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Research and the Imperial Conference.

THE Imperial Conference which has just closed in London will be memorable for the new stimulus which it will give to the enterprising spirits of our age. Little of the earth's surface is left unmapped, but over vast expanses of the British Empire there are fields of endeavour which provide a new outlet for the adventurous. It has been the privilege of the members of the recent Imperial Conference to state these fields of endeavour. They have been able to indicate the enormous potential resources of the Empire and the infinite variety and complexity of the problems which confront its peoples. What is more, they have stated their belief that for the development of their resources and the solution of their problems they must depend upon science.

This general appreciation of the function of science is the outstanding feature of the recent Imperial Conference. It is probably unique in the history of the British Empire and has a deep significance. It substitutes a scientific basis for the attempt to find a political solution for Empire economic problems. Through it the people of the British Empire have been enabled to take stock of their enormous responsibilities, to realise the tasks before them, and to understand the means by which they can rise to the height of a wonderful opportunity. Lord Balfour, in his introduction to the report of the Research Sub-Committee, the most important produced by the Conference, states in unequivocal terms that if full use is to be made of the opportunity we must turn to applied science for aid:

"The Empire includes states and territories of the most varied economic capacity, possessing every gradation of climate and soil, every species of mineral wealth, subject in parts to special diseases with which only science can hope to deal; enjoying in parts unique natural advantages which only science can fully develop. It possesses distinguished investigators in every branch of research. It has therefore everything to gain from full scientific co-operation, yet we can hardly flatter ourselves that we practise this, either within Great Britain or throughout the Empire."

Various recommendations are made in the report regarding the organisation of research. Co-operation can best be secured, it is suggested, by the extension of the number of Imperial bureaux for special fields of investigation. The existing bureaux for entomology, mycology, and tropical medicine have greatly facilitated the interchange of results obtained in various parts of the Empire. It will be left to the delegates to the forestry conference which will assemble in Australia and New Zealand in 1928, and the Imperial Agricultural Research Conference, already arranged for 1927, to decide whether Imperial bureaux in these fields are necessary.

It is made clear that it is not assumed that any organisation intended to serve the whole Empire should necessarily be situated in Great Britain. It is suggested, for example, in the event of it being decided to create an Imperial Veterinary Science Bureau, that this bureau should set up in South Africa, which is ideally situated for purposes of research into the diseases of domestic live-stock, being faced with a greater variety of diseases than any other part of the Empire. Although it is not suggested in the report, it is not improbable that the Agricultural Research Bureau, if decided upon, would be situated in Jamaica, for it is in connexion with the development of tropical agriculture that the greatest advances are to be expected.

Reference is made to the imperfect machinery for the interchange of information. As at present conducted, correspondence fails to meet the need for rapidity, and not infrequently, because of some gap or misunderstanding, fails to reach the best objective. Instead of complete reliance upon such bodies as the Colonial Office, the Imperial Institute, the specialised Imperial bureaux, as the channels of communication of information, it is suggested in addition that direct communication should be established between the various parts o the Empire, through the accredited representatives of special broad fields of research.

The parts of the report dealing with the present position of recruitment of staffs for the various scientific services in the Empire is, in effect, a reflection upon the educational training provided in the schools and universities of the Empire and upon the inducements offered in the scientific services. " The evidence before the sub-committee shows that there is a shortage of suitable candidates for most branches of scientific services supported by Governments." The report emphasises, moreover, that this shortage will become more pronounced as the development of the Empire proceeds, since the demand for highly trained scientific workers is likely to be accelerated with the rapid development which must be expected, particularly in the tropical parts of the Empire. Various reasons have been given to the sub-committee for the shortage. Most of them have been emphasised again and again in these columns. The shortage is attributed to " the inadequate appreciation of the importance and value of scientific research on the part of the public, of the Press, and even of Governments themselves; the uncertainty in the minds of men embarking on a university course as to the amount, interest, and continuity of the employment which will be available in their branch of science when they have completed their studies"; the increasing demand by private employers for university-trained scientific workers, and ignorance on the part of parents and educational institutions of the number and attractions of careers in the scientific services overseas.

The fact is that neither the schools nor the universities of Great Britain provide adequate facilities for training in the branches of science for which there is the greatest scope in the less developed parts of the Empire. There are too many chemists, too few geologists; too many engineers, too few biologists. For example, in one of the leading secondary schools in London, containing five hundred boys, about half that number are receiving instruction in chemistry or physics, but only two are taking biological subjects; and this is probably a fair indication of the instruction given in most of the secondary schools in the country. It is true that some may take up biological subjects at the university, but the general tendency is to persist in the special branches of study for which the schools provided facilities.

The difficulty can be overcome, but it will take time. It involves the staffing of schools and revision of curricula; it involves considerable expenditure on laboratory accommodation and equipment; it involves the overhauling of our educational administration and the removal of the anomaly of two departments of State competing in the sphere of secondary and higher education, namely, the Board of Education and the Ministry of Agriculture and Fisheries.

We endorse the opinion of the sub-committee, that the basic remedy for the shortage of scientific staffs " is the adoption of a settled policy in regard to the application of research to development in the various parts of the Empire." We can also whole-heartedly endorse the opinion expressed that the best inducements to offer students to take up appropriate lines of training are good salaries, satisfactory status, and proper recognition of their important function. If the best brains of the country are to be attracted to the scientific services, these services must rank at least equal in importance with the administrative and fighting services. They must be regarded as an indispensable part of the machinery of government and not as a luxury to be dispensed with in times of financial stringency. They must also be administered by men with a scientific outlook, which is almost impossible unless these officers have received a thorough training in the methods of science.

The sub-committee points out the desirability of interchange between members of the staffs of the research institutions and the scientific services in the various parts of the Empire. It goes further, and recommends that students should be trained for their scientific work in various institutions. Obviously it would be all to the advantage of the student if, after a course at a home university, he completed his training at an agricultural college in one of the tropical colonies. If the committee's recommendations are adopted regarding the interchange of scientific staffs, one of the greatest difficulties in the way of recognising special merit of scientific officers will be removed. Even in the scientific services at home, an officer in a very small department has very little prospect of promotion unless he is afforded an opportunity, and possesses the ability after a long period of specialisation, to take up new work in another department. Unquestionably there are far greater difficulties in the way of interchange between members of scientific services than exist in connexion with the interchange between members of administrative services. But much could be done in this direction. The sub-committee appreciates the difficulty which an officer in a scientific service in a remote part of the Empire must experience in keeping abreast of the latest developments in his special branch of science. It recommends the provision of refresher courses for these officers. It also recommends that picked officers should be given every facility to hold travelling fellowships for study on the spot of the latest developments in their particular fields.

The report of the Research Sub-Committee illustrates remarkably the growing appreciation of science by members of the present government. For this welcome manifestation scientific workers owe a deep debt of gratitude to Mr. Ormsby-Gore, the Under-Secretary of State for the Colonies. He has travelled far in his quest for knowledge. In the two reports he has presented to Parliament, those dealing with East Africa and West Africa, were set out clearly the problems inherent in the development of our tropical colonies, and the rôle which science must play in their solution. Through these reports the attention of statesmen has been directed to the possibilities of science. They are now prepared to state, and find their colleagues from the Dominions in agreement with them, that " money devoted to research is not a luxury; it is rather a condition of survival, without which the Empire cannot hope to keep abreast of its competitors in the economic field." Not content with a pious expression of opinion, they " cordially approve of the projects of fostering a chain of research stations situated in appropriate centres in tropical and sub-tropical parts of the Empire, and commend this project to the sympathetic consideration of governments, institutions, and private benefactors throughout the Empire."

It is now the bounden duty of scientific workers to ensure that practical effect be given to all the recommendations in this epoch-making document. They have to equip themselves and train others for the discharge of the duties and responsibilities involved in the realisation of the immense and varied resources of a mighty inheritance, and in the promotion of the intellectual as well as the material well-being of the peoples of the British Empire.

The Significance of Animal Coloration in the Struggle for Existence.

Camouflage in Nature. By W. P. Pycraft. Pp. xiv+280+36 plates. (London: Hutchinson and Co., Ltd., n.d.) 21*s.* net.

THE aim of this excellent book is to present, as the author states in the preface, " the essential features of the coloration of animals, and the various interpretations for that coloration which have been advanced by the sportsman-naturalist, as well as the man of science. . . ." Of the fifteen chapters, the first four are devoted respectively to an introduction, pigments, the infinite variety of coloration, and the evolution of colour-types; the fifth deals with rapid changes of colour in response to stimulus; the sixth to the ninth with protective coloration, both procryptic and anticryptic; the tenth with mimicry, Batesian and Müllerian; the eleventh with warning coloration; the twelfth with the coloration of young animals; the thirteenth and fourteenth with sexual selection; the fifteenth with colour aberrations.

The subject is illustrated by examples drawn exclusively from the animal kingdom, and it would have been an improvement to justify the title " Camouflage in Nature " by including the description of a few plants. The principle of cryptic coloration has been known to operate in the vegetable kingdom ever since Burchell, more than a hundred years ago, described a Mesembryanthemum and a sluggish grasshopper, both protected, in the same locality near the Orange River, by resemblance to rounded stones. Examples of cryptic and mimetic resemblance are of course extremely rare among plants as compared with animals, but are of great interest.

It may be doubted whether 'camouflage' is a convenient name for so comprehensive a subject, including the most varied uses of colour and pattern in the animal kingdom, together with the discussion of their evolution. The word originated in the military operations of mining and countermining, when the discharge of a smoke-cloud (*camouflet*) was employed to suffocate the enemy. The next step was the use of the smoke-cloud above ground as a screen, and from this the meaning of 'camouflage' was extended to cover all methods of concealment and also the appearances by which an enemy may be misled in judging of speed and direction. Camouflage in its original meaning would be applicable only to such protective devices as the discharge of the Bombardier beetle or the inky cloud of the Sepia, but its extended meaning may be fairly held to include all methods of concealment and Batesian mimicry. The inclusion of Müllerian mimicry is doubtful, while warning coloration is opposed to the whole conception of camouflage, as are also the epigamic colours and modes of display, which the author, with his long and intimate knowledge of birds, discusses with so much insight and learning.

The coloration of desert animals, discussed by Buxton in a recent work, is treated by the author in Chap. ix., where he reaches conclusions in entire agreement with those of Canon H. B. Tristram in his paper on the birds of the Sahara published in the *Ibis* for October 1859, a few weeks before the appearance of the "Origin of Species." The foundation of Canon Tristram's belief, clearly expressed in his words at this date, is of great importance in the history of evolution: "Writing with a series of about 100 larks of various species from the Sahara before me, I cannot help feeling convinced of the truth of the views set forth by Messrs. Darwin and Wallace in their communications to the Linnean Society. . . . It is hardly possible, I should think, to illustrate this theory better than by the larks and chats of North Africa." It is of much interest to learn that, after all the changing opinions and conflicting beliefs of well-nigh seventy years, the author builds, as Canon Tristram did, on the foundation laid by the Darwin-Wallace essays of July 1, 1858.

The confident assertions of those field naturalists who maintain that colour and pattern are of no great significance in the struggle for life, are keenly criticised, as are also the extreme opinions of the opposite school of thought. In discussing these subjects, the essential importance of behaviour in co-operation with colour and pattern is strongly emphasised. The criticism of F. C. Selous's suggestion that the leaf-like under surface of the African butterfly, *Precis artaxia*, has "more probably been produced by the influence of its environment than by the need for protection" (p. 6), would have been strengthened by pointing out that it is only the dry season form of this insect which is leaf-like, and that it produces, in the more abundant insect-life of the wet season, strongly marked eye-spots which presumably divert attack from the vital parts. The description of our own wonderfully concealed Comma butterfly (p. 105) might have been improved by reference to the meaning of the *C*—the light coming through a curved crack in a weather-beaten leaf—and to Dr. R. C. L. Perkins' recent observation that the edges of the wings diverge in the attitude of rest. The author states that the Comma lies over on one side when at rest, but this is not my experience, although true of the Green Hairstreak and the leaf-like Satyrine *Melanitis leda* and doubtless many other species. Furthermore, the larvæ of the Large and Common Emerald moths are not like bits of grass but resemble respectively the catkins and the twigs of their food-plants.

Although the value of the caddis-worm's case cannot be doubted, it is too much to assume that "when at rest they defy detection by even the hungriest fish" (p. 116). I have seen the stomach of a blind trout, unable to capture insects on the surface, entirely filled with these case-bearing larvæ, presumably detected by the senses of smell and touch.

Concerning the okapi, mentioned on p. 89, it would be very interesting to learn whether observations of the living animal would confirm a suggestion made to me many years ago by my friend Sir Ray Lankester—that the dark chestnut of the upper part is procryptic among the shadows of thick foliage, and the striped lower part of the legs procryptic (like the coat of the zebra) in a stronger light below the branches.

The history of the classical discovery of mimicry in the African *Papilio dardanus* is not quite as described on p. 151. By careful analysis, and comparison of the patterns of the females in Madagascar, and, so far as they were then known, in Africa, Roland Trimen revealed "the true state of affairs." He was at first disbelieved by Hewitson and Westwood, but they were soon converted—Hewitson by receiving a West African mimetic female *in coitu* with the non-mimetic male, Westwood by receiving from Mansel Weale the mimetic females and non-mimetic males bred from wild larvæ collected in the same spot in South Africa. Families with the different forms reared from the eggs of a single female were only obtained much later.

Müllerian mimicry is illustrated by a coloured plate (opposite p. 152) reproduced from Punnett's work. Five species of Heliconius are here represented in a left-hand column and five species of the Ithomiine genus Mechanitis in one to the right. The Ithomiinae have undoubtedly acted as models for the Heliconinæ, a fact which would have been more clearly conveyed if the position of the columns had been transposed. Furthermore, the species of another Ithomiine genus, Melinaea, would have provided a better illustration of the principle, the Heliconines being of about the same size and presenting a closer likeness to the Melinaea patterns than to those of Mechanitis. It should, moreover, have been pointed out that each of the five pairs—Ithomiine model and Heliconine mimic—belongs to a different association, characteristic of a different part of tropical America.

The significance of the markings within and at the corners of the mouth of certain nestlings is discussed and illustrated on pp. 185-188, and the interesting conclusion reached that they serve as guides to the parent birds in feeding their young.

Mr. Pycraft's book is very well illustrated with thirty-six plates, of which four are coloured. The references to these are insufficient, and it would be an improvement in future editions to number the plates and thus facilitate co-ordination with the text. The index is also very inadequate for a work so full of interesting detail. The following errors in spelling require correction: Mosely for Moseley (p. 14), Fort Hail for Fort Hall (p. 83), *prideuxi* for *prideauxii* (p. 115), *Danias* for *Danais* (p. 151), Swinnerton for Swynnerton (p. 168), *jacobae* for *jacobaeae* (p. 172), Weissmann for Weismann (p. 255), *Eudromis* for *Endromis* (p. 258); *Acentrophus* for *Acentropus* (p. 259), Bombysid for Bombycid (p. 260). Again, in the description of germ-plasm as the "stuff of which living bodies are made," 'of' has, probably accidentally, been substituted for 'from.'

Although many corrections and some additions are required, which, it is hoped, will be provided in the near future, the book is an excellent introduction to a very large and complex subject and, with its wise and well-balanced treatment of many controversial subjects, is especially welcome at the present day. E. B. P.

The Aurora Borealis as observed from Norway.

Geofysiske Publikasjoner utgitt av det Norske Videnskaps-Akademi i Oslo. Vol. 4, No. 7: *Résultats des mesures photogrammétriques des Aurores boréales observées dans la Norvège méridionale de 1911 à 1922.* Par Carl Størmer. Pp. 108+48 planches. (Oslo: A. W. Broggers Boktrykkeri A/S., 1926.) 12 kr.

IT is fortunate for our knowledge of the aurora that, although the regions of most frequent auroræ are mainly polar seas or cold and sparsely populated lands, they border on the country of Norway. The population of Norway is small, less than half that of greater London, but the level of culture is high, and the intellectual activity and distinction are manifested in no branch of study more signally and appropriately than in auroral investigation. Much the greater part of our exact knowledge of auroræ is due to Norwegians, among whom, though many have made valuable contributions, two are pre-eminent, Birkeland and Størmer. The generally accepted theory of auroræ, incomplete but successful in explaining a large range of facts, was originated by Birkeland, who supported his hypothesis by numerous experiments. The extent to which these bear on the actual terrestrial case is not always clear, however, whereas Størmer's mathematical development of Birkeland's theory gives incontestable proof of its soundness in essentials. But, in addition to their theoretical researches, both men have been great observers, and have organised important expeditions for auroral or magnetic investigation, or both, to regions within the Arctic circle.

Størmer's share in auroral observation has been of outstanding importance. The photography of auroræ was put on a workable basis by him, and he first achieved clear and indisputable success in the determination of the height of auroræ, though the task had previously been attempted by visual observation. For his purpose simultaneous photographs of the aurora from two or more stations connected by telephone are necessary, and from 1911 to the present time he has organised such observations, directing them himself from the base station. Initially this was at Oslo, where he is professor of pure mathematics in the university; since 1916 it has been at Bygdö, a suburb of Oslo. In addition he has made expeditions to Bossekop, in the far north of Norway, on the border of the zone of maximum auroral frequency as determined by Fritz; in 1913 he took numerous photographs from Bossekop and a neighbouring station. In 1914 Vegard and Krogness conducted similar work in the same region, and for these two years there are consequently independent (and concordant) sets of observations of the position of the aurora in space. The results of these two expeditions have already been published by the Norwegian Academy of Science in its "Geophysical Publications" instituted a few years ago. The results of the observations made or organised by Prof. Størmer in middle Norway from 1911 to 1922 are now issued in the memoir under review. Like its predecessors, it is handsomely illustrated by photographs and diagrams.

The period covered by the volume is twelve years, but during four years (1912–1915) no photographs were taken (apart from those at Bossekop, already published). These were years of minimum frequency of auroræ, and moreover the watch on the sky was less close than later, when Prof. Størmer changed his residence from Oslo to a house at Bygdö, whence there is a clear view down to 3° or 4° above the northern horizon. During 1920–22 watch was kept every night either by himself or his assistant.

In the remaining eight years, photographs were taken on thirty-five nights in all, namely, two in 1911, and 1, 4, 8, 8, 4, 6, 2 in the respective years 1916 to 1922. This number may seem small, but is explained by the difficult conditions of auroral observation; sufficiently bright auroræ do not occur every night, of course, and even when they do occur, clouds and bright moonlight limit the possibility of photography, though without in all cases precluding it. Further, apart from the difficulty of organising a watch every night and the occasional failure of telephonic communication, photography is practically limited to the winter and equinoctial months, since in midsummer the sun is only a few degrees below the northern horizon even at midnight. The actual distribution of the 35 nights of observation between the twelve months of the year (beginning with January) is as follows: 1, 5, 7, 6, 1, 0, 0, 2, 2, 7, 3, 1—a series in which the greater frequency of auroræ near the equinoxes makes itself apparent. Auroræ were of course observed on other nights but not photographed. The great majority of photographs were taken between 10 P.M. and 1 A.M., observations both before and after midnight being made on ten nights. The exposure of the photographs varied from a second to about two minutes, in general being a few seconds.

By notices inserted in the press, Prof. Størmer gained offers of assistance and was thus able to establish substations for co-operation with his own station at Oslo or Bygdö. The administration of telegraphs and telephones placed telephonic lines between these stations at his disposal during auroræ. The stations were separated by distances which ranged from 25 to 250 kilometres. Eleven stations were established for a greater or less period, but four seems to have been the greatest number working at one time; 304 sets of simultaneous photographs were taken from two stations, or in a few cases from three. In addition there were 189 photographs taken from one station only.

To obtain trigonometrical parallaxes and precise heights and positions of the auroræ, it is necessary, of course, to have pairs of simultaneous photographs of the same aurora, with star images also showing on the plates, to give indication of direction; the aurora itself must have sufficiently definite features for the same points to be identifiable on the two plates. In other cases, and when only a single photograph of an aurora is available, all that is possible is to estimate the geographical position and vertical extent of the aurora, by making probable assumptions about the height of its lower edge.

The lower limits of the auroræ observed from Oslo were mostly at about 100 km. height, but heights so low as 80 or 82 km. were observed in a few instances. The observations made at Bossekop gave 107 km. as the most frequent lower limit, and about 87 km. as the minimum. The more southerly auroræ thus appear to penetrate more deeply into the atmosphere, an observation which is doubtless connected with the fact that the aurora appears the farther south the greater its intensity. Again, the auroræ observed from Oslo are much the greater in vertical extent, the upper limit of height (about 800 km.) being roughly twice as great as at Bossekop. This difference seems to be associated with the relatively frequent appearance at Oslo of auroral rays as compared with other types of auroræ. Most of the Oslo photographs are of auroral rays (including draperies, coronæ, and striated arcs), whereas at Bossekop rays were relatively few; possibly the latter was partly due to 1913 being a year of minimum auroræ, for the Oslo observations indicate that rays are more frequent and pronounced the greater the intensity of auroral (and magnetic) activity. During the great display of March 22-23, 1920, the rays attained astonishing heights, and their bases also were far above the ordinary lower limits of height, being in some cases at a level of 400 km.

