was uniform throughout the world. Prof. Seward does not think this theory tenable, and he brings forward evidence to show that the Greenland plants were not contemporaneous with the forms from the Wealden beds of England and from the Cretaceous rocks of the United States, which resemble them so closely. He holds that some of the older European plants migrated northwards, where they became mingled with new forms, and afterwards many species of the Greenland flora travelled southwards again. Distinct climatic zones may then have already existed and "it is reasonable to assume that in Cretaceous Greenland, as at present, short summers with continuous sunshine alternated with longer periods of comparative darkness."

For the botanist these Cretaceous plants are of special interest, for they grew in the period when angiosperms, agreeing with the present-day flowering plants in the morphological character of their foliage shoots, assumed a prominent position in the vegetation of the world. This work has led its author to the view that "the Greenland Cretaceous flora represents more fully than the floras of other countries the early stages in the transitional period from an older Jurassic-Wealden vegetation in which flowering plants were absent, to a type of flora which still persists in regions remote from its ancestral home." Together with ferns and gymnosperms of an archaic type were found dicotyledonous leaves of a surprisingly modern form, and the view is supported that the evolution of the deciduous angiosperms progressed with greater rapidity in these high latitudes. The alternation of prolonged periods of continuous activity with complete rest from growth through the winter, may have provided conditions of the type under which we should expect the evolution of the deciduous habit.

Prof. Seward makes the important suggestion that the shifting of the balance of the vegetation types was not merely the expression of a stage in organic evolution, but may have been a response to some physical stimulus. He does not make any suggestion as to the nature of the stimulus, but in this connexion the work of Garner and Allard, and Tincker may be significant. These investigators have found that alterations in the number of hours of daylight in which plants are grown produce changes in the time of flowering and also in some morphological features of many of the species investigated. Thus the northern and southern migrations referred to above may have induced morphological changes owing to the changes of illumination experienced in the course of the migration.

The rapid evolution of the angiosperms in high latitudes is no new theory, but though flowering plants appear to be quite absent from the lowest Cretaceous rocks, it is likely, as Seward points out, that they had antecedents in much earlier times. It may be that the evolution of the deciduous habit led to the frequent and abundant preservation of leaves from plants the evergreen ancestors of which had little chance of fossilisation, and so the sudden appearance of the flowering plants in the rocks does not represent the real history of the group.

The general conclusions which have been discussed above form but a small portion of this publication and, whatever their fate in the future, the great bulk of accurate and critical information which Prof. Seward has amassed will always remain of the greatest value and serve as a solid foundation for future work. The paper terminates with a fine paragraph in which the author hopes that his labours may stimulate others to extend and render more precise our knowledge of the Cretaceous plants of Greenland. It is interesting to record that within a few days of the publication of the work Mr. T. M. Harris, whose help is acknowledged in the introduction, landed in Greenland with the intention and prospects of making a more extended examination of the Rhætic plant-bearing beds of eastern Greenland than has hitherto been possible. We may look forward to further important contributions from Cambridge in this fascinating study.

H. H. T.

Electric Waves and their Propagation.[1]

By Sir ERNEST RUTHERFORD, O.M., P.R.S.

AMONG the many developments of science during the past thirty years, none has left a deeper impression on the lay and scientific mind alike than the remarkable growth of wireless as a means of long-distance transmissions of signals, speech, music, and even of pictures. The history of this new method of signalling is of special interest to all scientific men, for it illustrates in a vivid way the value of a close co-operation between pure and applied science for rapid progress. The first great chapter in the history of radio-communication we owe to the genius of Maxwell, who, in a paper communicated to this Society in 1864 entitled "A Dynamical Theory of the Electromagnetic Field," showed that electric and magnetic effects cannot be produced instantaneously at a distance, but must be propagated through space with the velocity of light. He demonstrated the wave-nature of these electrical disturbances in space and the mode of their propagation. It is no exaggeration to say that the complete theory of electrical waves and their transmission in space is contained in his famous equations, and that too at a time when no experimental methods were known of producing or studying such electrical waves.

The next great step in advance we owe to the brilliant researches of Hertz, who in 1887, in his laboratory at Karlsruhe, showed how electrical waves in space could be produced by an open electric oscillator, and devised methods for their detection and study.

It was not long before the results of these small-scale laboratory experiments were applied for practical ends. In 1896, attempts began to be made in England to utilise electric waves for signalling purposes, and the rapid development of this new branch of applied science owes much to the pioneer work of Marconi and Lodge. Progress in the later stages has been largely influenced by the utilisation of another scientific discovery, namely, the use of electric currents in vacuum tubes as a powerful method of producing and detecting electrical waves. It is of interest to note that the first

[1] From the anniversary address delivered before the Royal Society on November 30.

use of an electron tube as a detector of electrical waves was made by Prof. J. A. Fleming.

