence, Chree's papers are illustrated by very few curves and the reader needs the greatest concentration to follow the involved text and examine the lines and columns of innumerable tables. Another trait of Chree's character which reacted on his work was his rooted objection to speculations as to the cause of the relationships he was examining. This does not mean that he was not prepared to examine and discuss the physical phenomena lying

behind the relationships he found; but such speculations had to come after and separate from his statistical investigations. If only Chree could have let himself go, make hypotheses even if they were nothing more than mere guesses, and then use his statistical data to illustrate, prove or disprove his thesis, his papers would certainly have been more interesting and might have been more widely read. Chree was well aware of this side of his character and frequently went out of his way to defend it. A typical example of his defence occurs in the preface to his monograph "Studies in Terrestrial Magnetism," in which he collected together the main results of his work up to 1912:

> "The book deals almost entirely with facts, or supposed facts. The absence of a definite theory as to the origin of the several magnetic changes is due to no lack of curiosity as to the causes of things, but to a belief that at the present stage theorising is less likely to be of substantial advantage than the extension of positive knowledge. It is sometimes claimed that a theory is essential as a guide in selecting the directions in which to prosecute research. This is a partial truth. When a man devotes himself to a subject, allowing free ingress to his mind to all the ideas which the results obtained by investigators naturally suggest, he must be a very unimaginative person if profitable lines of enquiry do not force themselves on his intelligence. The difficulty is not in thinking of something to do, but of deciding what to do next. In making a choice, some may prefer the guidance supplied by a definite theory, but others will prefer to rely on their natural instinct for detecting a weak spot in the defence offered by Nature to the discovery of her secrets."

The mere volume of Chree's published work is a witness to his industry, especially when it is remembered that for the greater part of his time at Kew administrative and routine work took up a large proportion of his time. But industry went also with a high standard of criticism, and an utter want of dogmatism. When Chree, by a certain arrangement of data, had obtained the result he expected he was not satisfied until he had re-arranged his data in all possible ways and satisfied himself that each showed the effect or at least did not contradict it. Even then he was pedantically careful in stating his results and never slurred over inconvenient evidence. An example is contained in the quotation regarding the relationship between H ranges and sunspot areas which I have given above. Nine physicists out of ten would have announced this result by saying that they had "absolutely proved" clear association of H ranges with sunspot area some days previously, and on the evidence no one would have blamed them; but Chree's statement is no such confident claim, he states the weak points as well as the strong points of his results, and that was always his habit.

This critical habit Chree carried into all his work and no amount of trouble would deter him from re-investigating any result which did not come up to his standard; but as he expected other writers to come up to the same standard he made rather an unsatisfactory referee of papers. When given a paper to referee, Chree went through it with conscientious thoroughness, and while the author might be exasperated on receiving a long list of "remarks made by the referee," his paper could not fail to be better after he had attended to them.

Chree's nature was naturally retiring and diffident, and although he formed strong opinions, he never tried to force them on other people. He was a delightful colleague to work with, as the present writer knows from personal experience. Chree was about to graduate at Aberdeen when I was born, he taught me how to make magnetic observations; yet when in the course of time I became officially responsible for the work at Kew, Chree always consulted me and never made me feel that in comparison with him I was young and inexperienced. The same cordial spirit existed between Chree and his staff at Kew, and everyone who worked with him had a real admiration for Chree as a man and a scientist. His patience with those who went to Kew to be trained as magnetic observers was remarkable and no trouble was too great for him to take to ensure that each observer thoroughly understood the theory and practice of the magnetic instruments.

When Chree retired in 1925 under the age limit, he was in full possession of all his powers, both mental and physical, and everyone, himself included, looked forward to many years of productive scientific work, for he had much to do. He was collaborating with Mr. Stagg and was himself engaged on a discussion of the Kew records of magnetic declination from 1858 onwards and on a further discussion of Mawson's Antarctic records. He had not finished writing his paper on the magnetic declination when he was attacked by what proved to be his fatal illness, but he was able to complete this before he had to give up work early in the present year. Although he knew sometime before the end that there was no hope of recovery, he remained bright and was pleased to see his friends. The end came somewhat suddenly on August 12, when he was staying at Worthing.

Chree's degrees were Sc.D. of Cambridge and LL.D. of Aberdeen. As already stated, he was elected a Fellow of the Royal Society in 1897. He was awarded the James Watt medal by the Institution of Civil Engineers in 1905 and the Hughes medal of the Royal Society in 1919. He served as President of the Physical Society and of the Royal Meteorological Society. For a number of years Chree had the distinction of being President simultaneously of the two international organizations which deal with terrestrial magnetism. He retired from one in September, 1927, but retained the other to the time of his death.

G. C. S.