At Oslo draperies and vertically striated arcs are the most luminous forms of auroræ, and moreover the least elevated, their bases being sometimes at heights less than 85 km. Their vertical extent also is small, often only 10 or 12 km., and rarely more than 100 km. Homogeneous arcs were often observed from Oslo, generally to the north or near the zenith, and often forming the southern limit of all the auroræ visible at the time; more rarely they appeared to the south, persisting unchanged for half an hour or more, with no other aurora visible. Another rare type of arc was pulsating; this also was observed alone in the sky. The homogeneous arcs are often of great lateral extent, sometimes stretching right across the sky from the eastern to the western horizon; in such cases their length must be of the order of 1000 km. Maps are given, showing the geographical position of the measured points of auroræ; the arcs lie predominantly nearly along the circles of magnetic latitude (centred at the pole of the earth's axis of magnetisation), and are inclined at about 10° to the circles of geographical latitude; their centre of curvature is slightly to the north of the magnetic pole. The magnetic colatitude of the arcs observed from Bossekop and Oslo varies from 21° to 34°, that of Oslo itself being 30°. The colatitude of the arcs was notably greatest on the days of great magnetic activity, being, for example, 34°, 32°, and 33° respectively on March 22-23, 1920; May 13, 1921; and Dec. 16, 1917.

Sixty-one photographs of auroral coronæ are included in the series, and these enable the direction of the auroral rays to be determined to within 1° or 2°. The results show surprisingly little variation, and the mean direction is less than 1° different from that of the magnetic force at Oslo (dip 71°, W. declination 9°). The rays therefore lie almost exactly along the lines of force of the earth's magnetic field.

Besides the maps already mentioned, the volume gives full details of the photographs, and of the stars and measured points of auroræ appearing on them, both by tables and diagrams, and there is a series of interesting descriptive notes about the auroræ and conditions of observation on each night. There are also 96 beautiful reproductions of the photographs, including many simultaneous pairs, enabling the auroræ to be viewed stereoscopically. The auroræ are situated mainly over Norway and the North Sea, in some cases near to Ireland and Scotland.

Prof. Størmer directs attention to the desirability of similar observations elsewhere, mentioning the Antarctic regions in particular. To the reviewer it seems even more useful to gain as detailed information as possible about one auroral zone, by observations in the British Isles, northern Canada, Greenland, Iceland, and other northern lands, simultaneous with those in Norway. The magnetic colatitude of Aberdeen, for example, is the same as that of Oslo, and there is great scope in northern Scotland and northern Ireland for a band of skilled amateur photographers working on the lines initiated by Prof. Størmer. He himself is continuing his observations in Norway, and since 1922 has obtained 250 further photographs which are now being studied.

S. CHAPMAN.

Official Publicity for Agricultural Research.

Ministry of Agriculture and Fisheries. Research and the Land: an Account of Recent Progress in Agricultural and Horticultural Science in the United Kingdom. By V. E. Wilkins. Pp. xiv + 388 + 34 plates. (London: H.M. Stationery Office, 1926.) Paper, 2*s*. 6*d*. net; cloth, 3*s*. 6*d*. net.

EVEN when they forsake their opprobrious blue and appear in hodden-grey, the publications of H.M. Stationery Office have but a feeble appeal to the lay public, but this book—in the words of the Minister of Agriculture, "not exactly a popular account" of agricultural research, but "at least one which with little trouble an educated farmer or even townsman might understand"—is in a different category. Its success as an appeal to the lay press has been undoubted, and deservedly so, for it is written in an attractive style, is profusely illustrated, and, as a whole, makes a good journalistic story. Much of the matter embodies results already familiar to readers of NATURE through the medium of recognised scientific journals, which it would be tedious to notice in any detail here. A novel feature of this publication, however, is the account which it gives of new work in progress, and even of the speculations and hopes of the workers engaged on it.

It is a commonplace of scientific work that progress can only be won at the cost of many fruitless endeavours, and in admitting the lay public to their confidence the workers concerned take their courage in both hands. On the other hand, these confidences should prove of great and even stimulating interest to workers on the same subject elsewhere. By elsewhere we mean primarily other countries; but as the book discloses, there must be a great want of jointly-shared knowledge even in Great Britain. To take one example, we find that research on 'sourness' of soil is proceeding (and on diverse lines) at various centres in Britain. There is no subject more likely to attract the interest of farmers than this, for by common consent the agricultural land of England, speaking generally, has exhausted the stores of lime so generously provided by the improvers of the nineteenth century. No economical means of replenishing the soil are in sight; and how little can the man of science satisfy the farmers' thirst for guidance! For, as it happens, the fundamentals of scientific knowledge on this subject appear to be in process of readjustment. The facile certainties of the last century have been abandoned, and the use of such new tools as hydrogen ion concentration, base exchange, and colloid chemistry is still not fully learned. Whether co-ordination—blessed word—would help is, as we know, a matter of controversy: some workers appreciate team work, some would rather hug their souls in solitude. Incidentally, an example of happy team-work is given in Mr. Wilkins' book, namely, that carried on by the Rowett Institute in Aberdeen in association with the University of Cambridge, on animal nutrition. But State-supported research workers, at any rate, should recognise that co-ordination is desirable.

The publicity given by such books as this is, however, the price that departments dominated by a democratic Parliament must pay even if that body has still to learn what a 'gamble' (from an economic viewpoint) scientific research must always remain. But it would be unfair to the author of the work under notice to lay the burden of such considerations upon him. He has performed his allotted task with distinguished ability, and has earned, we trust, the gratitude of his superiors.

Our Bookshelf.

A Manual of Hygiene. By Sir William H. Hamer and Dr. C. W. Hutt. Pp. xi + 821. (London: Methuen and Co. Ltd., 1925.) 30*s*. net.

THIS manual is designed to meet the requirements of those seeking to obtain a diploma in public health, though at the same time the authors take the opportunity of referring to most questions now uppermost in public health work. A few of the chapters have been contributed by writers having special knowledge of the subjects dealt with, *e.g.* tuberculosis and sanitary administration and law, by Dr. James Niven; school hygiene, by Dr. Kenneth Fraser; venereal disease, by Mr. Kenneth Walker; chemical disinfectants, by Dr. Wynter Blyth; and air, by Dr. King Brown. The arrangement of the matter and contents of the chapters follow well-known lines and present little or no novelty. The book is well produced, is illustrated with 94 figures in the text, and is very readable.

The book is exceptionally complete, and the information is accurate and up-to-date. Thus, the vitamins are adequately considered, the possible influence of deficiency of iodine in the production of goitre is mentioned, the life-histories of the various parasites are correctly given, and the causation of rickets is particularly well discussed. In addition to the diseases of Great Britain, several tropical diseases are also described, *e.g.* sleeping sickness, leishmaniasis, undulant fever, and others, and in all cases the information given appears to be accurate.

Here and there, perhaps, a section might have been extended or differently worded with advantage, but on the whole there is singularly little to criticise. We miss any reference to the Owens' instrument for the determination of atmospheric pollution, and manganese poisoning does not seem to be mentioned. Chlorination of water is somewhat briefly dealt with, and in the excess lime method of purifying water the unlimed water finally added is described as 'untreated,' whereas this should have been first purified by long storage. Under filter candles (p. 137) the reference to "Bullock and Crow" should be "Bulloch and Craw." Under "Vital Statistics" we question the value of introducing the complicated subject of life tables (though we are aware that it usually appears in public health text-books) and consider the space might be better utilised. The index might be somewhat extended with advantage.

We consider that this book gives an adequate presentation of present-day public health work within the limits imposed, and can recommend it to the student with confidence.

General Physics for Students: a Text-Book on the Fundamental Properties of Matter. By Edwin Edser. Reprinted, with additions. Pp. ix+676. (London: Macmillan and Co., Ltd., 1926.) 8*s.* 6*d.*

THE merits of this well-known text-book are sufficiently attested by the demand for a fourth issue. It should not, however, be allowed to pass without renewed recognition that there exists no other text-book dealing so thoroughly with mechanics, elasticity, surface tension, hydrodynamics, and kinetic theory, without mathematical aid more advanced than elementary algebra and trigonometry.

The new portion is of a different character from the rest of the book, being an appendix on surface tension, embodying the author's recent researches. The most important part is a calculation of the surface tension and internal pressure for assemblages of molecules attracting according to some inverse power of the distance. The difficulties of applying the calculus of continuous functions to molecules comparable in size with the range of attractive forces, are overcome by estimating the probable number of centres of molecules within an infinitesimal region of space, and integrating. The assumptions seem legitimate, at any rate as a first approximation for more or less symmetrical molecules; the conclusion is reached that the attractive force varies as the inverse eighth power of the distance, and that nearly all the surface energy is resident in a single layer of molecules.

There is a good deal of miscellaneous information on capillarity, and though the author's avoidance of the modern view which ascribes the phenomena to the surface properties of the molecules—that is, their chemical properties—and takes account of their motions and orientations according to kinetic theory, probably leads to incorrect explanations in some cases, it is an excellent thing to have Mr. Edser's long-considered views set forth in a convenient form. It may not be long before the obscure points are cleared up, with much advantage to both points of view.

N. K. A.

Lehrbuch der physiologischen und pathologischen Chemie in 75 Vorlesungen: für Studierende, Ärtze, Biologen und Chemiker. Von Prof. Dr. Otto Fürth. Zugleich zweite völlig neubearbeitete und erweiterte Auflage der "Probleme der physiologischen und pathologischen Chemie." Band 1: *Organchemie.* Lieferung 1: *Bausteine der Organismus—Blut.* Vorlesung 1 bis 16. Pp. xiii+208. (Leipzig: F. C. W. Vogel, 1925.) 15 gold marks.

IT is fifteen years since the first edition of this work was published and the text has required drastic revision. The complete work will consist of two volumes, each divided into three parts of about 200 pages. The present part contains accounts of the chemistry of the proteins, fats, and carbohydrates, and also of the blood and lymph. The treatment of the more purely chemical side of materials of physiological significance appears full, yet concise and up-to-date. The chapter on blood serum is considerably condensed, especially on the subject of the hydrogen ion concentration, but fuller treatment can, of course, be obtained from special monographs. The account of the gases of the blood is reserved for a later part. There are copious references to the literature, structural formulæ are given in detail, and the paper and printing are of the best. Altogether the volume is a most useful work on this branch of chemistry.

Fishery Board for Scotland. Scientific Investigations, 1926, No. 1: *Rays and Skates; a Revision of the European Species.* By Dr. Robert S. Clark. Text. Pp. 66+15 plates. 9*s.* net. Plates. Pp. iii+36 plates. 5*s.* net. (Edinburgh and London: H.M. Stationery Office, 1926.)

THE increasing importance of rays and skates as marketable food-fishes emphasises the need for a greater knowledge of their life-histories than is at present available. Dr. Clark's revision of the European species is therefore a most welcome monograph. In this work, which represents several years of patient labour in a trying task, twenty-three species are separately described and finely illustrated by beautiful photographs, and in each case a full discussion on the troublesome matter of nomenclature is given. It would have been rather more convenient for the reader if the successive sections of the text had been more clearly indicated by the use of appropriate type; in its present form the text is a little confusing. This monograph, used in conjunction with Dr. Clark's earlier account of the egg-capsules and young (*Jour. Mar. Biol. Assoc.*, vol. 12, No. 4, 1922), should prove of the greatest assistance to workers for the identification of their material.

Letters to the Editor.

[*The Editor does not hold himself responsible for opinions expressed by his correspondents. Neither can he undertake to return, nor to correspond with the writers of, rejected manuscripts intended for this or any other part of* NATURE. *No notice is taken of anonymous communications.*]

Luminescence from Solid Nitrogen, and the Auroral Spectrum.

IN NATURE of September 18 and 25, McLennan and his collaborators have published statements regarding the origin of the auroral spectrum which call for some remarks. Dealing with the N_2-band from solid nitrogen, they confirm the result which I published in June 1925, showing that N_2 consists of a number of components. Applying this to the auroral problem they say (p. 409):

"Since no band of anything like this character has ever been shown to be a feature of the spectrum of the aurora, in the neighbourhood of λ 5230, it would appear that Vegard's theory that finely divided solid nitrogen exists in that portion of the upper atmosphere where auroral displays originate is not tenable."

Now according to my experiments the structure of the N_2 band varies considerably with experimental conditions, and we cannot yet tell which structure corresponds to the conditions which, according to my view, exist in the auroral region. But even if we had experimented under comparable conditions, we cannot make any comparison with the auroral spectrum for the simple reason that we do not know anything about the structure of the auroral line (or group of lines) at λ 5230 Å.U. This line has never been obtained on spectrograms, although I have tried with spectrographs of small dispersion and very high illuminating power, but has merely been observed with spectroscopes of small dispersion and by using a broad slit. *Under these conditions also the N_2 band would appear as a line.*

Thus our present knowledge of the auroral line 5230, *as well as the present state of the experimental conditions for obtaining N_2, do not enable us to compare the structure of N_2 with that of the auroral line* 5230.

The identification of the auroral line with an oxygen line observed by McLennan under certain special conditions seems to be in contradiction to observed facts. Thus:

(1) The line is a spark line, while the auroral spectrum from blue to ultraviolet is a nitrogen *band* spectrum.

(2) The density required to obtain the line is 10,000-100,000 times greater than that present in the auroral region.

(3) The excess of inert gases necessary to enhance the line does not exist in the auroral region.

(4) No other oxygen lines, or lines of the inert gases, are observed in the auroral spectrum.

(5) If light gases are dominant in the upper atmosphere, nitrogen must also dominate greatly over oxygen; and at altitudes of 500-600 km. the amount of oxygen should be negligible. All the experimental evidence we have at present shows that all oxygen lines are greatly suppressed by the presence of nitrogen.

(6) McLennan obtains approximate coincidence of wave-length of a single line, but fails to interpret the whole type of spectrum shown by the aurora, *and his interpretations would involve a spectrum quite different from that of auroræ.*

On the other hand, my continued experiments with solid nitrogen have shown that solid nitrogen gives the whole typical auroral spectrum from red to ultraviolet. Regarding the auroral line 5577, I have been able to show that the band N_1—in accordance with the consequences of my theory—is contracted and displaced when the nitrogen particles are diminished. A neon layer is found to have no specific influence on N_1, and if the nitrogen particles are diffused into neon, the N_1 band by diminution of the nitrogen concentration approaches a position which within the limit of experimental error coincides with the auroral line. For small concentration (c) the position is given by the following expression determined by the method of least squares:

$$\lambda = 5577 \cdot 56 - 0 \cdot 8754c.$$

L. VEGARD.

Physical Institute, Oslo,
October 29.

Properties of High Frequency Radiations.

IT is impossible to state accurately the properties of high frequency radiation (wave-length <0·02 Å.U.), for we have no exact knowledge of the variation, with wave-length, of the intensity and distribution of scattered radiation. We have good reason for believing that the intensity of the radiation scattered by an atom is, on an average, proportional to its atomic number, and that the distribution becomes more and more asymmetrical as the frequency increases. I have found that a formula of Dirac's (*Roy. Soc. Proc.*, A, 3, p. 405, 1926) fits some of the results obtained by Mr. H. M. Cave and myself in a series of experiments on the γ-rays of radium better than any other so far put forward. It may be stated that the best way to test this formula will be to examine the distribution of scattered radiation.

Owing to scattering, there is a tendency for γ-rays to become less penetrating as they pass through matter (see Gray, *Phil. Mag.*, 26, p. 611, 1913, and Oba, *Phil. Mag.*, p. 601, 1914). This is shown by the following experiment. γ-rays from radium, initially filtered through 2·2 cm. of lead, passed through a conical hole in a lead block, the hole having an average diameter of 1·9 cm. and a length of 20 cm. These rays were examined by absorption plates of brass and lead. An electroscope was placed one inch above the lead block. From the readings, what may be called the apparent mass absorption coefficient μ'/ρ (to distinguish it from the true coefficient μ/ρ) could be obtained. μ'/ρ was not constant but, owing to scattered rays having a greater wave-length, increased in 2·28 cm. of brass from 0·0208 to 0·0287, and in 2·06 cm. of lead from 0·034 to 0·041. The true coefficients were (μ/ρ) brass = 0·0470 and (μ/ρ) lead = 0·0560; μ'/ρ is greater for lead, mainly because of the greater fluorescent absorption. As the thickness of absorbing material is increased, in each substance a state will be reached after which (μ'/ρ) will have a constant value which will be about 0·037 for brass and 0·043 for lead. If the rays for which (μ'/ρ) brass = 0·037 were examined by lead 4·8 cm. thick and water of corresponding thickness, it would be found that the respective values of μ'/ρ were about 0·046 and 0·040. These values have been obtained by rough calculations from known data. It will be seen that there is not a great deal of difference between the absorption in brass, lead, and water.

The most penetrating γ-rays we could use were obtained by filtration through lead plates placed at appropriate distances in the conical hole. For these rays (μ/ρ) copper was equal to 0·0443 and (μ/ρ) lead 0·0472, so it is not possible to obtain much further information in this way about the effect of scattering on apparent absorption coefficients. It seems certain, however, that, as the primary frequency increases, the differences in apparent absorption in water and lead will diminish. Indeed, as water contains more electrons per unit mass, it is to be expected that the apparent absorption per unit mass will ultimately be greater in water. In any case, maximum values of μ'/ρ will diminish as the frequency increases, and judging from the above experiment will not be greater than the corresponding initial values of μ/ρ. In particular, if we assume Dirac's formula to be the correct one, (μ/ρ) air for rays of wave-length 0·0004 Å.U. will be equal to 0·00236, and if such rays enter the earth's atmosphere, μ'/ρ will increase, but at any depth below, water will absorb the rays just as much as lead, μ'/ρ for both substances being not greater than 0·00236.

Dr. Millikan has recently put forward the view that a cosmic radiation of wave-length of the order of 0·0004 Å.U. is the primary cause of the ionisation observed in closed vessels, the effect of γ-rays and other disturbing causes being accounted for. If this were true, I should expect 4·8 cm. of lead to reduce the ionisation only 12·1 per cent. (taking $\mu'/\rho = 0{\cdot}00236$). Millikan and Otis, however, found that on Pike's Peak the number of ions per c.c. dropped from about 12·5 to 4·28 when their electroscope was shielded by 4·8 cm. of lead, a reduction in intensity of 56 per cent. In obtaining these figures I have made allowance for ionisation due to radiation from the walls and external radioactivity. It will be found that (μ'/ρ) lead $= 0{\cdot}0194$. On the other hand, Millikan and Cameron found that for these rays (μ'/ρ) water varied from 0·0030 to 0·0018, values agreeing with the view that the ionisation is due to rays of the wave-length assumed above. The comparatively large value of (μ'/ρ) found for lead, however, is not in agreement with this view and cannot, I believe, be accounted for by any of the following factors which I have not hitherto allowed for:

1. Scattered rays can enter the electroscope from the air and earth below it, and are more absorbable in lead than water.

Some years ago I found that the ionisation in an electroscope was increased only 12 per cent. by placing a block of graphite, thick enough to give the maximum effect, directly below the source of radiation, namely, radon contained in a glass tube. This percentage increase will diminish as the primary frequency increases, and so can have very little effect on the absorption by lead. It should be noted that scattering materials of low atomic number will produce a greater increase in ionisation than materials of high atomic number.

2. Secondary β-rays will produce X-rays which will be more absorbable in lead than light substances.

Our knowledge of the properties of such X-rays is rather fragmentary, but, so far as they go, experiments indicate that the intensity of these X-rays produced in lead screens will more than compensate for the absorption in the screens of X-rays produced outside them.

3. Secondary β-rays produced outside the electroscope may have sufficient energy to enter it. Such β-rays would be absorbed by the lead screen.

This absorption by lead will be compensated by the production of secondary β-rays in the lead. Experiment indicates that the ionisation produced in closed vessels by rays of high frequency tends to increase with the atomic number of the material of which the vessel is made.

From what has been stated above, it would appear that no conclusive evidence has been found to prove the view that the radiation causing the ionisation in closed vessels is a cosmic radiation of high frequency. It is possible to explain some of the properties of the radiation by assuming that it consists of electrons of very high energy, which, in passing through atoms, 'collide' sometimes with their nuclei and thereby lose energy. There are certain difficulties in the way of obtaining a complete explanation by this means. I should like to suggest that a great deal of light would be thrown on the problem by carrying out experiments with closed vessels of different materials surrounded by different screens of variable thickness.

An account of our experiments and of some of the views given here was presented at the annual meeting of the Royal Society of Canada. J. A. GRAY.

Queen's University,
Kingston, Ontario,
October 23.

The Size of the Iodine Molecule.

IN a recent paper (*Jour. Amer. Chem. Soc.*, October 1925) E. Mack has calculated the cross-section of the iodine molecule from the results of his experiments upon the rate of diffusion of iodine in air; the result of the calculation is a value agreeing closely with the figure given by Prof. A. O. Rankine ($15{\cdot}6 \times 10^{-16}$ cm.^{2}). But the agreement would seen to be accidental, and to arise from two circumstances: (1) Mack's experimental result for the diffusion coefficient is about 30 per cent. too large. (2) The method employed to calculate the cross-section is illegitimate.