It is not my object to detail later progress except to refer to the noteworthy developments that have taken place this year. On January 1 the new Post Office station at Rugby was opened for the transmission of messages to ships in all quarters of the globe and for Foreign Office messages. This long-wave installation is in many respects unique. It is the only high-power electron-tube station in the world, and contains many novel features in its design and operation. The frequency of the continuous waves emitted by this station is controlled with great accuracy by a vibrating tuning-fork, and the numerous high-power electron tubes in parallel are used to magnify five hundred thousand million times the energy of one of the harmonics of a small triode valve operating the tuning-fork. The extraordinary flexibility of these electron tubes both as oscillators and receivers has been fully utilised in the design of the installation, which incorporates all the latest developments in this branch of science. The success of the station for the purposes for which it was designed is a tribute to the breadth of the scientific knowledge and the boldness of the initiative displayed by the Imperial Wireless Commission and the engineering staff of the Post Office. This station has been also successfully used for experiments in radio-telephony with the Long Island station near New York. It is now possible, and will, it is expected, soon be practicable, to connect any telephone subscriber in western Europe with any telephone subscriber on the North American continent.

During the past two or three years, telegraphy on a commercial scale by the aid of short waves has been conducted in many countries. A still further development by the Marconi Company is to be recorded this year. Short-wave stations, in which a series of parallel wires are arranged to act as a reflector, and emit a beam of waves in a definite direction, have been erected near Bodmin in Cornwall and near Montreal in Canada. After a successful series of experiments, these stations began to operate commercially last month. Similar stations for communicating with the other Dominions are in the course of erection. It will be of great interest to see how far a continuous service is feasible by these new methods, in spite of the atmospheric disturbances which sometimes so seriously affect ordinary short-wave transmissions.

It is remarkable how the progress of applied science in many instances depends on the utilisation of some obscure property of matter discovered in the course of purely scientific experiments. For example, in 1888, the brothers J. and P. Curie, working on the properties of crystals, discovered the piezo-electric properties of quartz. In a suitably cut crystal of quartz, an electric charge on the surface appears when the crystal is compressed or extended. Conversely, a charge applied to the surface of the crystal alters its dimensions. No one at that time could have foreseen that this property could be utilised to control, automatically and with great accuracy, the frequency of the waves emitted by broadcasting stations, and thus be a factor of great importance in reducing interference between stations. Illustrations of this kind can easily be multiplied. For example, the discovery about thirty years ago in the laboratory of the photo-electric effect, in which certain substances exposed to light produce a copious emission of electrons, has formed the essential basis of the methods used to-day in transmitting radio-pictures and in experiments on television.

I should like to add a few words in connexion with the problem of the propagation of long and short electrical waves over great terrestrial distances, which has been the subject of discussion for many years, but on which valuable new data have been recently obtained. When wireless signals were first transmitted across the Atlantic, the late Lord Rayleigh immediately raised the question whether the waves were able to follow the curvature of the earth by the agency of diffraction alone. This problem has attracted the attention of many able mathematicians who have shown conclusively that some other agency must enter into the transmission of these waves over great distances. It was early suggested by Kennelly and Heaviside that the bending of the rays might be accounted for by supposing that there was in the upper atmosphere a layer which was electrically conducting and which guided the waves round the earth's surface. Precision was given to this view by the work of Eccles and others, who showed that ionised gases could refract and absorb electrical waves passing through them. A still further advance was recently made when Sir Joseph Larmor pointed out the paramount importance of the long free-path of the electrons in the upper atmosphere in producing scattering and refraction of electrical waves. He showed that a comparatively sparse distribution of electrons was sufficient to bend the path of the rays round the earth.

A direct attack on this problem has been recently made in Great Britain by several methods, and convincing evidence has been obtained of the existence and height of this refracting layer. Appleton and Barnett, using wave-lengths of about 400 metres, have shown that at moderate distances from a wireless transmitter two sets of waves are received which produce interference phenomena. One set of waves travels in a straight line from the transmitter along the ground, and the other passes into the upper atmosphere, where it is refracted or reflected back to the receiving station. These experiments are of much interest as providing large-scale analogues of the ordinary optical interference experiment but carried out with wave-lengths a thousand million times as long. From the results of these investigations the height of the effective layer is estimated to be about 90 kilometres. In general, the refracted ray is elliptically polarised, an effect no doubt connected with the action of the earth's magnetic field on the motion of the free electrons. Similar results by other methods have been obtained by Smith-Rose and Barfield of the National Physical Laboratory.

These observations not only give an explanation of night-time errors in direction-finding and of signal variations, but also in a general way throw light on the vagaries observed in the transmission of short waves, where a signal may be undetectable a few miles away from the transmitter but may be received strongly a thousand miles away.

While the study of the propagation of electrical waves through our atmosphere is of much interest in itself, it is of even more value as giving us a new and powerful method of attack on the problem of the electrical state of our atmosphere, particularly at heights where direct observations are impossible. We may anticipate that an extension of such experiments will provide us with much valuable information not only on the degree of ionisation of the upper atmosphere but also on its diurnal and seasonal variations. Although only preliminary observations have so far been made on this question, the results obtained show that there is much promise in this new method of attack on a difficult problem.