With regard to (2): Mack calculates the 'radius of the iodine molecule' from "the Stefan-Maxwell-Jeans equation," which is actually the formula given by Jeans as a result of correcting Meyer's formula for diffusion for persistence of velocities in a collision. This formula at best gives only the value of S, the distance of the centres of the molecules in an average collision at the temperature of the experiment; S is therefore the sum of two 'effective molecular radii,' and varies with temperature in so far as the diffusion coefficient ($D \propto T^n$) is variable with temperature according to an index which exceeds $\frac{3}{2}$. Mack, however, obtains the 'radius of the iodine molecule' by subtracting from S the figure $1{\cdot}542 \times 10^{-8}$, which is taken to represent the radius of the average air molecule. But this figure is calculated from viscosity data by introducing a term containing the Sutherland constant, and refers to the actual radius of the molecule (on the assumption that it behaves as an elastic sphere exerting an attractive force) and not merely to the radius which is effective in collision. This 'actual' radius is thus invariant with temperature.

Measurements of the diffusion coefficient of iodine vapour in air have been carried out by me for another purpose; at 25° C. and 760 mm. pressure, the mean value is $0{\cdot}0815 \pm 1$ per cent., instead of Mack's result, $0{\cdot}108 \pm 1{\cdot}2$ per cent.

I have attempted to compare this new value with Rankine's experiments on the viscosity of iodine vapour. For this purpose it is necessary to estimate the viscosity at 25°; calculation by means of the Sutherland constant $C = 590$ is obviously unjustified, but the extrapolation has been made by assuming that the viscosity can be expressed by $\mu \propto T^x$; the value of x obtained from the highest and lowest temperatures employed by Rankine is $x = 0{\cdot}9837$, and the corresponding value for the viscosity at 25° is $\mu = 1{\cdot}388 \times 10^{-4}$. Then the effective radius is calculated by Chapman's formula for viscosity, and comes out to $\sigma_{I_2} = 3{\cdot}656 \times 10^{-8}$ at 25°. Similarly, the effective radius of the average air molecule is $\sigma_{air} = 1{\cdot}86 \times 10^{-8}$ at 25°.

If it is assumed that the effective radius in collisions of like molecules is also appropriate to the collision of unlike molecules, then the average distance apart of the centres of an iodine molecule and an air molecule in collision would be $(\sigma_{I_2}+\sigma_{air}) = 5\cdot516 \times 10^{-8}$ as calculated from viscosity data. On the other hand, the diffusion coefficient $D = 0\cdot0815$ enables the quantity $(\sigma_{I_2}+\sigma_{air})$ to be calculated from Chapman's formula for diffusion :

$$(\sigma_{I_2}+\sigma_{air})^2 = \frac{3\sqrt{c^2_{I_2}+c^2_{air}}}{32\,\pi\,\nu\,D}.$$

The value of $(\sigma_{I_2}+\sigma_{air})$ at 25° is found to be $4\cdot783 \times 10^{-8}$. If we subtract $1\cdot86 \times 10^{-8} = \sigma_{air}$, we have $\sigma_{I_2} = 2\cdot923 \times 10^{-8}$ at 25°, as calculated from the diffusion coefficient. This is considerably smaller than the value $3\cdot656 \times 10^{-8}$ calculated above from Rankine's viscosity data.

The discrepancy is in the same direction as that found with gases, but is rather greater in magnitude, as is to be expected for a vapour.

Calculation of the actual molecular radius (*i.e.* of the attracting elastic sphere model) from diffusion data is admittedly unsafe, even for comparatively permanent gases. In the case of iodine the corresponding calculation from viscosity data would seem to be open to some question ; the specific heat of iodine vapour is changing rapidly at the temperature of Rankine's experiments, presumably owing to a progressive increase of vibrational energy ; this might be expected to affect somewhat the value of the Sutherland constant obtained from the temperature coefficient of viscosity.

B. TOPLEY.

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The Oogenesis of Lumbricus.

I TRUST that I may be allowed a small space in order to reply to certain criticisms of my work on *Lumbricus terrestris*, which have been made in a recent paper by Prof. J. B. Gatenby and Dr. V. Nath (*Q. J. Mic. Sci.*, **70**, pp. 371-389, 1926).

In the first place I am accused of not referring to much of the literature on the subject. But much of the work which they cite as having been omitted was published after my paper had gone to press in the early summer of 1924, and Gatenby and Nath still ignore what Dr. Cannon pointed out in his contribution to the previous discussion in these pages (NATURE, **116**, 1925, p. 97), that my work was more in the nature of a critique of the methods of argument used by this school, rather than of their observed results.

In the second place, my technique and powers of observation are called in question. The thread-like mitochondria in my preparations are stated to be " artefacts due to long exposure of the fresh ovaries to water of unsuitable tonicity, or to unsuitable fixation." The ovaries used for the work were not brought into contact with any fluid other than those of the worm itself before being transferred immediately into fixative. Further, Prof. Cowdry states (" General Cytology," p. 317, l. 11) that in cell injury " first we often observe a breaking up of filaments into granules (this may also be induced by faulty technique). . . ." The point need not, I think, be laboured.

Again, my critics " are at a loss to understand Harvey's difficulties in giving a clear account of the behaviour of the Golgi apparatus . . .," because of the favourable nature of the material used. In this connexion it is interesting to recall Nath's reference (*Pro. Roy. Soc. Lond.*, B., **98**, 1925 ; footnote to p. 54) to this organ as being remarkable and representing Calkin's yolk nucleus. The latter structure has now been shown to consist of mitochondria.

To take one more criticism, they state that there is no yolk in the egg of Lumbricus at all, that I have mistaken degenerating Golgi bodies for yolk droplets and also for Calkin's yolk plates, which I found in all my preparations. I have re-examined my slides, and find that I cannot modify my former statements. The yolk plates, yolk droplets, and Golgi elements are present side by side in many preparations, and there can be no mistaking one for the other. There is, however, little yolk present compared with the amount found in many molluscs, ascidians, and arthropods, but perfectly distinct, yellowish droplets are present in many young oocytes, and these, in the older oocytes, become colourless.

Finally, Prof. Gatenby and his school are content to accept the view that yolk is a general term covering anything in the cell which cannot otherwise be identified, and originating from all possible primordia. Is it not time that cytologists made some attempt to bring the observations on oogenesis to as orderly a state as are those on spermatogenesis ? Possibly there will be found to be much minor variation, but the materials from which yolk is derived will, it is to be hoped, be reduced to two or at most three definite sources in the ovary.

L. A. HARVEY.

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Magnetic Storms and Wireless Communication.

IN the issue of NATURE of November 6, p. 662, Sir Joseph Larmor directs attention to the fact that during the magnetic storms of October 14 and 15, the Canadian beam signals were greatly reduced in strength. The explanation that appeals to me is connected with the fact that ionic refraction is not the only factor which determines long distance short wave ($\lambda < 60$ m.) transmission. Together with this there is the effect of energy absorption by collisions of electrons with molecules. That this absorption plays an important part in transmission seems to me to be upheld by a considerable body of evidence, not the least of which is that afforded by the action of magnetic storms.

The ionic absorption factor for the ray which traverses the ionised medium is well known to be $4\pi c/\rho$, where ρ is the effective resistivity (at the frequency concerned). This quantity can be expressed in the form :

$$\frac{1}{\rho} \propto \frac{Ne^2}{m}\frac{T^2}{\tau},$$

where T is the time period of the waves and τ the average time between successive collisions of an electron with a molecule or positive ion.

The essential point is that the absorption factor is proportional to N, the number of electrons per c.c., a fact which is obvious from the physical consideration that the total energy drawn from the waves is proportional to the number of collisions, *i.e.* N.

We have only to suppose that there is an appreciable increase in N, due for example to the injection of charged particles or increased ionisation as a result of the solar activity, to account for the increased absorption and consequent decrease of signals during sunspot activity. That absorption plays a very considerable part in long distance short wave transmission is evidenced by the fact that the range of a station in summer and in low latitudes is less than that in winter and high latitudes.

On the ionisation theory the numerical value of N will be greater in summer and at low latitudes than in winter and high latitudes. The range is therefore correlated with the value of N, decreasing as N increases, and vice versa. Reasonable values for N and T show that this factor $e^{-\frac{4\pi c}{\rho}}$ has an appreciable effect in transmission over distances greater than about 1000 km.

At short distances the effect of increased bending, due to increased N, is most apparent. The strength of local stations received in England was considerably augmented at times during the magnetic disturbances.

T. L. ECKERSLEY.

Research Department,
Marconi's Wireless Telegraph Company, Ltd.,
Marconi Works, Chelmsford,
November 15.

Internal Rust Spot of Potatoes.

THE cause of sprain or internal rust spot on potatoes has long been a subject of speculation among mycologists, and the macroscopic resemblance of the disease to that of net necrosis, whilst adding to the interest of the problem, has still further increased its complexity. The disease is a very serious one in certain of the potato-growing areas in Yorkshire, and we have therefore been anxious to ascertain its true nature. A short preliminary announcement of the results of our investigation may be of interest.

Two organisms have now been isolated by my colleague, Mr. Sydney Burr, which in inoculation experiments have reproduced the disease in a very definite and characteristic way. The commonly accepted symptom of the disease is the appearance of rusty brown spots in the medullary and cortical parenchyma of the tuber which are closely invested by a thick layer of cork cells. It is now clear that in addition to this formation of disease 'islands,' the xylem of the vascular ring is frequently attacked, but in this case wound cork is not formed unless the adjoining cells of the pericycle are also involved. This xylem infection is sometimes invisible to the naked eye. So far as the infected tubers have been examined, it appears that the phloem bundles are not *directly* attacked, although ultimately they may be involved by the infection of the neighbouring parenchyma. Thus, net necrosis, which is primarily an infection of the phloem bundles, may now be definitely dissociated from rust spot disease.

Each of the organisms in question is an extremely short and motile rod which is cultivated on artificial media only with difficulty. They thrive best in liquid media, and have been grown in peat soil extract and in nutrient potato broth. On soil extract agar, each organism produces minute dew-like colonies in seven to ten days, which, later, become steely blue in colour. Slight growth has also been obtained on lactose agar and nutrient gelatine, and one of the organisms gives a poor thin growth on nutrient potato agar. There thus appears to be no resemblance between either of the organisms and the two variants of *B. solaniolens* isolated by Paine from potatoes showing similar symptoms of disease.

Further attempts to define the organisms are now in progress, and it is hoped to publish a detailed account of this work in due course, together with an account of the field experiments which have been carried out with the object of ascertaining some possible remedy for the disease.

W. A. MILLARD.

Department of Agriculture,
University of Leeds,
November 12.

The Double Normal State of the Arc Spectrum of Fluorine.

IN an earlier paper (*Proc. R.S.*, Amsterdam, June 1926) I have made a preliminary analysis of the arc spectrum of fluorine. I found it possible to arrange all strong lines in the red part of the spectrum in multiplets. The following terms are recorded:

$^4P_{123}$ $\Delta\nu = 160{\cdot}0$; $274{\cdot}5$.
$^4D_{123}$ $\Delta\nu = 83{\cdot}4$; $144{\cdot}4$; $176{\cdot}6$. (This term was found by Carragan, *Astr. Jour.*, 63, 145, 1926.)
^4S
$^4P'_{123}$ $\Delta\nu = 102{\cdot}1$; $122{\cdot}7$.
$^2P'$ $\Delta\nu = 325{\cdot}6$.
^2P $\Delta\nu = 145{\cdot}5$.
^2S ?
^2D $\Delta\nu = 250{\cdot}3$.

The structure of the FI spectrum resembles that of NI (C. C. Kiess, *Jour. Opt. Soc., America*, vol. 11, 1, 1925) and OII (A. Fowler, *Proc. R.S.*, London, vol. 110, 476, 1926). Doublet-quartet intercombinations are not found in the red part of the spectrum. Millikan and Bowen (*Phys. Rev.*, 23, 1, 1924; *Phil. Mag.*, 48, 259, 1924) have investigated the fluorine spectrum in the extreme ultra-violet. This spectrum has only two strong lines:

(7) 606·9 (Fine structure: 605·64; 606·23; 606·83; 607·43; 607·99).
(5) 656·4 (Fine structure: 656·00; 656·34; 656·84; 657·69; 658·31), indicated as L_α.

The purpose of the present note is to identify the line 606·9 as a $^4P^2P'$ combination and the lines 657·69, 658·31, as a ^2P combination. We assign one of the ^2P term differences 145·5 (expressed in volts, 0·02) or 325·6 (expressed in volts, 0·04) to the double normal state (*Grundterm*) of the fluorine atom. These values agree well with the value predicted by Franck (0·025 volt). More details will be given in a forthcoming paper in the *Zeitschrift für Physik*.

T. L. DE BRUIN.

Physical Laboratory "Physica,"
University of Amsterdam, September 21.

'Hard Seeds' in Leguminosæ.

WHEN offered ideal conditions for germination there commonly occur in seed of most cultivated Leguminosæ, seeds which do not absorb moisture and, in consequence, fail to swell up and germinate: they do not soften, and are therefore known generally as 'hard seeds.' This inability to absorb moisture endures for an indefinite period, extending possibly for many years, though ideal conditions for germination may be continuously or intermittently offered. The cause of 'hardness' has always been attributed to some peculiarity of the seed coat itself, largely because very slight damage, such as abrasion, enables the seed to behave in a normal way.

This summer, working with sweet peas and other legumes, I found good evidence for the belief that 'hardness' does not lie in the seed coat itself, but is the result of a varnish-like deposition on the seed surface, produced within and by the pod. On a nearly ripe but still green pod being opened, a quantity of watery fluid is found bathing the seeds, and, as ripening proceeds, this fluid becomes concentrated, so as to appear quite sticky on the fingers. It is suggested that this fluid, when fully concentrated, deposits the 'varnish' which on drying becomes insoluble in water and forms an impermeable film on the surface of the seed.

The chemical nature of neither the fluid nor the film has, as yet, been investigated, but it is interesting to note that treatment with dilute sulphuric acid, even for a short period, causes 'hard seeds' to behave normally. Prolonged digestion with concentrated caustic potash, on the other hand, has no effect, though normal seeds are reduced to a gelatinous mass in some thirty minutes.

The belief that hardness is not a characteristic of the seed coat, but is due to the deposition of an impermeable film during the last few days of ripening, offers a simple explanation of some facts long known to practical men. For example, 'hard seeds' occur quite promiscuously in any and every consignment, in some more, in others less, the nature of the weather just previous to harvest having a considerable effect on the number. Further, the best ripened seeds always contain most hard seeds.

I hope to proceed further and more critically with the work next summer, but the considerable commercial importance of the subject seems to justify this preliminary note. ALEXANDER NELSON.

Scientific Department,
David Bell, Ltd.,
17 Coburg Street, Leith,
October 26.

The Eggs of the Sucker-fish.

IN a letter on the eggs of the pilot-fish in NATURE of August 14, 1926, p. 228, Mr. K. H. Barnard also mentions the eggs of the sucker-fish (*Echeneis naucrates*) "which are apparently still undescribed." During my researches on the eggs and larvæ of East Indian fishes (cf. *Treubia*, vol. 2, p. 97; vol. 3, p. 38; vol. 5, p. 408; vol. 6, p. 297; vol. 8, p. 199; and vol. 9, p. 389), I also became acquainted with the pelagic eggs of the sucker-fish. They are very large, having a diameter of 2·5 mm. The yolk is colourless and fills up the egg membrane fairly well. It contains a small oil globule of a bright yellow colour, diameter 160 μ, and the developing embryo is yellow also, as a consequence of the presence of a large number of yellow pigment spots. Besides these yellow spots there are also black ones, especially on the head and behind the eyes. In due time I hope to give a figure of the egg in *Treubia*.

I have reared these eggs, isolated from the catches with the surface egg net, several times on board the investigation steamer *Dog*, in glasses with pure seawater. They invariably died, however, after some $2\frac{1}{2}$ days, about the moment of hatching. I counted 16 + 16 myotomes in an embryo freed artificially from the egg membrane, whereas *Echeneis naucrates* has 14 + 16 vertebræ. My determination is founded chiefly on the examination of a few fresh females with perfectly ripe eggs. These agreed in every respect with the pelagic eggs which I have known for a long time from the Java Sea. H. C. DELSMAN.

Laboratory for Marine Investigations,
Batavia, Java, October 2.

The Symmetrical Top in the Undulatory Mechanics.

BY applying the methods of Schrödinger (*Ann. d. Phys.*, 79, 361, 489, 734, 1926), which have proved so fruitful in treating atomic problems, to the case of the symmetrical top, we have obtained a complete quantum mechanical solution for this system. The results agree with those found by Dennison (*Phys. Rev.*, 28, 318, 1926) by means of the matrix mechanics; the energy values are

$$W_{jn} = \frac{h^2}{8\pi^2}\left[\frac{1}{A_x}j(j+1) + \left(\frac{1}{A_z} - \frac{1}{A_x}\right)n^2\right],$$

$A_x = A_y$ and A_z being the moments of inertia of the top.

The quantum number j and n must have integral values, a result which follows directly from the nature of the characteristic functions, which involve hypergeometric series. This question was not definitely decided by the matrix mechanics, both integral and half-integral values appearing to satisfy the problem. Each value W_{jn} occurs $(2j+1)$ times as the characteristic value of the system, corresponding to the fact that a state with this energy will divide into $2j+1$ levels under the action of an external field.

Full details will be published elsewhere in the near future. R. DE L. KRONIG.
I. I. RABI.

Department of Physics, Columbia University,
New York, October 26.

Complex Aromatic Hydrocarbons in Low-Temperature Tar.

FROM a tar produced by distillation of Pooley Hall-Wearmouth coal, carbonised at 600°, a fraction boiling at 313°-360° was obtained which yielded a complex mixture of aromatic hydrocarbons distinguished even in an impure state by their bright colours. Predominant among these hydrocarbons is β-methylanthracene which was identified by conversion into β-methylanthraquinone and anthraquinone-β-carboxylic acid. The identity of the β-methylanthraquinone obtained in our experiments was established by comparison with a specimen of synthetic β-methylanthraquinone furnished by Mr. W. H. Dawson of the British Alizarine Co. Additional proof of the identity of β-methylanthracene was obtained by comparing its carboxy acid with the anthraquinone-β-carboxylic acid prepared by oxidising the β-methylanthraquinone from the British Alizarine Co.

Investigation of these complex aromatic derivatives from low-temperature tars is being continued in collaboration with H.M. Fuel Research Station.

G. T. MORGAN.
D. D. PRATT.

Chemical Research Laboratory,
Teddington, Middlesex.

Welsh Romani.

As a believer at any rate in the constancy of the law which accords the last word in a discussion to the reviewer, and since the columns of NATURE seem scarcely the place for it, I do not propose to deal further here with the novel Romani etymologies propounded by Prof. Turner. The place for this is obviously the *Journal of the Gypsy Lore Society*, of which he is a member, and where scholars who understand Romani and are familiar with what has already been written upon it, will have an opportunity of forming their own opinion. We should then, I presume, learn Prof. Turner's reasons for supposing that **suil* could in any dialect of Romani be a possible word, and why a Welsh Gypsy variant of a south European Gypsy word should have a separate origin in a different Indian stem.

JOHN SAMPSON.

The University,
Liverpool.

DR. SAMPSON has not replied in any particular to the charge I advanced that in many of his etymologies he had violated the principle of the constancy of the "laws of sound change."

R. L. TURNER.

School of Oriental Studies,
University of London.

A Half-Century of Chemistry in America: 1876–1926.

IN commemoration of its fiftieth anniversary, the American Chemical Society has issued a "golden jubilee number" under the above title. In the earlier part an account is given of the origin and development of the Society. Four of the first chapters in the section are written by original members: I. on The Priestley Centennial, by Samuel A. Goldschmidt; II. on The Organisation of the Society, by William H. Nichols; III. on The Evolution of the Society, by Frank Wigglesworth Clarke; IV. on The First General Meeting and the First Local Section, by Charles E. Munroe; V. on The Activities of the Society, by Dr. Parsons, the Secretary. Part 2 consists of articles on progress in various branches of chemistry in America—Mineral Chemistry being discussed by Edgar F. Smith; Physical, by Wilder D. Bancroft; Inorganic, by James Lewis Howe; Organic, by Treat B. Johnson; Agricultural, by Charles A. Browne; Industrial, by Charles E. Munroe; The Chemistry of Physiology and Nutrition, by Graham Lusk; Chemical Education, by Samuel R. Powers. The Society is to be congratulated upon the issue of a historical volume full of interest, containing not a little that is informative to chemists generally.

The first important chemical meeting of a national character to be held in the United States was the Priestley Centennial celebrated at Northumberland, Pennsylvania, on August 1, 1874. The Society owes its origin largely to influences then set in action. To-day, it numbers little short of 15,000 members. At first, the Society held monthly meetings in New York but the best American contributions to chemistry were not published in its journal and the Society had little more than a local existence. Other societies were established. The need of uniting the several existing organisations as local sections of a national society was not fully realised until 1891. The change was gradually effected and the present constitution came into force in April 1901. At first, the reorganised society had four local sections. Others were soon organised and now the sections number seventy, fairly covering the whole area of the United States. The sections hold their own meetings but general meetings, for the transaction of general business, are held twice a year.

The Society publishes three journals: *The Journal of the American Chemical Society*, *Chemical Abstracts* and *Industrial and Engineering Chemistry*: the first accommodates the academic, the last the industrial element. The United States is far in advance of Great Britain in the way in which the interests of chemists have been consolidated, especially is it to be congratulated upon having established and maintained a firm union between science and practice. With us cliques and chaos reign and receive almost monthly additions; the interests are in no way co-ordinated and there is constant overlapping and great waste of energy and funds: the consequence is, chemistry has no acknowledged place in the State, whilst in America it is not only publicly recognised but even regarded with respect and highly valued by the commercial class. Our Chemical Society is now a positive danger as it is supposed to be representative of the subject generally, whilst, in effect, it is but the preserve of a narrow academic clique, aloof from the world. On the other hand, the Society of Chemical Industry does not sufficiently represent the higher industrial interests. Here there is no bond of social union, as chemists acknowledge no leadership: our subject has yet to rank socially. No mere *Corner House* will give it status.

The American Society has done much to consolidate publication but still allows the separate publication of a *Journal of Physical Chemistry*, which it even patronises. There is no reason why this should be continued. It has recently instituted a new publication, *Chemical Reviews*, but on the 'penny-wise, pound-foolish' plan of not paying contributors; this is not supplied to its members. Under strong editorship, such a journal might well be made an invaluable asset—nothing is more in need of encouragement at the present time, than the writing of considered, critical scientific essays—thus far, the journal has contained useful but usually limp, monographic surveys. Chemists have yet to learn to put their thoughts into satisfactory essay form. The Society has also undertaken the issue of *Book Monographs*. The enterprise is one of extreme difficulty. Men with sufficient experience and literary ability, who will study a subject until they have mastered it and then deal with it critically, dispassionately and judicially, are scarcely to be found.

The American Society began to publish *Abstracts* in 1907. Our Society's activity in this direction dates back to 1872. There never should have been two such publications *in English*. A real effort *was* made, on both sides, to institute a joint publication, but adverse influences in Britain, the narrow outlook of a few leading members of the Society of Chemical Industry, made this impossible. The magnitude of the enterprise grows daily; the number of abstracts published by the American Society in 1918 was 13,357, whilst in 1925 it was 26,426. The average length of the abstract has been reduced from 0·251 of a page in 1917 to 0·190 in 1922.

There is little to choose between the two publications, except that the English abstracts are at least readable, whilst often the American are not, on account of the contractions used. The American survey of the literature is probably the more nearly complete. To-day, neither is much more than a subject index and the sooner we recognise this and so treat the work, the better it will be.

Having been an abstractor at the beginning and being able to overlook an even longer period than that covered by the English enterprise, I am of opinion that the gross effect of the publication of abstracts has been greatly to the detriment of chemistry. In my early days, we read everything as it appeared: many of us bought at least the leading English and foreign journals. We were, therefore, constantly learning and constantly kept in training: the voices of the master-workers were continually in our ears. To-day, very few read and scarcely any one maintains a library. Students and even workers glance through this or that section of the abstracts, just as they skim *Tit-Bits* in the train. 'Tit-bitry,' in fact, prevails everywhere, the art of reading is uncultivated and all but unknown, the whole chemist is a fast disappearing species, the 'bit-o-chemist' will soon be sole survivor. As of Cock Robin, we may ask—"And what will the chemist be worth then, poor thing?" To-day, already, he can scarcely be hired. Abstracting and examining together are killing chemistry as a science and preventing the upgrowth of men of real worth. Our younger generation cannot even appreciate its own work, cannot criticise, because it is not sufficiently informed and is being 'trained' on unscientific, dogmatic lines.

The *Journal of Industrial and Engineering Chemistry*, we are told, is the one journal of the American Chemical Society which is financially remunerative, yielding through its advertisements a net income of approximately 70,000 dollars a year: this has enabled the Society to publish at a reduced cost to its members the Journal and Abstracts. Everyone knows its taking 'get-up'—the area and mass of polished china clay to be handled. Obviously it is highly attractive to advertisers but has it any special value for industrial and scientific workers? Might it not, with advantage, be less loosely strung together and more compact in form? Yes! but then it would not appeal to advertisers—our *Blue Bits*, we know, is not specially attractive to the class. Ought not we to face this problem squarely, in the interests of our science—whether pure or applied? Surely, in a country like the U.S.A., a country of high ideals, a country of untold resources with a vast superabundant wealth, a country which can spend millions upon 'the pictures' (the industry ranks fourth), it should be possible to find the 20,000*l*. a year necessary to enable the corporation which represents chemistry to dispense with advertisements. Chemistry being the science of life, the science underlying all earthly, if not heavenly change, advertisements are no more in place in its journals than in a Family Bible. Surely, we may say to America and to ourselves in lesser degree, *Schäme Dich*! at such failure to recognise what is owing to our *science*! To what better purpose could a multi-millionaire wishing to save his soul devote his fortune than to the endowment of a great organisation charged with the publication of the considered results of real chemical inquiry by English-speaking peoples? That the English and the Americans are destined some day to work together in this direction cannot be doubted. The task is not difficult: given the will! given a few leaders!

It is disappointing that these and similar problems should not have been considered by the Americans in their survey of progress. Much will happen during the next fifty years but dare we hope that, at their centenary, they will be able to come forward and paint chemistry as a pure religion? There is nothing in the chapter on chemical education to show that such is their aim. In America, as here, leaders are called for to fashion higher ideals.

Turning to the reviews of progress, that on mineral chemistry by the veteran Edgar F. Smith, whose worn-out Göttingen degree was returned to him replated at the meeting in Philadelphia, is specially interesting, inasmuch as he chiefly portrays the activities of five past presidents, all remarkable men, Frederic Augustus Genth, J. Lawrence Smith, T. Sterry Hunt—with whom he links Wolcott Gibbs—William Francis Hillebrand and Frank Wigglesworth Clarke. Essentially, the essay is an appeal for greater attention to mineral chemistry.

Wilder D. Bancroft follows with a rambling essay, without any clear, logical, underlying *leitmotif*, in which the *Impresario* plays the veritable 'bull in the china shop of physical chemistry' to perfection—little is left unbroken. Recognising this, apparently, and the need of glue to mend things, he ends by asking for two new institutes of colloid chemistry. To comfort us he quotes a leading American chemist as saying—

> Physical chemistry exists no longer. The men who have been called physical chemists have developed a large number of useful methods by which the concrete problems of inorganic chemistry, organic chemistry, biochemistry and technical chemistry may be attacked. As the applications of these methods grow more numerous, it becomes increasingly difficult to adhere to our older classification.

It will be interesting to "Kahlenberg in America and Traube in Germany," as it is to "H. E. Armstrong in England" to be told that they are members of a Triptych: "three irreconcilables who do not believe at all in the electrolytic dissociation theory" and that whilst "they have not accomplished what they set out to do, they are not likely to." The only interpretation I can give of this cryptic statement is, that we set out hoping to find an intelligent appreciation and interpretation of the facts of chemistry and are now persuaded that such is non-existent. Still, there is hope for the sinner that repenteth, as follows:

> It is easy enough to point to one factor which has been neglected practically completely and which may be the one which has caused most—and perhaps all—of our difficulties. For years H. E. Armstrong in England has chided the physical chemists for considering water only as water, whereas it is a complex and variable mixture. This criticism seems well founded; but, unfortunately, Armstrong has never succeeded in showing what could be done with his idea and consequently the idea has been valueless hitherto.

To have an American 'high priest' admit that water has been left out of account is certainly amusing. The gibe is proof of the thesis I have long advocated that publication in the *Proceedings of the Royal Society* is a form of decent burial. However, Bancroft is evidently 'reading some' and perhaps, having swallowed the water-complex in this age of prohibition, will ultimately come to realise what are the essentials of chemical change. It is pitiable that we should have wandered these fifty years past in the wilderness of doubt on such a subject. I await the day when he will call out—

> O ——, speak no more:
> Thou turn'st mine eyes into my very soul
> And there I see such black and grained spots
> As will not leave their tinct.

In the remaining essays, a rapid survey is given of American contributions; we all know these to have been of consequence in many fields and it is interesting to be reminded of particular cases, to be led to think back to work such as that done by Morley and Richards, by Michel, by Osborne, by Franklin, by Gomberg. What is missing from all the essays, however, is the attempt to assess the value of chemical study in its various branches. That chemical discovery has contributed greatly to public and industrial welfare is beyond question. What, however, has been done, what is being done, to make the study of mental and moral value? Is not its value for all purposes steadily diminishing under the influence of examinations and the degree-hunger? Instead of being severely trained in scientific method and the worship of truth, the student to-day is taught didactically and dogmatically and 'faith' now plays as great if not a greater part in science than it does in religion. The 'research' work for the degree, for the most part, is mere exercise work, the equivalent of figuring out an untried example in the mathematical primer: there is no element of imagination or discovery in it. The teacher dare not set a task of difficulty of doubtful outcome. We talk ecstatically of the great increase in the number of papers published in our journals but the work, in large part, is of no real scientific merit or value. Much of it were better left unpublished.

The pursuit of science is necessarily an anti-human practice as it involves an all but impossible self-abnegation and a modesty which is more than rare. Let us admit that publication is largely a matter of personal advertisement: we shall then realise what is desirable in the interests of scientific altruism.

Problems such as these are in sore need of attention in Britain and America, if the faith of our forefathers is to be justified. Science to-day is as much in danger as is religion—there is a lack of morality behind it as there is behind religion—it is being overcome by the democracy of ignorance, by our failure to recognise that it is probably only attainable by the few, by the lack of discipline owing to lack of leadership. The American Jubilee proceedings are particularly disappointing in this respect. Chemists are in no way alive to the greatness of the subject of which they are guardians. HENRY E. ARMSTRONG.

The Cretaceous Plants of Greenland.[1]

IT was a noteworthy event in the annals of the University of Cambridge when a Master of a College undertook a successful expedition to Arctic regions shortly before becoming Vice-chancellor, and the publication of the scientific results of the expedition must also be described as an important event. For the significance of this work goes beyond the confines of palæobotany and geology into the regions of cosmic history. A knowledge of the plants which grew in Greenland in the far past provides, within certain limits, good evidence as to the former climate of the region, and so provides data for the study of secular climatic changes. This paper concerns the evolution of plants and the evolution of climate.

It has long been known that the remains of abundant vegetation are found in high latitudes. These are not merely fragments of plants which have been drifted by ocean currents far from their place of origin, but, as Prof. Seward has shown, may be accompanied by beds containing remains of roots and rhizomes *in situ*. In one place a great mass of remains of the fern Gleichenia indicates a district covered with this bramble-fern, while at another locality the abundance of conifer leaves reminded Heer of the carpet of fir-needles in a modern forest.

The Cretaceous plants of Greenland are of especial interest because the majority are allied to plants now living. It has been assumed that the Cretaceous forms grew under climatic conditions closely approximating to those under which their modern representatives grow to-day. Prof. Seward points out, however, that as times have changed in the world the plants themselves have in all probability changed in their relations to external factors. But no conclusions can be drawn without a thoroughly sound knowledge of all the forms making up the flora. Hitherto our information has been mainly based on the determinations of the famous Swiss palæobotanist, Oswald Heer, but his work belongs to an epoch when fossil species were established somewhat less critically than to-day. Seward has had the heavy task of working through Heer's results and reducing them to data which will satisfy modern requirements. A part of this critical review recently appeared in the jubilee volume of the Geological Society of Belgium, and it is here completed.

The list of species now given is very different from that of Heer, for many of his specimens were found to be too fragmentary or too badly preserved for reference even to their genera, while other remains of leaves were referred to modern genera on quite inadequate grounds. The names of many modern genera have therefore disappeared from the list, while others have been altered to indicate that leaves of the form possessed by certain modern genera were present, though their actual identity with these genera is not yet proved; for example, some leaves previously called Magnolia are now called Magnoliæphyllum. But while the author is very cautious in attributing fossil-leaf impressions to modern genera, he considers that many of them belong to modern families, and, after considering the distribution of some of these, he comes to the unquestionable conclusion that the fossils point to an Arctic environment very different from that of to-day. From the study of the chief forms he infers that "the climate of Greenland in Cretaceous times was probably comparable with that of Southern Europe to-day. Genera that are now characteristic members of tropical floras, the floras which are in part legacies from the Cretaceous age, were then represented by species less sensitive than their modern descendants to external factors."

The importance of these conclusions is that the changes in temperature needed to enable such a flora to live at high latitudes is not great. A freer interchange between the Arctic Ocean and the tropical oceans might be quite sufficient to allow the growth of the flora described, in the absence of the Greenland ice-sheet. There is no need to postulate considerable movements of the pole.

On the evidence of fossils, the view has been widely maintained that during the Mesozoic period the climate

[1] "The Cretaceous Plant-Bearing Rocks of Western Greenland," by A. C. Seward, *Phil. Trans. Royal Society*, Ser. B, vol. 215, pp. 57-175. London, 1926.

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.

Hedley was an indefatigable worker and a voluminous writer, his published papers and articles totalling more than 160, and he was joint author of about twenty more. Most of these dealt with his special subjects, molluscs and zoogeography, but they also include botanical, ethnographical, and geological contributions. His earliest papers were mainly descriptive of the land shells of Queensland, but after his transfer to Sydney he devoted himself to general conchology, though he was always greatly interested in terrestrial molluscs, particularly in regard to their distribution and the evidence they offer as to the former relations of land and water. Some of his most useful contributions are various faunal lists such as "The Marine Fauna of Queensland" (*Rept. Austr. Ass. Adv. Sci.*, 1909, pp. 329-371); "A Check List of the Marine Fauna of New South Wales, Part 1, Mollusca" (Suppl. to *Jour. Roy. Soc. N.S. Wales*, 51, pp. M. 1-M 120, 1917). He was a contributor to the Reports of the Shackleton British Antarctic Expedition of 1907–1909, writing on the molluscs of the 'raised beaches' of McMurdo Sound, and he described the molluscs of Mawson's Australasian Antarctic Expedition of 1911–1914. He was the author of a delightful sketch of the ecology of the Sydney beaches (*Jour. Roy. Soc. N.S. Wales*, 69, pp. 15-77, 1915). One of his longest conchological papers was his masterly "Revision of the Australian Turridæ" (*Rec. Austr. Mus.*, 13, pp. 213-359, 1922, 15 plates). He was skilled in pen-and-ink drawing, and many of his papers were illustrated by himself.

Hedley was a fellow of the Linnean and Malacological Societies of London; honorary member of the New Zealand Institute and of the Royal Societies of Victoria, Queensland, and Western Australia; corresponding member of the Zoological Society of London and of the Academy of Natural Sciences of Philadelphia. He was a past president of the Royal, the Linnean, and Royal Zoological Societies of New South Wales. In 1916 he gained the David Syme prize for scientific research, and in 1925 the Royal Society of New South Wales awarded him the Clarke Memorial Medal, the highest honour in its gift.

Hedley was completely absorbed in his work, which was also his hobby, and he was always ready to make sacrifices in the interests of scientific advancement. He was a most generous donor to the Australian Museum, both of specimens and works of reference, and many of his collecting trips, which invariably yielded a rich harvest of results, were financed by himself.

His body was cremated and the ashes scattered on the waters of the Great Barrier Reef, which he knew and loved so well. C. ANDERSON.

News and Views.

DR. JEANS's article, which forms our supplement this week, may be regarded as a summing up of the hypothesis of stellar evolution and contributions which he has adumbrated in various publications for several years past. Even those who share neither his view-point nor his conclusions will be unable to withhold their admiration for the extreme ingenuity of the hypothesis and the masterly manner of its presentation. Indeed, it may even, somewhat paradoxically, arouse suspicion by its very perfection it is so rarely that a complex phenomenon reveals its secret through so small a fragment of itself as is our actual, compared with our possible knowledge of the stars. We could scarcely have complained if more uncertainties had been left over for further observation to remove. The picture which Dr. Jeans unveils, of a vastly extended field for physics and chemistry, is an arresting one, but it is also very tantalising. The field, he tells us, is there, but we are never to enter it, being possibly merely a disease infesting the rubbish-heap in the corner.

As men of science, we must be prepared—to change the metaphor—for truth to be unpalatable, but we do not like to be debarred from the possibility of testing it. For that reason we may be permitted to hope that Dr. Jeans has not yet said the last word on the subject. The alternative views of Russell and Eddington likewise include phenomena unknown on the earth—namely, a transformation of matter into radiation which is a function of temperature and pressure—but such a transformation is not necessarily unknowable; if it takes place in the stars we may in time reproduce it terrestrially. Dr. Jeans, however, does not admit extra-terrestrial processes, but believes in extra-terrestrial matter. One possible objection to his postulates which occurs to us is that it is not easy to conceive how such highly unstable material as his primitive atoms could have come into existence. Evolution from simple to complex implies an infinitely simple origin, which is intelligible, but the reverse process seems to require an infinitely complex origin, which appears to be absurd. We know, of course, that the radio-active elements exist, but a minute fraction of the total matter in the universe might plausibly be attributed to an evolutionary process (from simple to complex) overstepping itself in special circumstances. It is a different matter when the whole universe is regarded as radio-active.

ON November 27, the authorities of the city and cathedral of St. Albans joined in a commemoration of a distinguished man of science belonging to St. Albans, Richard of Wallingford, Abbot 1326–35. Ecclesiastically, the observance took the form of a "Solemn Evensong" in the cathedral. This was attended by the Mayor and Council, by representatives of the University of Oxford, particularly of Wallingford's own College of Merton, and by representatives of the Honourable Company of Clockmakers. At the end of the anthem a procession was formed up the aisle to the altar, where the Astronomer Royal presented a wreath to the Dean, who placed it on Wallingford's tomb within the sanctuary. Later, there was a well-attended meeting in the Town Hall, which was addressed by Profs. H. H. Turner and H. W. Garrod, Dr. Gunther, and Mr. Howgrave-Graham, of the Honourable Company of Clockmakers, on various aspects of Wallingford's work. Dr. Gunther also showed a small collection of medieval scientific instruments, which included a reproduction of "Wallingford's Rectangulus," made according to the working-drawings and descriptions which that most practical of medieval savants left behind him. The instrument was intended merely to supersede rather clumsy astrological instruments of the day, such as the 'armillary sphere' and the 'Torquetur,' but actually, as was pointed out, it opened the way to much that the inventor may not have foreseen. It was by far the handiest surveying instrument of its day for things on the earth as well as those in the heaven.

BY his combined use of the 'rectangulus' and the plumb-line, Wallingford was led to see the usefulness of the right angle for purposes of measurement, and thus, as one of his treatises shows, was led to grasp for the first time the principles of trigonometry. By introducing the system of measuring the chord instead of the arc, he made such improvements as Mercator's projection a possibility, and gave men of scientific bent a handy tool to work with and on, instead of a cumbrous one. It was hoped that another instrument, Wallingford's 'Albion,' would be on view, but here the visitors were disappointed. Tradition had asserted that this instrument was in the possession of a local family of very long standing, acquired by their ancestor from the Abbey at the time of dissolution. Unfortunately, they had themselves been under a misapprehension about the heirloom, having confused Wallingford's Albion (an astrological instrument) with the clock that he is also recorded as having made, which was probably a large 'turret clock.' Thus they had considered a most exquisite clock in their possession as 'Wallingford's,' and thought this the Albion. Actually, the clock that was on view, though an excellent specimen, was considered by experts to be of later date, and probably not earlier than the end of the sixteenth century. If Wallingford's Albion could not be seen, the authorities of Oriel College made amends to those who had come to see it, by the loan of 'Bredon's astrolabe,' an instrument left to that society by Bredon in 1340. As Bredon was himself a pupil of Wallingford, it is by no means impossible that the astrolabe was Wallingford's work and his gift to the man who bequeathed it to its present owners.

No names are more worthy to be held in honour by all who are interested in scientific collections than those of the two Tradescants, father and son, "Both gardeners to the Rose and Lily Queen," *i.e.* Queen Henrietta Maria. The elder Tradescant it was who by the specimens of plants, animals, coins, arms and other objects of science and art accumulated by him in his travels to various parts of Europe and of northern Africa, and stored by him at his garden in West Lambeth, gave the first impulse to the formation of public museums, and so started a movement which has been of incalculable benefit to the advancement of knowledge and education. The younger Tradescant continued the work begun by his father; and, like him, travelled abroad in search of specimens to add to the collection known as "Tradescant's Ark." His visits to Virginia (1642 and 1654) resulted in the importation of many interesting plants, amongst others, of the Commelinaceous genus named Tradescantia in his honour. The gift of an armorial window by the Garden Clubs of Virginia was therefore a graceful and appropriate recognition of the merits of their seventeenth-century visitor; and no more suitable position for the window could have been found than the Old Ashmolean Museum at Oxford. This building was opened in 1683 to hold the famous collection; which had been bestowed by John Tradescant the younger on his friend Elias Ashmole, and by the latter presented to the University. On November 26 the window was duly unveiled by Lord Fairfax, whose ancestor during the civil war fought on the opposite side to his friend Ashmole, and was at once the successful besieger and protector of Oxford. An inscription on the window in elegant Latin verse by Mr. J. U. Powell, of St. John's College, may be freely (and inadequately) translated as follows: "John Tradescant: Virginia's kindred spirits own his fame, and flowers in English gardens bear his name."