The phenomena of the aurora and the diurnal variation of the earth's magnetism have long been supposed to indicate that the upper atmosphere is highly ionised and an excellent conductor of electricity. The origin of the ionisation is a matter of much interest. Part, no doubt, is due to the ultra-violet light emitted by the sun, but there may be other important contributory causes. During this year, E. A. Milne has shown how certain atoms of matter, ejected from the sun, notably those of calcium, may, in consequence of absorption and emission of radiation, acquire sufficiently high velocities to penetrate deeply into our atmosphere. It may be that the brilliant auroræ and magnetic storms which so often accompany sunspot activity are a consequence of the projection into our atmosphere not only of electrons, as has long been supposed, but also of swiftly moving atoms of matter.

Another source of ionisation to be taken into account is the very penetrating radiation in the upper atmosphere brought to light by the experiments of Kolhörster and Millikan. The origin and nature of this radiation is still *sub judice*. Some have supposed it to be of cosmical origin and see in it evidence of the disintegration or formation of atoms of matter in worlds remote from us. On the other hand, we must not exclude the possibility of a mundane origin, for C. T. R. Wilson has given very strong reasons for believing that very high-speed electrons and penetrating radiations may be produced as a result of the movement of electrons in the intense electric fields which arise during thunderstorms. This penetrating radiation has been detected by the minute ionisation observed in electroscopes at high altitudes. The effects are very small and the experiments difficult, but we may hope to obtain more definite information as to the origin and nature of this radiation by the experiments now in progress.

Obituary.

MR. CHARLES HEDLEY.

THE sudden death of Mr. Charles Hedley at Mosman, Sydney, on September 14, deprives Australia of one of its foremost scientists, who was deservedly popular among a wide circle of friends. Hedley was the younger son of the Rev. Canon Hedley, and was born at Masham, Yorkshire, on February 27, 1862. Though in later years he was capable of great physical endurance, as a youth he was delicate, and on that account his school life was limited to two years at Eastbourne College; his wide knowledge was acquired by reading and observation, and instruction received from his father, who was a distinguished graduate of the University of Cambridge. For health reasons he spent much of his youth in the south of France and in Switzerland, where he acquired a taste for long walks and mountain climbing, two avocations from which he always derived much pleasure.

At the age of eighteen Hedley emigrated to New Zealand, where he proposed to engage in sheep farming, but he found the winter too severe and sought the warmer clime of Australia, where the rest of his life was spent. For some time he was engaged in fruit farming in Queensland, but natural history always had a strong attraction for him, and in 1889 he became attached to the Queensland Museum, Brisbane. Shortly afterwards he accompanied Sir William Macgregor on an expedition to British New Guinea, during which he made important zoological collections and observations.

In 1891 Hedley removed to Sydney and entered the service of the Trustees of the Australian Museum as assistant in charge of land shells. In 1896 he became conchologist, and in 1908 assistant curator. In 1920, on the death of R. Etheridge, jun., he became acting curator, and, later, principal keeper of collections. He resigned in 1925 to become scientific director of the Great Barrier Reef Investigation Committee, and was in that service at the time of his death. He had returned from Queensland, where he had been superintending the operation of boring the Barrier Reef at Michaelmas Cay, and was happily preparing to go to Japan as one of the Australian delegates to the Pan-Pacific Science Congress, when he contracted a cold, which was followed by more serious illness, and resulted in his death from heart failure.

Hedley was a seasoned and intrepid explorer both by sea and land, and had made many trips to New Guinea, Torres Strait, and various Pacific islands; his knowledge of the South Pacific and its natural history and ethnography was very extensive, perhaps unsurpassed. In 1896 he accompanied the expedition organised by the Royal Society of London to bore the atoll of Funafuti, Ellice Group. He remained on the island for two and a half months, and made extensive collections, which were afterwards described in "The Atoll of Funafuti" (Australian Museum Memoirs, 3, 1896–1900), to which Hedley contributed the "General Account," and the sections on ethnology and Mollusca.

Hedley was recognised as one of the world's leading conchologists, and much of his published work dealt with the Mollusca, but there were few branches of zoology of which he did not have an extensive knowledge, and he was also an accomplished botanist and ethnographer. He was greatly interested in zoogeography, and had made valuable contributions to our knowledge of that subject, particularly as regards the Pacific area and the faunal relations of southern lands. He was a firm believer in the former extension northwards of the Antarctic Continent, which had resulted in a faunal community between South America, South Africa, and Australia, and his conception of the vicissitudes of this land bridge (*Jour. Royal Soc N.S. Wales*, 29, 1895, pp. 278-286; *Proc. Linn. Soc.* London, Session 124, 1911-1912, pp. 80-90) is generally accepted by those who believe in the former connexion of South America and Australia.