THREE hundred years ago, on December 10, 1626, there died the Rev. Edmund Gunter, one of the first school of English mathematicians, the friend of Briggs, Oughtred and Gellibrand, and for the last seven years of his life, professor of astronomy in Gresham College, London. Of Welsh descent, Gunter was born in Herefordshire, but was educated at Westminster and Christ Church, Oxford, taking the degree of B.A. in 1603, and that of M.A. in 1606. He entered the Church, and from 1615 onwards held the living of St. George's, Southwark. To the astronomer he is known for his invention of a portable quadrant; to the mathematician, for his *Canon Triangulorum*, the first printed table of artificial sines and tangents; to the physicist, for his discovery of the alteration in the variation of the compass; and to the surveyor, for the invention of the 'Gunter's chain,' which is 22 yards long with 100 links, an instrument which superseded the old measuring rods for land surveying and has remained in use until the present time. During the latter part of his life he had chambers in Gresham College, Sir Thomas Gresham's famous old mansion in Bishopsgate Street, where forty years later the Royal Society held its first meetings. He died in the College, and was buried, like his contemporaries Gellibrand and Foster, in St. Peter le Poor, a city church which has long since vanished.

SIR ISAAC NEWTON died on March 20, 1727, so that Sunday, March 20, 1927, will be the two-hundredth anniversary of his death. A meeting to celebrate this bicentenary will be held under the auspices of the Yorkshire Branch of the Mathematical Association at Grantham, near which Newton was born, and in which he went to school. The programme includes a scientific meeting on Saturday morning, March 19, to be addressed by Sir J. J. Thomson, Master of Trinity College, Cambridge; Sir Frank Dyson, Astronomer Royal; Dr. J. H. Jeans, Prof. G. H. Hardy, and Dr. Horace Lamb; who will speak about

Newton's work in physics, astronomy, mathematics, and mechanics. On the same day there will be a pilgrimage to the house at Woolsthorpe where Newton was born, and a visit to Stoke Rochford. In the evening there will be a dinner at the George Hotel, Grantham, among the speakers at which will be Prof. E. T. Whittaker, Prof. H. H. Turner, and other distinguished men of science. A bicentenary sermon will be preached at the Parish Church, Grantham, on Sunday, March 20, by the Bishop of Birmingham. Detailed programmes will be issued in due course. Any one interested and desiring to take part in the meeting should write to Mr. A. B. Oldfield, Rydal Villas, Crawshaw Avenue, Pudsey, near Leeds, or to Prof. S. Brodetsky, The University, Leeds. As the accommodation is very limited, application should be made as early as possible.

THE British Science Guild recently instituted an annual lecture in commemoration of its founder, Sir Norman Lockyer, and the second of the series was delivered at the Goldsmiths' Hall on November 22 by Prof. Julian Huxley, who took as his subject "Biology and Human Life." The lecture, which was delivered in the afternoon, attracted a crowded audience. Prof. Huxley prefaced his sketch of some industrial and social applications of biology by a reminder that such applications do not constitute the primary motive of research in pure science, but must be regarded as a fortunate by-product of the thirst for new knowledge. After describing some of the more recent contributions of biology to the prevention of disease and to the art of healthy living, and some of its applications to the extirpation of agricultural pests, Prof. Huxley made a strong plea for the fearless application of biological knowledge to human population problems. The relative rates of increase of the more and the less desirable groups within the species is so unfavourable to the former that every one acquainted with the facts must agree as to the disastrous consequences of permitting prejudice to obstruct practicable eugenic reforms. Such lectures do a valuable service to the community in bringing home to the educated layman the gravity of the issues at stake.

THE Council of the Royal Anthropological Institute has decided that two Rivers Memorial Medals shall be granted for the year 1926. Of these one has been awarded to Prof. Edward Westermarck in recognition of his researches on the customs and beliefs of the natives of Morocco. The other has been awarded to Dr. Alfred P. Maudslay in recognition of his work of archæological exploration in Central America, which laid the foundations of our knowledge of the art and culture of the early inhabitants of that region and provided the nucleus of the collections of Central American antiquities, small but in certain respects unrivalled, which are exhibited in our national museums. The Rivers Medal was founded in memory of the late Dr. W. H. R. Rivers, who was president of the Royal Anthropological Institute at the time of his death, and is awarded for specially meritorious anthropological work in the field.

THE new coal-treatment laboratory of the Mining Department of the University of Birmingham was opened on November 25 by Lord Chelmsford, chairman of the Central Committee of the Miners' Welfare Fund (which has contributed 9400*l*. to the cost). In this laboratory the whole subject of cleaning and grading of coal will be dealt with; but the main problem, the solution of which is to be sought, is the economic use of very small coal (of size ⅜ inch and less). The plant consists of screening devices, capable of dealing with twelve tons per hour, together with washing and pneumatic separating machines for separating the coal from shale and other dirt. There are also crushing and briquetting plants for producing pulverised fuel and briquettes. A furnace, in which pulverised fuel is used for raising steam, is fitted with means for studying the processes and products of combustion (serving in effect as a large-scale calorimeter for pulverised fuel). There is, in addition, a special laboratory for the testing and analysis of the coal. The establishment of this coal-treatment laboratory is an important step in the application of scientific methods to the reduction of waste in the utilisation of coal.

IT will be noted with regret that Prof. Garstang's resignation of the directorship of the Department of Antiquities at Jerusalem has been accepted by the High Commissioner. According to an announcement which appeared in the *Times* of November 29, the resignation will take effect in December. As head of the British School of Archæology in Palestine and director of the Department of Antiquities during the last seven years, Prof. Garstang has done a valuable work in placing archæological studies in Palestine on a satisfactory footing. He was largely responsible for the formation of the Department of which he was the first director; he drafted the model Antiquities Ordinance, and organised the national and local museums. Prof. Garstang will now return to the University of Liverpool, of which he is Rankine professor of archæology.

AT a meeting of the Newcomen Society held at the Science Museum on November 24, Mr. J. W. Hull was elected president in succession to Mr. Rhys Jenkins. The annual report was read, and showed a satisfactory increase in membership, the Society claiming more than sixty members in America, where considerable interest is being taken in engineering history. After the passing of the report, a paper was read on "High-Pressure Steam and the Work of the Perkins Family." Jacob Perkins, the founder of the well-known London firm, came from Massachusetts about a century ago. He made improvements in engraving machines for bank notes, etc., but is principally known as a pioneer in the use of steam at very high pressures and of compound engines, and as the original inventor of the Uniflow engine, a type which has become popular during recent years. His work was carried on by his son Angier March Perkins, and grandson Loftus Perkins, and it was the latter who, forty-five years ago, fitted the little yacht *Anthracite* with triple expansion engines supplied with steam at 350 lb. pressure, and drove her across the Atlantic.

THE twenty-fourth annual meeting of the Imperial Cancer Research Fund was held on November 23, the Duke of Bedford presiding. The yearly report showed a satisfactory financial position and gave an account of sound progress in the scientific work both in the laboratories at Queen Square, London, and at the farm at Mill Hill. The investigations in hand arise mostly either from the discovery of Yamagiwa and Ichikawa that cancer can be easily produced experimentally by tar, or from the analysis by Gye of the factors concerned in its propagation. Under the former heading Dr. Cramer has shown that the systemic disturbance accompanying the absorption of autolysed normal tissues favours a cancerous response to irritation. In the second field Dr. Begg has worked extensively with the Rous sarcoma and another foul tumour and has obtained results which are, on the whole, concordant with Gye's experiments. Dr. Findlay is engaged with the inoculable warts of man and the dog and the somewhat similar growths of fowl-pox and pigeon-pox. Taking the work all round, it is evident that the Fund continues to consolidate our knowledge of the nature of cancer, and that the admirable foundation of good work laid by Dr. E. F. Bashford is being carried on in the same tradition by Dr. J. A. Murray. One suspects that the relatively small size of the organisation has had a good deal to do with its success: it admits of a degree of co-operation which would be impossible in a larger establishment.

THE paper on rural electrification in Sweden read to the Institution of Electrical Engineers on November 18 was both interesting and instructive. The population of Sweden which earns its livelihood by industry is now at least three times greater than it was in 1920. One reason for this is the rapid development of technical engineering. Smiths and wood carvers, having experienced the benefits which accrue from electric power, have extended their small handicraft workshops into prosperous factories employing many workmen. The agricultural industry has failed to attract the best man power. This has had grave financial consequences. Cheap electrical power is now almost a necessity in the rural districts. An attempt was recently made to connect all the important hydro-electric stations in Sweden into a State-controlled system. Dr. Ekstrom stated that he is glad that this scheme never materialised. At present the northern area is being developed under a State scheme, whilst the southern portion of Sweden is in the hands of a private company. The large power stations are all planned for ultimate interconnexion by means of 220,000 volt mains. At present the southern company transmits from its power stations at 50,000 volts. This is stepped down to 20,000 volts for country lines and to 6000 volts for town supplies. By means of a 50,000 volt submarine cable across the Sound, the company also co-operates with Copenhagen in supplying electric power in Denmark. The importance of standardising the systems of wiring used on farms and the necessity of only using good insulating material were insisted on. Electric cooking is popular, and attempts are being made to standardise the sizes of the electric motors used in farming operations.

IT was appropriate that the first annual Malcolm Morris Memorial Lecture, which was delivered by Prof. H. J. Fleure in the hall of the Royal Society of Medicine on November 15, should have dealt with racial characters of the human skin and racial types in relation to disease, in view of the interest of that great physician in health problems connected with the skin. Prof. Fleure pointed out the importance of the investigation by both medical men and anthropologists of the diversities of human skin, and suggested that it might give clues to many other racial characters as well as to health problems. In dealing with his own thesis, Prof. Fleure sought to show in an ably developed argument that, while the fact that physiological efficiency is greatest under cool temperate conditions suggested that modern types of man originated in a zone with that type of climate, dispersions from this zone toward the southern desert fringe of Africa or the cold northern areas have brought about variations of skin character in pigmentation and growth of hair, and vascularity—specialisations affecting heat loss. The high metabolism and the fair skin of northern Europeans limit the possibilities of their adaptation to tropical climates. In the cold plateau of central Asia, man developed specialisations to meet the long period of severe dry cold. America received the bulk of its aboriginal population in drafts from north-east Asia. Consequently the American Indians have the modifications of the type of skin which were developed in central Asia. Bates noted that the Amazonians were ill adapted to the conditions of steamy heat in which they lived.

AT the fifth annual general meeting of the fellows of the National Institute of Agricultural Botany at Cambridge on November 25, the chairman of the Council, Mr. W. Hasler, presented the seventh annual report and accounts. Papers were read by Dr. E. S. Beaven and Mr. F. L. Engledow. Dr. Beaven, speaking on "Field Trials of Cereals," stated that operations have been extended to field trials of varieties already in cultivation. The merits of the many 'new' varieties of cereals cannot be adequately tested by individual growers. The difference in value between two races of the same cereal, taking both yield and quality into account, often amounts to more than 20 per cent. One per cent. only added to the value of the cereal crops of Great Britain is equal to more than half a million of money per annum, and the cost of field trials is a negligible fraction of this amount. It is comparatively easy to sort out the distinctly inferior varieties. A variety which gives both low yield and inferior quality compared with others at four widely separated stations in two successive years is set down as of less than average value; if nothing more than this resulted from the trials they would be justified. Mr. F. L. Engledow spoke on "The Problem of the Adaptation of Varieties." He said that a great advance would attend the elimination of the worst varieties and the concentration of the best in localities most suited to them. The Institute's trials now offer a means of identifying the worst and the best; progress is, however, only possible when the best varieties only are grown. Quality helps to determine monetary value per acre and constitutes a separate problem of adaptation. English wheats are used for bread, biscuits, poultry, pudding and cake flours, and prepared breakfast foods. The exact adaptation of the separate varieties to those several purposes needs more careful study.

DR. F. A. PICKWORTH has been appointed to succeed the late Sir Frederick Mott as honorary director of the Joint Board of Research for Mental Disease, Birmingham. Dr. Pickworth was laboratory director at the Hollymoor Mental Institution under Sir Frederick, and has also had experience in research in biochemistry.

MR. NEVILLE CHAMBERLAIN, Minister of Health, will preside at the re-opening on December 8 at 3.15 P.M. of the Wellcome Bureau of Scientific Research and the Museum of Medical Science at 25-28 Endsleigh Gardens, London, W.C.1. Sir Walter Fletcher, Secretary of the Medical Research Council, will deliver an address on "Research and Citizenship" after the opening ceremony has been performed, and the Bureau and Museum will then be open for inspection.

AT the annual general meeting of the Royal Geological Society of Cornwall at Penzance, held on November 25, the William Bolitho Gold Medal was presented to Dr. R. H. Rastall for his researches in the geology of ore deposits. The presentation was made by Mr. J. C. Williams, Lord-Lieutenant of Cornwall, who is president of the Society for the period 1926–28. Among the papers read at the meeting was one by Dr. Rastall on "The Zonary Structure of the Earth." The retiring president, Mr. F. J. Stephens, gave an address on the geotectonics of Cornwall.

THE Philadelphia meeting of the American Association for the Advancement of Science will be held on December 27–January 1. This will be the fifth occasion when the Association has met in Philadelphia. Meetings will be held in the University of Pennsylvania, and a general science exhibition is being arranged in the Weightman Hall, which is the gymnasium of the University. Reduced passenger rates will be available from all parts of the United States and from the eastern parts of Canada. The general chairman of the local committee for the meeting is Dr. C. E. M'Clung, Zoological Buildings, University of Pennsylvania, Philadelphia.

THE annual report of the Raffles Museum, Singapore, for 1925, by the director, C. Boden Kloss, reports satisfactory progress and an increased number of visitors. The accessions include a Malayan cow elephant, an example of the squirrel *Glyphotes simus* Thomas, hitherto known only from the type-specimen, and the rare flying squirrel *Petinomys vordermanni*. Eighteen papers on material in the Museum were published, and there is a list of 28 specialists co-operating in this work.

THE Ministry of Agriculture and Fisheries has published a leaflet (No. 149) on bacillary white diarrhœa of chicks. The disease, which is caused by a micro-organism *Bacillus pullorum*, is essentially one of artificial incubation and may cause considerable mortality within a few days of hatching. Full particulars are given respecting the disease and its prevention. The Ministry is prepared to undertake post-mortem examinations and agglutination tests for moderate fees if the carcase or a specimen of blood is sent to its laboratory, New Haw, Weybridge.

THE Survey of India has published its General Report and its Report on Map Publication and Office Work for 1924–25. A summary of the progress of topographical surveys shows that 44,317 square miles were surveyed during the year, leaving a balance of about one million square miles still to be done. About half of this balance will probably be surveyed on the half-inch or smaller scales. Of the modern topographical maps of India, about one-third each of the total number of one-inch and half-inch sheets are now published. Practically the whole of India, much of Burma, and most of Baluchistan, Afghanistan, and Persia are now completed on the scale of 1 to 1,000,000. In the International Map on the one million scale good progress is being made. The output of general and special maps for various purposes was considerable. The Map Publication Report contains index sheets for the various issues.

THE International Health Board of the Rockefeller Foundation has recently issued its annual report for 1925. Assistance was given to public health enterprises of various types in ninety-seven States and countries. It participated in infection and sanitation surveys, operations for the control of yellow fever, hookworm disease, and malaria, county and rural health work, the development of special divisions of public health services, and the establishment and maintenance of schools and institutions of hygiene and public health. It also provided 197 fellowships for training in public health, and contributed funds to the Health Section of the League of Nations. The report contains illustrated articles on the campaigns against hookworm disease, malaria, and yellow fever, and on other subjects. The expenditure for the year amounted to about 630,000*l*.

WE have received from Messrs. Ogilvy and Co. (20 Mortimer Street, W.1) the second edition of their catalogue of microscopical illuminating apparatus. Many types of lamps are listed, ranging from a simple electric lamp with shade for ordinary laboratory routine work to an elaborate research model, and a quartz mercury vapour lamp illuminator on a new principle, not exhausted of air, both of which are expensive items. Several ingenious and new illuminators are included.

APPLICATIONS are invited for the following appointments, on or before the dates mentioned:—A senior chemist under the Northern Coke Research Committee at Armstrong College—Prof. H. V. A.

Briscoe, Armstrong College, Newcastle-upon-Tyne (December 6). A full-time secretary of the Institute of Physics—The President, Institute of Physics, c/o Royal Institution, Albemarle Street, W.1 (December 14). A junior assistant in the engineering department of the National Physical Laboratory—The Director, National Physical Laboratory, Teddington (December 15). A live-stock officer and 7 assistant inspectors under the Ministry of Agriculture and Fisheries—The Secretary, Ministry of Agriculture and Fisheries, 10 Whitehall Place, S.W.1 (December 20). A professor of pathology and a professor of bacteriology in the University of Cairo—Sir H. J. Waring, 37 Wimpole Street, W.1 (December 23). A physicist to the Dominion Laboratory, Wellington, New Zealand—The High Commissioner for New Zealand, 415 Strand, W.C.2 (December 24). An organiser of agricultural education for the county of Wilts—The Clerk of the County Council, County Offices, Trowbridge (December 28). A director of tubercular research in the University of Melbourne—The Agent-General for Victoria, Victoria House, Melbourne Place, Strand, W.C.2 (February 1). A senior lecturer in natural philosophy in the University of Melbourne—The Registrar, University of Melbourne, Melbourne, Victoria (February 14). A head of the electrical engineering department of the St. Helens Municipal Technical School—The Secretary for Education, Education Office, St. Helens. A lecturer in pharmacy and chemistry at the Portsmouth Municipal College—The Secretary, Offices for Higher Education, Municipal College, Portsmouth. An assistant dairy bacteriologist at the University of Bristol—The Registrar, The University, Bristol. An assistant instructor and lecturer in dairying at the British Dairy Institute, Reading—The Registrar, The University, Reading. A junior assistant chemist under the Directorate of Explosives Research of the Research Department, Woolwich—The Chief Superintendent, Research Department, Woolwich, S.E.18.

Our Astronomical Column.

COMETS.—The following ephemeris for 0^h of comet Comas Sola is from Mr. G. Merton's elements:

	R. A.	N. Decl.	log *r*.	log Δ.
Dec. 7	$2^h\ 28^m\ 41^s$	9° 32′	0·2931	0·0351
,, 11	2 26 36	10 4	0·2909	0·0411
,, 15	2 25 17	10 41	0·2886	0·0484
,, 19	2 24 36	11 20	0·2864	0·0564

The comet crosses the meridian at about 9 P.M. at a considerable altitude.

Mr. G. Neujmin gives the following ephemeris for 0^h of his comet in *B.Z.* No. 41:

	R.A.	Decl.	log *r*.	log Δ.
Dec. 7	$11^h\ 44{\cdot}8^m$	5° 40′ N.	0·159	0·078
,, 11	11 56·5	3 48		
,, 15	12 8·2	1 53 N.	0·141	0·056
,, 19	12 19·8	0 4 S.		
,, 23	12 31·4	2 3 S.	0·135	0·017

Prof. G. van Biesbroeck, assisted by Mr. O. Struve, has made a fine series of cometary observations at the Yerkes Observatory. Comets Orkisz, Borrelly, Faye, and van Biesbroeck were all observed for several months in 1926. The prolonged observation of Orkisz will settle the question of its deviation from a parabolic orbit (*Astr. Jour.*, No. 872).

SPIRAL NEBULÆ.—Dr. G. E. Hale contributes an interesting article to the September number of *Scribner's Magazine*, entitled "Beyond the Milky Way," in which the character of spiral nebulæ is discussed. The conflict between the distances of these objects suggested, on one hand by van Maanen's measurements of internal motion, and on the other by Hubble's observations of Cepheid variables, is described, but no final conclusion is drawn. The distances indicated are respectively of the order of 3000 to 30,000 light years and 1,000,000 light years. With regard to the possibility of systematic error in van Maanen's measurements, Dr. Hale says: "As van Maanen is unsurpassed in his skill in measurement, there can be no doubt of the existence of some form of displacement. It is difficult to conceive of systematic photographic or instrumental differences between the old and new plates which would always give an outward motion along the arms of a spiral, and the question remains whether the displacements can be accounted for by some other obscure source of error. As matters stand, van Maanen's conclusions as to the distance and dimensions of the spirals are radically different from those of Curtis and Hubble, and much work may be needed to clear up the discrepancy." In the concluding paragraphs of the article, reference is made to the suggestion of Millikan and Jeans that the recently discovered penetrating cosmic rays may originate in spiral nebulæ.

SOLAR RADIATION AND WEATHER FORECASTING.—An article bearing this title is contributed by C. F. Marvin and H. H. Kimball, of the U.S. Weather Bureau, in the September number of the *Journal of the Franklin Institute*. Methods of observing the solar constant are first given, and the various forms of pyrheliometers are described, including the pyranometer, an instrument developed by the Smithsonian Institution in 1920, which, in combination with the bolometer, has proved most successful. The observed values of the solar constant are then discussed, especially from the point of view of the probable errors of observation. Two graphs are given to show that the probable variation of the determinations has decreased from ±1·3 per cent. (earliest efforts ±3·0 per cent.) to ±0·5 per cent. after the introduction of the pyranometer. From the nature of the scatter of Calama observations, it is concluded that it is impossible to determine whether solar variability, atmospheric variability, or errors of observing are the predominating cause, in fact that "such solar variability as exists is submerged in the errors of determination." As regards forecasting, the important question is whether an apparent fluctuation in the sun's total thermal energy of less than 0·5 per cent. can constitute a scientific basis for short- or long-range weather forecasting. The authors give their reasons for believing that the weight assignable to solar variability as a factor in the making of the weather is almost vanishingly small. H. H. Clayton's forecasts made with the help of solar constant values do not, they claim, show a marked increase in prevision in the forecasting of temperatures for New York, as compared with those made at the Weather Bureau from a superficial examination of weather maps alone. While at variance with the conclusions drawn by Dr. Abbot from the Smithsonian observations, the authors comment upon the great importance of his contributions to the subject of solar radiation and atmospheric absorption.

It may be recalled that a recent paper of Dr. Abbot's, dealing with the observations of the solar constant and their correlation with sunspot data, appeared in the *Monthly Weather Review* for May 1926 (see also NATURE, August 21, p. 280).

Research Items.

THE GHOST DANCE RELIGION AMONG THE POMO OF CALIFORNIA.—In the course of a study entitled "Pomo Folkways," by Edwin M. Loeb, which is published as vol. 19, No. 2, of the *University of California Publications in American Archæology and Ethnology*, reference is made to the effect of the introduction of the modern ghost dance among the Pomo on their own religious esoteric cult and ghost dance. The Pomo are a typical central Californian Indian people, sedentary, living in small villages in a coastal and an inland group, among whom the arts, excepting basketry, were slightly developed. They depended on the chase and fruits and roots for food. It may be noted in passing as an interesting fact that the greater part of the information concerning them has been obtained from a Pomo who had devoted himself to ethnographical studies and made a living by passing on the information thus obtained. The native Pomo ghost dance had as its essentials the use of the bull-roarer, the impersonation of ghosts and clowns, the use of semi-masks, the "death and resurrection" initiation, and mutilation by cutting. The modern ghost dance religion arose among the northern Pai Ute of Nevada about 1870, travelled west and entered California from the north. It reached the Pomo from the Patwin in 1872, when it extinguished the Pomo ghost dance and Kuksu religion, though both supplied material for the new cult. The desire for the return of the dead which underlay Pomo culture now became an essential of the new cult. The new religion supplied a "big head" dance and a pole ceremony. The old secret society also died away. The priests of the new cult, instead of acquiring office by inheritance or long instruction, as in the old, were summoned by some unknown person or some one recently deceased, who appeared to them in a dream and instructed them in the ceremonial. All the ceremonial was supposed to have been received in this way instead of having been installed in the beginning of the world, as was held in the old ghost dance ceremony.

THE AURIGNACIAN HUMAN FIGURE FROM THE CAVERNE DAVID, CABRARET.—An interesting example of the application of technical knowledge to the interpretation of a palæolithic engraving is furnished by a criticism of M. H. Breuil's description of the male human figure of Aurignacian Age found in the Caverne David at Cabraret (Lot) which is contributed by Prof. R. Anthony of Paris to the *Bull. Société d'Anthropologie de Paris*, 7^{e} Sér. T. 5, Fasc. 1-3. The figure in question lies on its back and, as described by M. Breuil, apart from certain adjuncts which need not be mentioned, the chief characteristics are the indefinite character of the head, the extraordinary outline of chest and abdomen, which are abnormally expanded, although in the case of the latter a second outline is shown which is nearly flat and terminates in the genitalia, and a sharply defined slender waist-line between chest and abdomen. Three women are shown near as if approaching the body. M. Boule interprets the drawing either as a representation of a man who has been killed, and the women approaching as mourners, or an initiation scene. Prof. Anthony, regarding the engraving from the point of view of a medical man, offers a different interpretation. The most important element is the phallus, but so far from being the representation of the complete genitalia, the drawing represents three successive morphological states. Viewed in the light of this conclusion, it is suggested that the drawing is a representation of a coitus in which the abnormal curves are feminine. The peculiar and apparently ill-drawn lines of the man's haunch and leg are due to muscular contraction natural in such conditions. If Prof. Anthony's interpretation be correct, it is an addition to a type not without importance for the interpretation of representation of the human figure in palæolithic art, and serves further to emphasise the artist's accurate representation of detail in the attention given to the muscular curves.

SCOTTISH MARINE BIOLOGY.—The annual report for the Scottish Marine Biological Association gives a short account of its activities for the year 1925–26. It opens with a note of regret on the death of Prof. J. F. Gemmill, and we welcome the suggestion that some useful form of memorial should be raised to facilitate the carrying out of research in the laboratory to which he was so attached. The lines of research followed by the Association during 1925–26 are noteworthy for the co-operation between the two permanent workers, Mr. A. P. Orr, who has worked on the seasonal chemical and physical changes of the water in the Clyde sea area, and Miss S. Marshall, who has studied the seasonal variations in the phytoplankton in the same region. The changes in the amounts of phosphate in solution in the sea-water of Loch Striven, which has been visited at weekly and fortnightly intervals this year, show striking correlations with the seasonal fluctuations in the abundance of phytoplankton in the different water layers. Their work has, in fact, produced a confirmation of the generalised theories put forward by Atkins as a result of his researches at Plymouth, direct correlative evidence of phytoplankton changes not having been obtained in that locality. The Millport Station has accommodated seventeen research workers from other parts of Great Britain in the period under review, as a result of which two important papers by Mr. G. S. Carter on "The Control of the Velar Cilia of the Nudibranch Veliger" and by Mr. J. Gray on the mechanism of cell division, have already been published. Mr. R. Macdonald has worked for a year at the laboratory on the life-history of *Meganyctiphanes norvegica*, an important constituent of the food of many fish. The superintendent, Mr. R. Elmhirst, is to be congratulated on a successful year.

ORGANIC MATTER IN LAKE WATER.—For a number of years investigations have been prosecuted by Prof. Birge and several co-workers concerning both the organic life and the physical and chemical conditions in American Lakes. Among the most interesting studies have been the various reports dealing with annual variations in the amount of organic matter, including that organised into plants and animals or existing as organic debris, and the substances in solution. Observations concerning the latter are dealt with in the latest report on these investigations ("The Organic Matter in Lake Water." By E. A. Birge and C. Juday. *Proc. U. S. Nat. Acad. Sci.*, vol. 12, pp. 515–519, August 1926). The water of Lake Mendota contains a standing crop of nearly 15 milligrams per litre of organic matter in solution, an amount considerably in excess of that found in the plankton and higher aquatic plants. Besides carbohydrates and fats, it consists of nitrogenous compounds which yield the amino acids indispensable in food, such as tryptophane, cystine, tyrosine, histidene, and arginine. The dissolved organic matter of lake water, if it is to be judged by amount and chemical composition, constitutes a potential food supply for aquatic animal life several times as large as that offered by the plankton. Whether such food substances in solution can be utilised directly by aquatic animals is controversial and awaits further investigation. Indirectly, it doubtless nourishes bacteria which are the food of protozoa, and these, in turn, nourish higher animals.

BRITISH BARK-BEETLES.—*Forestry Commission Bulletin* No. 8 deals with British bark-beetles, which form a group of insects closely associated with forestry practice. It is the outcome of several years' work and first-hand study of these insects by Dr. J. W. Munro, the author of this bulletin. Much that is known concerning bark-beetles is to be found in German periodicals and text-books and for this reason is not readily accessible to those concerned with forestry problems in Great Britain Dr. Munro has made copious use of this information and, by adding personal observations of his own, has produced an illustrated brochure of great value to foresters and also to the general entomologist. In addition to providing an account of the chief facts of the biology of bark-beetles, he also gives useful keys to their identification and accounts of each individual species. In Britain, all the bark-beetles prefer suppressed, less vigorous, and felled trees to healthy trees for breeding. The majority of such insects are secondary enemies the attacks of which are associated with adverse influences. The inter-relations between the bark-beetles and influences inimical to the proper growth of trees is the prime feature of bark-beetle economy. In modern forestry practice the most important factors contributing to the increase of bark-beetles are the systems of pure, that is, unmixed, forest planting and of clear-felling. In forests composed of several species of conifers, or of conifers and broad-leaved trees intermixed, such beetle outbreaks seldom become severe. Under the shelter-wood systems the danger of increase of these beetles is rare, but in clear-felling of pure woods in large areas, bark-beetle attacks supervene unless adequate precautions are taken.

SEX-LINKED INHERITANCE IN FOWLS.—The fact of sex-linked inheritance in poultry is being put to practical use in the determination of the sex of young chicks. A recent bulletin by Prof. Punnett (Miscellaneous Publications, No. 55, Ministry of Agriculture and Fisheries) explains the method in simple language. Three pairs of easily distinguishable sex-linked characters may be used: (1) silver or gold ground colour of plumage; (2) barred or unbarred plumage; (3) light or dark yellow shank colour. A hen, for example, of any silver breed, such as Light Sussex, transmits silver (which is dominant) to her sons and gold to her daughters, whereas a silver cock transmits silver to all his offspring. Hence in a cross between a Light Sussex hen and a Red Sussex cock the sex of the chicks can be determined by the down colour at the time of hatching. The same applies to all crosses between a hen of silver breed such as Silver Campines, Wyandottes, and Hamburghs as well as Dorkings and Salmon Faverolles and a cock of any gold breed such as Brown Leghorn, Indian Game, Buff Orpington, etc. But when a breed, *e.g.* Campines, with heavy dark markings is used, the down colour of the chicks is more difficult to distinguish. Similarly when a Plymouth Rock hen is mated with a Minorca cock, the male chicks will be barred and the females black. When a White Leghorn hen is mated with a dark-shanked breed the cockerels have light shanks and the pullets dark, but this distinction is not always clear in other crosses.

FACTORS OF THE SEX CHROMOSOMES IN FOWLS.—A recent paper by Serebrovsky and Wassina (*Journ. of Genetics*, vol. 17, No. 2) carries further the knowledge of sex-linked characters in fowls. Crossing-over between sex-linked factors has been observed in various cases, and the various percentages of cross-overs between the different pairs of sex-linked factors are used to construct a chromosome map of the sex chromosomes. In addition to the three pairs of factors mentioned in the note above on sex-linked inheritance in fowls, a fourth has been studied which inhibits the rate of feathering in chicks, and a fifth—spangling—is receiving attention. It is suggested that the order of the genes in the sex chromosome is barring yellow legs, silver and late feathering, but the percentages of cross-overs are not all consistent with this conclusion, and other sex-linked characters are being sought to test these results.

EFFECT OF X-RAYS ON *VICIA FABA*.—H. Komuro, in *Jour. Coll. Agric. Imp. Univ. Tokyo*, vol. 8, No. 2, gives a historical résumé of earlier work with X-rays on plant growth, and details his own experiments on *Vicia faba*. He concludes that irradiation is harmful in all circumstances, the degree of injury being correlated with the water content of the seeds, checking of growth being caused by the dose of rays in inverse proportion to the water content. With high doses, development is not stopped immediately but germination occurs and the growth below ground reaches the same stage as with seeds of the same initial water content exposed to lower irradiation. It was noticeable that when the dose of X-rays exceeds a certain limit, varying with the water content of the seed at the time of irradiation, it does not induce a visible difference in the degree of injury proportional to the dose. No acceleration of germination was obtained by treating air-dried seeds with rays of $7H$-$15H$, and retardation occurred with increasing doses both with air-dried (14 per cent. water content) and steeped seeds (57 per cent. water content). Germination is not affected if the seed coat is removed, the plumule and radicle being equally influenced by the rays whether the seed coat is present or not. The sprouting of air-dried irradiated seeds is delayed more than that of steeped irradiated ones for the same doses, probably because the latter, with a large water content, are more stimulated than the former containing less water. No anatomical differences were observed in the mesophyll of leaves of plants with different treatments of rays, but there was less chlorophyll in the plant treated with high doses ($80H$ and $120H$), so that they appeared yellowish in comparison with the controls.

PLEISTOCENE AND TERTIARY MOLLUSCA OF JAPAN.—A few months ago we had the pleasure of recording the publication by Prof. Matajiro Yokoyama of six papers on the Tertiary mollusca of Japan (NATURE, Sept. 11, 1926, pp. 389-90). Six further papers by the same eminent palæontologist are now before us (*Jour. Coll. Sci. Univ. Tokyo*, vols. 44 and 45). These treat of the Pleistocene "Mollusca from the Coral-bed of Awa"; "On some [Upper Pliocene] fossil Shells from the Island of Saishū in the Strait of Tsusima"; "Tertiary [Pliocene] Mollusca from Dainichi in Tōtōmi"; and three papers on the "Molluscan remains [Pliocene and Miocene] from the . . . Jô-Ban Coal-field." Each paper is preceded by a brief but very clear introduction discussing the topography and geology of the area in question, with a list of the fossils, while the main part contains the descriptions of the species, very many of which are regarded as new, followed by plates of figures.

FLOW PAST A ROTATING CYLINDER.—The Flettner rotor ship has brought before the public one practical method of utilising the special properties of a rotating cylinder in a wind. The aerodynamic efficiency of the cylinder has been studied in various laboratories. In a short paper by Relf and Lavender (Aeronautical Research Committee: R. and M. 1009. London: H.M. Stationery Office, 9*d*. net) a visual study of the flow of water past a rotating cylinder is made. While the results are purely qualitative, the photographs bring out clearly the extent to which the circulation of the fluid increases with rotational speed of the cylinder. While the proximity of the water channel walls interfere with the free flow of the liquid, the photographs make it appear that at high rotational speeds an unsteady state of flow maintains.

SOFT X-RAYS.—Various improvements in the technique of the measurement of soft X-rays are described in a paper by K. T. Compton and C. H. Thomas (*Phys. Rev.*, October 1926). The soft X-rays generated were detected by their photoelectric action. A system of gauges was used to prevent ions from reaching the detecting plate, and the range of voltage applied to these gauges was carefully studied. The thermionic and photoelectric currents, I and E, were measured by balanced methods in which the full scales of the instruments were employed to determine the current increments resulting from small changes in the voltage applied to the tube. The latter changes were also measured by a similar balanced method. The experimental observations thus made were so precise that the critical potentials were determined from curves in which the second differences in the ratio E/I were plotted against the voltage. In this manner any discontinuities were rendered much more marked than in previous methods. The operation of the tube was tested by examining the critical potentials for an iron target which had been used in previous experiments. The new methods of plotting were used in the examination of the critical potentials of carbon and copper, 62 critical potentials being found for carbon in the range 0 to 160 volts, and 31 critical potentials for copper in the range from 65 to 280 volts, which had not been previously investigated for fine structure. The authors indicate the need for direct spectroscopic work on the spectra from solid targets in this low voltage region.

RATING INCANDESCENT LAMPS.—Much attention has recently been given to methods of photo-electric colour matching, as greater sensitivity and higher accuracy are obtained in this way than by the ordinary visual methods. In the November number of the *Journal of Scientific Instruments*, N. R. Campbell and C. G. Eden, of the G.E.C. Research Laboratories at Wembley, describe a machine based on a photo-electric method for determining the voltage at which incandescent lamps will burn with a prescribed efficiency. In practice it is rarely necessary to determine this voltage with the highest accuracy, but it is of great commercial importance to be able to determine it rapidly with a maximum inaccuracy of about 2 per cent. The speed is limited by three factors: the period required to make an estimate of the photo-electric balance, the period required to introduce the lamp into the photometer, and the period required for the lamp to take up a steady state. This last period depends on whether the lamp has been aged or not previous to the test. If the lamp is burnt for the first time it may be so long as 3 minutes. The electrometer used is a Lindemann quartz needle instrument made by the Cambridge Instrument Co., Ltd., which reads very quickly and has a very stable zero. The machine is calibrated by the use of standard lamps of which the rated voltage is known. It was found that the machine enabled lamps to be rated with a mean error in volts of about 0·1 per cent. at the rate of about 200 lamps per hour. If the machine were modified so as to make certain of the motions automatic, so that all the operator had to do was to insert and remove the lamps and watch the deflexions of the electrometer, nearly double the speed could be obtained.

DIRECT READING WAVE-LENGTH SPECTROMETERS.—Messrs. Bellingham and Stanley, Ltd., have recently added to their catalogue of spectroscopic apparatus a description of two instruments exhibiting novel features. A direct reading wave-length spectrometer is now available, mounted on a stand in such a way that it can be used in the horizontal or vertical position or tilted to any convenient angle. The prism is of the usual constant deviation form, and is rotated by a micrometer screw to which is attached a large divided drum-head on which the wave-lengths of the spectrum lines can be read. The second piece of apparatus is a visual wave-length spectrometer for ultra-violet light. The light enters by a slit, is sent by a quartz reflecting prism to a quartz mirror, and thence in a parallel beam to a reflecting quartz half-prism where the dispersion takes place. The issuing beam is then reflected by another quartz mirror to a fluorescent screen adjacent to a wave-length scale, where it is viewed by an eyepiece. The instrument is very compact, and a large screen is attached to shield the observer from the ultra-violet radiation. It is said to be of considerable use for the examination of the lamps used in actino-therapy. The Universal spectroscope constructed by this firm has recently been improved and the price considerably reduced.

IONISATION POTENTIAL AND THE PERIODIC SYSTEM.—The *Gazzetta Chimica Italiana* for August contains a paper by Rolla and Piccardi in which some relations between the ionisation potential of elements and their position in the Periodic System are discussed. It is shown that non-metals have high ionisation potentials, metals low ionisation potentials, and metalloids potentials of medium value. The ionisation potential is a periodic function of the atomic number; it is a function of the atomic structure in general and of the peripheral structure in particular, and is in quantitative relation to the chemical character of the element. A curve showing the periodic character of the ionisation potential is given, which resembles the well-known Lothar Meyer atomic volume curve.

ISOLATION OF ILLINIUM.—Since the appearance of a paper by Harris, Hopkins, and Yntema in the June issue of the *Journal of the American Chemical Society* on the isolation of illinium, a new element with atomic number 61, a preliminary note describing some independent research on this element has been published in the *Gazzetta Chimica Italiana* for July by L. Rolla and L. Fernandes. Starting in 1922, by June 1924 they had obtained strong evidence for its separation from a specimen of didymium earth from Brazilian monazite sand, but they refrained from publishing their results because of the small quantity of substance at their disposal. With a larger amount of material and using an improved method of fractionation, after about 3000 complete crystallisations they arrived at a residue rich in samarium possessing an absorption spectrum in which the peculiarities observed in 1924 were greatly accentuated. A thorough examination of the emission and absorption spectra of this fraction was in progress when the work of the American chemists appeared.

Anniversary Meeting of the Royal Society.

IN his presidential address to the Royal Society delivered on November 30, Sir Ernest Rutherford referred to the deaths of sixteen fellows and one foreign member of the Society, several of whom were distinguished workers in the field of general biology and pathology. Sir Ernest then remarked on the improvement in international scientific co-operation which is marked by the unanimous resolution passed at the recent Brussels meeting of the International Research Council inviting the Central European Powers to full membership of the Council. Another event of importance during the past year was the gift, by Mr. A. A. Campbell Swinton, of 1000*l.* for a fund for other than directly scientific purposes. The donor expressed the hope that others may be induced to subscribe to this fund so that the income may in time become sufficient for general purposes.

Continuing, Sir Ernest gave a brief account of recent striking advances in radio communication, and referred to the many avenues of research which are being opened up by the study of the propagation of electric waves over the earth (see p. 809).

Presentation of Medals.

THE COPLEY MEDAL, AWARDED TO SIR FREDERICK GOWLAND HOPKINS.

For twenty years Sir Frederick Hopkins has been a foremost leader in biochemistry, a branch of science that has grown rapidly in importance and influence during this period. The guide and director of a great Research Laboratory in Cambridge, he is everywhere recognised as one of the great pioneers of his science. In his active life he has made a series of fundamental discoveries, each of which has led to the opening up of new fields of work. The isolation and identification of tryptophane twenty-five years ago, at a time when but few of the amino-acids that enter into the composition of proteins were recognised, marked an epoch in the pure chemistry of these substances. The importance of this discovery was enhanced by Hopkins' later work on this substance, which led to a revolution in the physiology of proteins in nutrition, the end of which is not yet in sight. Some of the most fruitful work in recent physiology has been upon the nature of muscular contraction. The work of A. V. Hill and Meyerhof, of Embden, and many others, turns upon the fundamental earlier discoveries by which Hopkins, in collaboration with W. M. Fletcher, defined the conditions governing the appearance of lactic acid in muscle during activity, and its disappearance during recovery. One of the most important discoveries of this century is summed up in the word 'vitamins.' Fifteen years ago, Hopkins had carried out experiments which not only showed that appropriate mixtures of proteins, carbohydrates, fats and salts, might, for lack of traces of unknown substances, be inadequate for the nutrition of animals, but also at the same time established the general lines of the methods used ever since in the investigation of these substances, by important groups of biochemists in all parts of the world. The discovery of the dipeptide glutathione, coming at a time when the nature of the processes underlying biochemical oxidations was the subject of significant work in many laboratories, has again brought Hopkins into the van as a leader in yet another part of the field of biochemistry and given the signal for intense renewed activity there. Hopkins' work throughout has shown a genius for discovery. It has inspired a very large part of the best work in biochemistry in this century.

THE RUMFORD MEDAL, AWARDED TO SIR ARTHUR SCHUSTER.

Sir Arthur Schuster began his work on optics in the early days of spectrum analysis, and, indeed, was the first to employ in 1881 the word 'spectroscopy' to designate this branch of science. He has made numerous original contributions to optics in many directions. We may refer particularly to his work in the group velocity of waves and the pulse theory of white light. The breadth and penetration of his knowledge is clearly shown in his book on "Optics," a standard work which has served as a guide for generations of students. Schuster has made valuable contributions to many branches of experimental and mathematical physics. When professor in the University of Manchester, he made with Gannon a well-known determination of Joule's equivalent, and did valuable work in that connexion by calibrating the thermometer originally used by Joule in his fundamental experiments. He was a pioneer in the study of the discharge of electricity through gases, and has taken a deep interest in the problems of geophysics, particularly in connexion with the magnetism of the earth and the state of the upper atmosphere, and is responsible for valuable additions to knowledge in these fields. Besides this original work, Schuster has always shown an active and keen interest in the progress and organisation of science. He was a member of the General Board of the National Physical Laboratory from its inauguration and for six years acted as chairman of its Executive Committee. He was Secretary of the Royal Society 1912–19 in the difficult War period, and Foreign Secretary 1920–24. He took an active part in the formation of the International Research Council, and since its inception has acted as its secretary.

A ROYAL MEDAL, AWARDED TO SIR WILLIAM BATE HARDY.

The scientific investigations of Sir William Hardy in physical chemistry and physics are of outstanding importance in many different fields of work, and are characterised by the highest degree of originality. In colloid chemistry his name is known for the fundamental and pioneer work which he has accomplished in that field. The stability of colloid sols in relation to the electric charge, the theory of flocculation, the nature and importance of the iso-electric point, the theory of protein ampholytes, and the electric charges of the positive and negative colloid ions, represent some of the important discoveries with which his name will be for ever associated. The modern theory of protein solutions, which is of such great importance in biochemistry and physiology, is very largely due to his pioneer work in that field. Sir William Hardy has also been a pioneer in the elucidation of the nature of surface forces and surface films and the orientation of molecules at surfaces. This work has been of the highest importance for the development of a new and extremely important branch of physico-chemical science. As a natural outcome of this work, Sir William Hardy has turned his attention in recent years to the friction between surfaces and the nature of lubrication, and in a series of important investigations has thrown a flood of light on a subject which had long been neglected by both physicists and chemists. For the first time in the history of science the dependence of friction and lubrication on the structure and molecular orientation of surface films and the force-fields of molecules in relation to their structure and polarity have been elucidated in a series of beautiful and highly important researches.

A ROYAL MEDAL, AWARDED TO PROF. ARCHIBALD VIVIAN HILL.

Prof. A. V. Hill has made important contributions to knowledge of muscle and nerve. As to the former, his inquiries, begun some sixteen years since, were taken up at a time when, owing to the emergence of new facts, views of general acceptance stood in essential need of re-examination. In the past seven years Hill has accomplished this with a success beyond expectation. He has related to the mechanical the thermal aspects of muscular activity with a precision hitherto unattained, and obtained data as valuable for the chemical as they are fundamental for the physical study of the problem. The technique developed by him enabled for the first time the discrimination, in the heat production of muscle, of successive quantities and rates characterising successive stages of that activity, in spite of the closely consecutive and in part evanescent character of those phases. 'Initial heat,' uninfluenced by oxygen, the immediate accompaniment of the mechanical changes in the muscle, was thus distinguished from a 'delayed heat' associated with functional recovery of the muscle; and in this latter there were recognised two portions which evaluate the relative shares of aerobic and anaerobic disappearance of lactic acid in the processes of restoration of the muscle. In association with this recovery process the molecular ratio between removed and oxidised lactic acid has thus been estimated. Besides furnishing this essential analysis of the functional reactions of isolated muscle, Hill has prosecuted notable inquiries into the factors conditioning the performance and maintenance of muscular effort in the human body, measured its chemical cost, and traced to their causes certain of the limits set to the speed and endurance of the athlete. Further, he has succeeded not only in detecting but also in measuring heat-production accompanying the conductive activity of nerve. The scale of energy-change involved in this has required the devising of a refined technique; here again he with his pupils has obtained and measured the heat not only in block but also in its separate phases of production. Whenever the intimate mechanism of the activity of muscle and nerve may finally be elucidated, it is certain that the contributions of Professor Hill will remain fundamental for the explanation of the mechanism of them both.

THE DAVY MEDAL, AWARDED TO SIR JAMES WALKER.

The investigations of Sir James Walker in the field of physical chemistry have been of great importance in the advance of that science. His work on the electro-synthesis of organic compounds, carried out originally in conjunction with the late Prof. Crum Brown and continued up to the present time, has thrown much light on the phenomena of electrolysis and has led to the synthesis of a large number of new and interesting substances. One of the pioneer investigators of ionic equilibria, he has developed the theory of Arrhenius in many directions. His discovery of the nature and equilibria of amphoteric electrolytes constitutes a fundamental advance which has been of the greatest fruitfulness not only for the general theory of electrolytic solutions, but also for the development of the chemistry of the proteins. The work of Sir James Walker on the theory of amphoteric electrolytes represents one of the greatest advances in the elucidation of the nature of solutions. His investigations on the adsorption of dissolved substances by solids—for example, the adsorption of picric acid by silk fibres—were of cardinal importance in the recognition of the true nature of a class of phenomena the occurrence of which has been established in many branches of science. In the theory of reaction-velocity and chemical reactivity, and in many other parts of physical chemistry, the work of Sir James Walker is of high value and importance.

THE DARWIN MEDAL, AWARDED TO DR. DUKINFIELD HENRY SCOTT.

At a moment when there seemed some danger that the brilliant advances in palæophytology made by Prof. Williamson might slacken owing to advancing years, Dr. Scott entered upon a fruitful co-operation with the veteran. Several joint memoirs were the result of this happy coalition; but later Scott established a quite independent position of his own. Among the numerous memoirs published by him during the last forty years, none stands out more prominently as a model of presentation of complex structure than that on Cheirostrobus, a new type from the Calciferous Sandstone. Not only was its elaborate structure fully described, but also the comparative treatment showed a master hand. This quality came out with even greater effect in the study of the new class of the Pteridosperms, or primitive seed-plants with fern-like habit. The extensive knowledge of these early land-plants which we now possess has been mainly based upon the work of Scott, Oliver and Kidston. Such work, of which these examples do nothing more than suggest the nature and the scope, has been gathered up by Scott into his "Studies in Fossil Botany," now in its third edition. It deals primarily with early vascular plants, placing them in natural relation to their living correlatives, and giving a picture of early land-vegetation that has never been surpassed in clarity of presentment, combined with accuracy of detail and of reference. It supplies not only a great mass of fact that is positive and new; but it also subjects those facts to a detailed criticism and a philosophical treatment such as Darwin himself would have been among the first to appreciate.

THE HUGHES MEDAL, AWARDED TO ADMIRAL OF THE FLEET SIR HENRY BRAWARDINE JACKSON.

Sir Henry Jackson's experiments date from 1899, and in the following year apparatus of his design was fitted to certain of H.M. ships, and some of the problems connected with the screening effects of high land were investigated by him. At a later date he was responsible for the erection of one of the earliest continuous wave stations, in which an arc of 100 kilowatts was used. In 1915, at his suggestion, work on directional wireless was begun at the National Physical Laboratory. As chairman of the Radio Research Board, his wise guidance and his enthusiasm for his subject have in no small measure contributed to the success of the important investigations on the fundamental problems of radio transmission carried out under the auspices of that Board.

The Copley Medal.

In connexion with Sir W. B. Hardy's discourse at the Royal Institution on lubricating films of oil, and of other forms of matter in thin films (NATURE, November 13, p. 700), the following extracts from a letter written by Benjamin Franklin contain many points of interest. It may be recalled that Franklin was a Copley medallist, and that Sir W. B. Hardy is this year a Royal medallist whose work has dealt with the theory of lubrication. The Copley medallist for 1926 is Sir Frederick Gowland Hopkins.

Writing to Pringle from Philadelphia, on December 1, 1762, Franklin says:

"During our passage to Madeira, the weather being warm, and the cabin windows constantly open for the benefit of the air, the candles at night flared and ran very much. At Madeira we got oil to burn, and with a common glass tumbler or beaker, slung in wire and suspended to the ceiling of the cabin and a little wire hoop for the wick, furnished with corks to float on the oil, I made an Italian lamp, that gave us very good light all over the table. The glass at bottom contained water to about one-third of its height. Another third was taken up with oil; the rest was left empty, that the sides of the glass might protect the flame from the wind. There is nothing remarkable in all this, but what follows is particular. At supper, looking on the lamp, I remarked that though the surface of the oil was perfectly tranquil, and duly preserved its position and distance with regard to the brim of the glass, the water under the oil was in great commotion, rising and falling in irregular waves, which continued during the whole evening. The lamp was kept burning as a watch-light all night, till the oil was spent and the water only remained. In the morning I observed that though the motion of the ship continued the same, the water was now quiet, and its surface as tranquil as that of the oil had been the evening before. At night again, when oil was put upon it, the water resumed its irregular motions, rising in high waves almost to the surface of the oil, but without disturbing the smooth level of that surface. And this was reported every day during the voyage.

"Since my arrival in America, I have repeated the experiment frequently thus: I have put a pack-thread round a tumbler, with strings of the same from each side, meeting above it in a knot at about a foot distance from the top of the tumbler. Then putting in as much water as would fill about one-third part of the tumbler, I lifted it up by the knot, and swung it to and fro in the air; when the water appeared to keep its place in the tumbler as steadily as if it had been ice. But pouring in upon the water about as much oil, and then again swinging it in the air as before, the tranquility before possessed by the water was transferred to the surface of the oil, and the water under it was agitated with the same commotions as at sea.

"I have shown this experiment to a number of ingenious persons. . . . And I think it is worth considering: for a new appearance, if it cannot be explained by our old principles, may afford us new ones, of use perhaps in explaining some other obscure parts of natural knowledge."

In 1753 the Royal Society awarded Franklin the Copley medal. This was the first time the award was made by the president and council of the Society, previous awards having been by nomination of trustees under the will of Sir Godfrey Copley. To mark the significance of the gift, the *Gentleman's Magazine* published a special plate of the medal (Fig. 1), and it is interesting to recall the comments of that old-time chronicle of social and general events. The account states that at the anniversary meeting of the Society, held on November 30, 1753, the annual benefaction of Sir Godfrey Copley, Bart. (the gift of which on the death of Sir Hans Sloane devolved upon the president and council), was adjudged to Benjamin Franklin, Esq., of Philadelphia, for his useful discoveries in electricity, and delivered to be transmitted to him by the care of P. Collinson, Esq., fellow of the said society. "On this occasion," we read, "the Earl of Macclesfield, their president, delivered a speech, which greatly enhances the value of the prize, and does honour to the judgment, candour, and strict impartiality of the Society. It gave assurance that in conferring this prize constant regard would be had to the advancement of useful knowledge; it declared that, overlooking their own circle, they would always, with the spirit of true philosophers, esteem ingenious men of all countries, and that they would accordingly distinguish the most deserving." The writer, in conclusion, remarks that the successful experiments of Franklin have given hopes of our being one day able to secure ourselves against the effects of lightning.

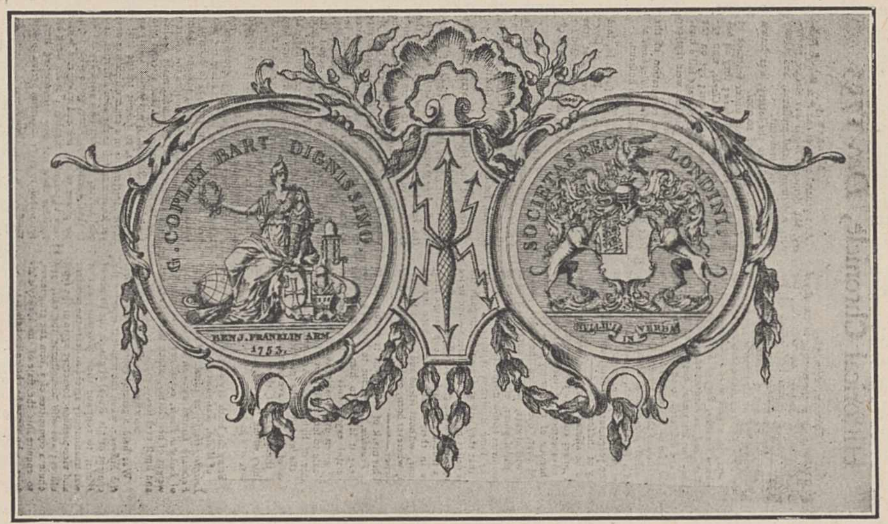

FIG. 1.—Copley Medal of the Royal Society, awarded to Benjamin Franklin in 1753. From the *Gentleman's Magazine*.

Folk Dances as a Survival of Primitive Ritual.

AT a joint meeting of the Royal Anthropological Institute, the English Folk Dance Society, and the Folk Lore Society, held on Tuesday, November 23, in the Parry Theatre of the Royal College of Music, Miss Violet Alford read a paper on "The Ritual Dance," which was illustrated by a number of English and other folk dances performed by members of the English Folk Dance Society. As the author dealt with the anthropological side of the dances, the illustrations were classified according to the function in primitive ritual which they were intended to fulfil, so far as this could be deduced from the character of the form in which they have survived.

The dances were therefore divided into three divisions. First, magical dances to procure food or, sometimes, the power of the animal hunted. Such a dance is "The Abbots Bromley Horn Dance," which is the only example of its kind in England and, it is believed, in Europe. This is a dance of an extremely primitive character, in which the men are dressed as deer and wear long branching antlers on their heads. The horns are kept in the church. The men, bearing these immense antlers, visit the whole parish. This is probably done as an imitative dance to ensure a supply of venison, and the dance may be compared with the well-known "Hobby Horses" and "Danse de l'Ours." A second example, the "Bean Setting" dance, is a morris dance from Headington, Oxon, which shows magical qualities, though not so ancient in spirit as the "Horn Dance." It imitates the planting of beans, beginning with a sun circle.

In the second class were dances belonging to spring festivals, processionals and maypole dances—the Whitsun morris. Such were the "Castleton Garland Procession," in which the leaf-clad king is the spirit of vegetation in person, and his spring bride and the morris dancers carry oak boughs; and "Sellenger's Round" and "Gathering Peascods," two maypole dances which date from long before plaiting ribbons was heard of, and show evidence of touching the pole to obtain power or 'luck' from it. "The Rose" is a morris dance always danced round the maypole at Leafield, Gloucester, and "The Sherborne Jig," a solo morris dance showing an elaborate kneeling posture. The "Newcastle," which was also shown, is a round country dance and shows the development of simple rounds into a beautiful and elaborate country dance. "The Whitsun Morris" is the most highly developed type of ritual dance in England. The morris men must leap for increase like the Kouretes of ancient Crete. They appear at Whitsuntide to fetch in the spring. They have a long and interesting history and were patronised by the Church. The parish even provided the morris bells and dresses. Each dance contains sun circles and heys—a representation of the form of the sacred serpent. A group of country dances was interpolated here showing the development into ballroom dances. This is the type of dance spoken of when it was said "none but country dances were done at Court." Examples of these were "Mr. Beveridge's Maggot," meaning 'notion'; "Picking up Sticks," containing a remarkable hey; and "None-such," probably named from Nonesuch House.

In the third division were dances to illustrate a later confusion of ideas of sacrifice founded on the primitive rite of killing the year god. This yearly death is seen in mummers' plays, sword dances, and occasionally in the allied morris. The ritual is known from Bulgaria to south-west Spain. "The Eynsham Morris" shows the raising of the captain as Visigothic chiefs were raised on shields. A similar dance from Spain was shown in the "Finale of the Viscaya Sword Dance" danced to its own tune, showing the raising of the captain in a lying position like a dead man. The "Askham Richard Long Sword Dance" showed the killing of the captain, and the "Winlaton Rapper Dance" gives the 'calling on song,' the ritual of the 'captain's sword,' and the display of the 'lock of swords' as a symbol of the death.

University and Educational Intelligence.

CAMBRIDGE.—G. Bateson, St. John's College, has been appointed to the Anthony Wilkin studentship in anthropology.

THE Educational Settlement Association publishes in the October number of its magazine, *The Common Room*, its annual report for 1925-26. Prominence is given both in the report and in several of the magazine articles to the place of science in adult education. Science is stated to have figured in the programmes of seven of the thirteen educational settlements affiliated to the Association, the object being, in four cases, "to gain some insight into the meaning of scientific method and the change in other realms of thought which the study of science is bringing about"; in the other cases "to obtain some first-hand knowledge of every-day phenomena." Keen interest in science was shown by the Aberdeen branch of the Workers Educational Association, which asked to be "instructed in the ways of life that are exhibited by plants and animals, the idea being that these might afford useful suggestions to thoughtful men." Some account is given of the Second International Conference of Social Settlements which was held in Paris on June 30-July 5, and was attended by representatives from England, the United States, Belgium, Germany, Scandinavia, Italy, Switzerland, India, and Japan. It culminated in the setting up of a committee to bring into being an International Association of Settlements, and to arrange for a third conference to take place in two years' time.

FROM the statement for the academic year 1925–26 recently issued by the Rhodes Trust, it appears that the number of Rhodes scholars in residence during that year was 188, of which 97 were from the British Empire and the remainder from the United States. Of the total, 42 were taking natural science and medicine, 3 mathematics, 3 education, 2 forestry or agriculture, and 4 miscellaneous subjects. The present year started with 183 Rhodes scholars and 10 ex-scholars in residence, and three more will come into residence in January. Examination successes include four D.Phil. degrees (three in natural science and one in medicine) and three B.Sc. degrees in natural science. Notices were received during the year of forty-five publications, including translations, by Rhodes scholars; these were mostly literary productions. As usual, many Rhodes scholars represented Oxford against Cambridge in sports. A Rhodes Memorial Lectureship, to be awarded to any person who has attained eminence in science, arts, business or public life, has been founded, and the first lecturer will be Sir Robert Borden, Prime Minister of Canada from 1911 until 1920. The first Rhodes Travelling Fellowships, to enable resident fellows and tutors to undertake study, especially in territories from which Rhodes scholars are derived, will be awarded in 1927. Particulars of the benefactions available under the Rhodes Trust can be obtained from the offices of the Trust, Seymour House, Waterloo Place, London, S.W.1.

Contemporary Birthdays.

December 4, 1875. Prof. George William O. Howe.
December 6, 1858. Prof. Hans Schinz.
December 7, 1865. Sir John Otto Beit, Bart., K.C.M.G., F.R.S.
December 9, 1855. Mr. W. H. Dines, F.R.S.
December 9, 1855. Dr. F. A. Dixey, F.R.S.
December 10, 1855. Mr. H. N. Ridley, C.M.G., F.R.S.
December 11, 1860. Dr. Leonard Huxley.
December 11, 1863. Sir Frank Heath, K.C.B.

After an apprenticeship with Messrs. Siemens Bros., Woolwich, Prof. HOWE was appointed lecturer at the Technical College, Hull; he then became assistant professor of electrical engineering, Imperial College of Science and Technology, South Kensington, and afterwards chief assistant, Department of Electrical Standards and Measurements, National Physical Laboratory. In 1921 he was appointed James Watt professor of electrical engineering in the University of Glasgow.

Prof. SCHINZ, born in Zürich, was educated there at the Polytechnic, and at the University of Berlin. Professor of botany in the University of Zürich, and director of its famous botanical gardens and museum, he is a foreign member of the Linnean Society of London. Prof. Schinz has conducted valuable botanical surveys in South Africa; with M. Théophile Durand, he issued the "Conspectus Floræ Africæ."

Sir OTTO BEIT's name is associated with the foundation of the Beit Fellowships for Scientific Research tenable at the Imperial College of Science and Technology, and the Beit Memorial Fellowships for Medical Research. The former fund has recently received, through Sir Otto's munificence, a further capital sum of 15,000*l*., enabling the trustees to make awards for two years instead of one year as hitherto.

Mr. DINES, the distinguished meteorologist, was educated at Woodcote House School, Windlesham' graduating afterwards at Corpus Christi College, Cambridge. He is the author of many valuable papers in meteorological and aeronautical science.

Dr. DIXEY is a Londoner. Educated at Highgate, he graduated at Wadham College, Oxford; he is subwarden, bursar, and lecturer there. An authority on insect bionomics, and a past president of the Entomological Society, he is curator of the Hope Collections, Oxford.

Mr. H. N. RIDLEY, who was educated at Haileybury, graduated at Exeter College, Oxford. A member of the botanical staff, British Museum, he became Director of Gardens and Forests, Straits Settlements, retiring in 1911 after twenty-three years' service. Whilst in the tropics Mr. Ridley conducted numerous scientific expeditions. Last year he published the final volume of his "Flora of the Malay Peninsula."

Dr. LEONARD HUXLEY, eldest son of Thomas Henry Huxley, is the author of the well-known biography of his father, published in 1900; this was supplemented in 1918 by a biography of Sir J. D. Hooker, both works of classic interest.

Sir FRANK HEATH is a Londoner. Educated at Westminster, he graduated at the University of London, from University College. He was assistant registrar and librarian of the University from 1895 until 1901, and in 1916 became Secretary to the Department of Scientific and Industrial Research. He has recently completed a tour in Australia and New Zealand and has put forward valuable schemes, which have been adopted, for State aid in research in these countries.

Societies and Academies.

LONDON.

Geological Society, November 3.—Sydney S. **Buckman**: Jurassic chronology (iii.): Some faunal horizons in Cornbrash. Faunal dissimilarity within strata of a supposedly synchronous time-unit, the Cornbrash, were observed about seventy years ago, but were not understood. Series of faunal analyses of the brachiopod species south of the Humber disclose a series of synclines, anticlines, and various non-sequences in the strata of the South Humbrian Cornbrash. The divisions of Cornbrash time on the basis of brachiopods and of ammonoids are compared and also the Cornbrash and the inferior oolite. If the time-value of brachiopod species be the same in the Cornbrash as in the inferior oolite—and there is every reason that it should be—then the Cornbrash must have taken in deposition a time far in excess of that of the middle and upper inferior oolite, with all its numerous ammonoid hemeræ.

The Physical Society, November 12.—H. **Dewhurst**: A rapid bolometer made by sputtering on thin films. Thin films of collodion are made by drying weak solutions in ether and alcohol on the surface of clean mercury. Flexible films which withstand great distortion, and can be punctured without fracture, are made in the same way. Both types can be produced rapidly and cheaply down to a thickness of one wavelength of light. Two novel types of sputtering apparatus are described, and a table is given containing sputtering data for 25 metals, nine of which appear for the first time. The method of making the bolometers, together with holders of various types, and apparatus for blackening, are detailed. Rings were moulded for supporting the thin collodion films and providing a reliable contact for overlying sputtered metallic films. The comparative sensitivity of these new bolometers is discussed, and curves and an empirical formula given from which an estimate of the speed of the instruments can be determined. The new type of instrument is roughly 400 per cent. faster than a representative bolometer of the Lummer and Kurlbaum type.—Ezer **Griffiths** and J. H. **Awbery**: A hygrometer employing glycerine. The variation of refractive index of glycerine solutions in equilibrium with air of various humidities has been studied; the time for equilibrium to be reached, when thin films of glycerine are used, has been investigated, and this property may be used very conveniently in a hygrometer.—J. W. **Avery** and C. J. **Smithells**: The effect of working on the physical properties of tungsten. Measurements of the densities of specimens cleaned in successive stages by etching reveal the presence of low density surface layers. Variations of heat treatment likely to occur in practice have no appreciable effect upon the density of worked tungsten. The density rises rapidly during swaging to a maximum value within 0·5 per cent. of the density of the perfect tungsten crystal. Further working produces a steady fall in density, which becomes more marked in the finest sizes. The resistivity falls rapidly in the early stages of working and reaches a minimum when the density is a maximum. It then increases at a uniform rate, which is approximately an exponential function of the diameter.

Royal Meteorological Society, November 17.—E. W. **Bliss**: The Nile flood and world weather. Correlation coefficients are given with pressure, temperature, rain, ice and wind, and it is shown (*a*) that the Nile takes part in the southern oscillation as a member of the first group; (*b*) that equatorial temperatures are in inverse relation to the Nile; and (*c*) that the winter North Atlantic circulation varies inversely with the preceding Nile. St. Helena pressure has no contemporary relationship with the Nile. A formula is derived for prediction on June 1 with a joint coefficient of 0·72.—D. **Brunt**: (1) An investigation of periodicities in rainfall, pressure, and temperature at certain European stations. A discussion is given of twelve periodograms: those of rainfall at Milan, Padua, London, and Edinburgh; of pressure at Edinburgh, Stockholm, London, Paris, Berlin, and Vienna. Their use for forecasting future weather is not recommended. (2) A simple period of vertical oscillation in the atmosphere. When an element of air is displaced vertically, it oscillates harmonically about its equilibrium position, with a period of the same order as those found in microbarograph records.

EDINBURGH.

Royal Society, November 8.—A. P. **Laurie** and John **Milne**: The evaporation of water and salt solutions from surfaces of stone, brick, and mortar. Sulphate of lime sometimes crystallises out in bricks and stones, and in other cases it does not do so. Prof. Guye's work on the conditions of evaporation where capillary tubes open on surfaces over which water can creep, shows that the flow of liquid under these conditions is governed by the rate of thinning of the liquid layer by evaporation. Experiments made on the surface of a wall soaked by the rain and then drying out indicate that the surface which is evaporating more rapidly draws water from the more slowly evaporating surfaces. Thus if the brick or stone is evaporating more rapidly than the mortar, water will be drawn from the mortar containing salts in solution which will crystallise out and break up the stone or brick; if, however, the mortar is evaporating more rapidly than a stone or brick, water will be drawn from the stone or brick to the mortar, causing the concentration of salts to take place principally in the mortar instead of in the stone or brick. Hence in repointing old buildings, the decay of the brick or stone will be stimulated if the mortar is too dense. Mortar joints should be raked out; a suitable preservative should then be used so as to reduce the rate of evaporation from the stone or brick surface, and then repointed.—J. H. **Ashworth** and Janet C. W. **Bannerman**: A tetracotyle (*T. phoxini*) in the brain of the minnow. Specimens were collected near Edinburgh, near Loch Lubnaig, and in the Thames Valley. The parasite appears to be identical with *T. phoxini*, a species originally described in 1910 from minnows collected in Switzerland and in Germany, but has apparently not been recorded since. The tetracotyle are 0·33 mm. to 0·42 mm. long and very immature. The minnow is the second intermediate host of this trematode; the first intermediate host, and also the host in which it reaches maturity, have still to be ascertained. In heavily infected minnows about 250 or more tetracotyles were present, chiefly in the cavities of the optic lobes, in the Sylvian aqueduct, and in the fourth ventricle. The epithelial lining of these cavities has undergone extensive proliferation, and forms a vacuolated tissue in which most of the worms lie.—David **Waterston**: Development of the hypophysis cerebri in man, with a note upon its structure in the human adult. A series of specimens from embryos 3 mm. in length, and over, and from a Tarsius embryo, are discussed. Evidence is shown of the division of the anterior lobe into central and lateral portions, and of the absence of a distinctive pars intermedia in the adult human pituitary.—Ekendranath **Ghosh**: On the anatomy of the Mastacembelidæ of Bengal, with notes on their habits.—Sir Thomas **Muir**: The theory of persymmetric determinants from 1894 to 1919.—Satish Chandra **Chakrabarti**: A factorable continuant.

PARIS.

Academy of Sciences, November 3.—Emile **Picard**: Certain partial differential equations connected with problems of calorific equilibrium.—**Charcot** and P. **Idrac**: A phenomenon of atmospheric depression produced by a lofty obstacle in the wind. Entrance of the ship *Pourquoi Pas* into the shelter afforded by the high volcanic mountain Beerenberg on Jan Mayen Island (2300 metres), caused a sudden drop of the barometer of 1·8 mm. on one occasion and 2·5 mm. on another.—V. **Grignard** and P. **Murat**: Pyrosulphuryl chloride. With water in excess the reaction is given by the equation

$$S_2O_5Cl_2 + 3H_2O = 2H_2SO_4 + 2HCl.$$

With the chloride in excess, the primary reaction appears to be

$$S_2O_5Cl_2 + H_2O = 2HClO + 2SO_2,$$

followed by the reaction

$$SO_2 + 2HClO = H_2SO_4 + Cl_2.$$

From this reaction and from measurements of the magnetic susceptibility and molecular refraction, the constitution of sulphuryl chloride is considered to be best represented as

$$Cl.O.SO-O-SO.O.Cl.$$

—Léon **Guillet** and Albert **Roux**: The influence of gases on the properties of steels. Steels from which the gases have been extracted by heating in a vacuum at 750°-850° C., show changes in mechanical and chemical properties when compared with samples of the same steels heated to the same temperature in air.—A. **Recoura**: Acetylated chromium sulphate.—Paul **Alexandroff**: Cantorian multiplicities and the generalised theorem of Phragmên-Brouwer.—Paul **Mentré**: The reciprocity of two complexes with double inflectional foci.—I. **Raramata**: Relation between the distribution functions of two series dependent on each other.—G. **Valiron**: The theorems of Bloch, Landau, Montel, and Schottky.—S. **Stoïlow**: Remarks on some properties of continuous transformations of n variables.—A. **Kovanko**: The necessary and sufficient conditions for the capability of summation of some functions.—R. **Mazet**: Flow through a jet.—B. **Polland**: The limit of absorption of the K series of the element of atomic number 75.—R. **Forrer**: The structure of the atomic magnet and the mechanical effects of magnetisation.—Edmond **Vellinger**: The rotatory dispersion of tartaric acid. The author concludes that in aqueous solutions of tartaric acid there exist two fundamental forms. Of these, one is dextrorotatory corresponding to the molecular structure of the tartrate, the other lævorotatory corresponding to a structure as yet undetermined, that of the molecules in the crystals of tartaric acid.—Charles **Prévost**: The catalytic dehydration of the α-ethylenic alcohols.—Charles **Dufraisse** and Alfred **Gillet**: Stereochemical researches in the benzalacetophenone series. Ethylenic isomerism and polymorphism.—Georges **Darzens**: A new general method for the synthesis of the tetrahydronaphthalene and naphthalene hydrocarbons. Benzylallylacetic acid, treated with 78 per cent. sulphuric acid, undergoes internal condensation, giving tetrahydromethylnaphthalene carboxylic acid. The method is generalised by starting with homologues of benzylallylacetic acid.—Pierre **Bedos**: The stereochemical isomerism of the ortho-cyclohexanediols and on the structure of the oxide of cyclohexene.—R. Weil: The influence of impurities on the temperature of the paramorphic transformation of cristobalite.—L. Petitjean: The thermodynamics of the surfaces of atmospheric discontinuity.—Marcel Lefèvre: A variation of tabulation in certain fresh-water species of Peridinium.—Pierre Georgévitch: *Ceratostomella Querci*.—Raymond-Hamet: The action of ergotamine on the respiration.—Raoul Bayeux: The transmission of erythroclasia, produced by change of altitude, by the serum of animals which have lived in a rarefied atmosphere.

SYDNEY.

Linnean Society of New South Wales, September 29.—A. J. Turner: Revision of Australian Lepidoptera: Drepanidae, Limacodidae, Zygaenidae. Nine genera and twenty species are described as new. Keys are given for the identification of the genera in each of the three families, and for the species of many of the genera.—H. J. Carter: Revision of Athemistus and Microtragus (Cerambycidae) with notes, and descriptions of other Australian Coleoptera.—T. C. Roughley: An investigation of the cause of an oyster mortality on the George's River, New South Wales, 1924–5. During the winters of the past eight or nine years there have been mortalities of oysters of varying intensity on the shores of the George's River and other rivers on the southern half of New South Wales. Where the mortality was greatest large numbers of the oysters remaining alive were affected with abscesses and ulcerations, commonest on the palps, gills, and inner surfaces of the mantles, but also found in the stomach, liver, gonad, and adductor muscle. A fairly definite ratio of this affection to the severity of the mortality was found, and the appearance of microscopic sections suggests a bacterial origin. The theory is advanced that the low winter temperatures lower the vitality and therefore the resistance of the oysters and induce infection by bacteria in the water.

VIENNA.

Academy of Sciences, October 14.—A. Dadieu: The electromotive behaviour of aluminium. The potential was measured of aluminium and aluminium amalgam in molten aluminium bromide plus potassium bromide and in the solution aluminium bromide, ethyl bromide. The oxide skin theory is preferred.—A. Rollett: β-amyrin from elemi resin from Manila.—A. Rollett and L. Bayer: The constitution of furoperylen.—O. Dischendorfer and H. Grillmayer: Betulin.—K. Przibram: An artificial blue colouration of rock salt at room temperature. Kahlbaum's pure sodium chloride or rock salt from Wieliczka was crushed to powder and then exposed to weak daylight for some days. Reference is made to former experiments with radium radiation.—K. Singer: Physiological and pathological chemistry of the brain (I.). The nitrogen and sugar apportionment in the brain of the horse. Total amino nitrogen was determined, also cholin nitrogen, galactosid nitrogen and residual nitrogen.—N. Alders, H. Chiari, and D. Laszlo: The glycolytic power of cell-free extracts from tumours and other tissues.—R. Weiss and K. Woidich: The condensation of ethoxymethylene-β-ketoneacidester with resacetophenone and its relation to xanthophanic acid.—J. Pollak and E. Gebauer-Fülnegg: The action of chlorosulphonic acid on phenols.—M. Holly: (1) New fish forms from the Sanaga River, Cameroons.—(2) Two new silurids and a new characinid from the Cameroons.—L. Lämmermayr: New contributions to serpentine flora with special relation to Styria.

Official Publications Received.

BRITISH AND COLONIAL.

London County Council. Annual Report of the Council, 1925. Vol. 4: Education. Elementary Education; Children's Care; Special Schools, Industrial and Reformatory Schools and Places of Detention; Accommodation and Attendance in Elementary Schools, and Employment of Children; Higher Education; Technical, Trade and Evening Education, Day Continuation Schools, and Juvenile Employment Centres; General. (No. 2471.) (Published by the London County Council.) Pp. 40+8 plates. (London: P. S. King and Son, Ltd.) 1s.

Society for the Provision of Birth Control Clinics. Annual Report, 1925–1926. Pp. 16. (London: Walworth Women's Welfare Centre.)

Department of Agriculture, Jamaica. Entomological Bulletin No. 4, Parts 1 and 2: Catalogus Insectorum Jamaicensis. By C. C. Gowdey. Pp. ii+114+10+2. (Jamaica: Government Printing Office, Kingston.) 2s.

Union of South Africa: Department of Agriculture. Division of Chemistry Series No. 68: The Solubility of Copper in Basic Copper Carbonate. By Thos. D. Hall. Pp. 8. (Pretoria: Government Printing and Stationery Office.)

Transactions and Proceedings of the Botanical Society of Edinburgh. Vol. 29, Part 3, Session 1925–26. Pp. xvii-xxiv+219-310. (Edinburgh.) 7s. 6d.

The Journal of the Institution of Electrical Engineers. Vol. 64, No. 359, November. Pp. 1093-1212+xxx. (London: E. and F. N. Spon, Ltd.) 10s. 6d.

Diary of Societies.

SATURDAY, DECEMBER 4.

ROYAL SOCIETY OF MEDICINE (Otology Section), at 10.30 A.M.—G. Wilkinson: Have we a Resonance Theory of Hearing, or only a Resonance Hypothesis?—Sir James Dundas-Grant: Remarks on the Use of Weber-Liel's Intra-tympanic Tube in Chronic Eustachian Catarrh.

INSTITUTION OF MUNICIPAL AND COUNTY ENGINEERS (South Midland District) (at Shire Hall, Hertford), at 10.45 A.M.—S. M. Senior: Hertford Sewage Disposal Works and Housing.

ROYAL INSTITUTION OF GREAT BRITAIN, at 3.—Dr. G. C. Simpson: Atmospheric Electricity (2).

MONDAY, DECEMBER 6.

CAMBRIDGE PHILOSOPHICAL SOCIETY (at the Museums, Cambridge), at 4.30.

ROYAL SOCIETY OF EDINBURGH, at 4.30.—Dr. A. G. Cannon and Miss S. M. Manton: On the Feeding Mechanism of a Mysid Crustacean, *Hemimysis Lamornæ*.—J. H. Awbery and Dr. E. Griffiths: Further Experiments with the Ewing Ball and Tube Flowmeter.—E. A. Baker: The Law of Blackening of the Photographic Plate at Low Densities (second paper). IV. Results for Isochromatic and Blue—Sensitive Plates and Filtered Light.—Dr. F. Walker: The Igneous Geology of Ardsheal Hill.

VICTORIA INSTITUTE (at Central Hall, Westminster), at 4.30.—Prof. J. A. Fleming: Evolution and Revelation.

BIOCHEMICAL SOCIETY (at Imperial College of Science), at 5.—D. Krestin and J. R. Marrack: The Calcium in Body Fluids in Nephritis.—D. J. Lloyd: The Mutual Influence of pH and Salt Concentration on Protein Swelling.—C. R. Harington and Prof. G. Barger: Chemistry of Thyroxin. III. Constitution and Synthesis of Thyroxin.—H. W. Buston and Dr. S. B. Schryver: The Basic Hydrolysis Products of Gelatine.—Prof. I. M. Heilbron, E. D. Kamm, and R. A. Morton: Absorption Spectra of Cholesterol and its Possible Biological Significance with reference to Vitamin D.—O. Rosenheim and T. A. Webster: Further Observations on the Photochemical Formation of Vitamin D.—Demonstration of Methods Employed for Purifying and Investigating the Proteins (Electro-dialysis, etc.).

ROYAL INSTITUTION OF GREAT BRITAIN, at 5.—General Meeting.

BRITISH PSYCHOLOGICAL SOCIETY (Education Section) (at London Day Training College), at 5.30.—Annual General Meeting at 5.45.—At 6.—M. M. Lewis: Personality and Verbal Expression.

SOCIETY OF CHEMICAL INDUSTRY (South Wales Section) (jointly with Institution of Mechanical Engineers) (at Engineers' Institute, Cardiff), at 6.—Dr. J. H. Paul: Water, and its Action in Steam Boilers.

INSTITUTION OF AUTOMOBILE ENGINEERS (Bristol Centre) (at Merchant Venturers' Technical College, Bristol), at 6.45.—G. Rushton: The L.G.O.C. Methods of Repairing Motor Buses.

INSTITUTION OF ELECTRICAL ENGINEERS (Informal Meeting), at 7.—Ll. B. Atkinson and others: Discussion on Notes on the Trend of Electrical Development in America and Canada.

SOCIETY OF CHEMICAL INDUSTRY (London Section) (at Chemical Society), at 8.—Dr. R. H. Pickard: Some Scientific Problems confronting the Leather Industry.

INSTITUTION OF THE RUBBER INDUSTRY (London and District Section) (at Engineers' Club, Coventry Street), at 8.—A. Fraser: British and American Machine Practice.

ROYAL GEOGRAPHICAL SOCIETY (at Æolian Hall), at 8.30.—Earl Cawdor: The People of the Tsangpo Gorge.

INSTITUTE OF CHEMISTRY (Leeds Area Local Section).—F. Scholefield: Registration of Chemists.

INSTITUTE OF CHEMISTRY (Manchester and District Section) (at Manchester).—Dr. H. Levinstein: Address.

TUESDAY, DECEMBER 7.

ROYAL INSTITUTION OF GREAT BRITAIN, at 5.15.—Sir William Bragg: The Imperfect Crystallisation of Common Things (3).

INSTITUTION OF ELECTRICAL ENGINEERS (East Midland Sub-Centre) (at Loughborough College), at 6.45.—Col. J. F. Lister: Address.

INSTITUTION OF AUTOMOBILE ENGINEERS (at Royal Society of Arts), at 7.—Prof. W. Morgan: The Use of the Optical Indicator as a Means of Examining Combustion in Internal Combustion Engines.

ROYAL PHOTOGRAPHIC SOCIETY OF GREAT BRITAIN, at 7.—H. Venn: Bromoil (Lecture).
INSTITUTION OF AUTOMOBILE ENGINEERS (Coventry Graduates' Meeting) (at Coventry), at 7.15.
INSTITUTE OF CHEMISTRY AND SOCIETY OF CHEMICAL INDUSTRY (Edinburgh and East of Scotland Sections) (at 36 York Place, Edinburgh), at 7.30.—F. H. Carr: Vitamins in their relation to Industry.
INSTITUTION OF ELECTRICAL ENGINEERS (Scottish Centre) (at Royal Technical College, Glasgow) (Informal Meeting), at 7.30.—R. B. Mitchell: Home Lighting.
INSTITUTE OF METALS (North-East Coast Local Section) (at Armstrong College, Newcastle-upon-Tyne), at 7.30.—A. Logan: Foundry Work.
RÖNTGEN SOCIETY (at British Institute of Radiology), at 8.15.—W. V. Mayneord: An X-ray Study of the Crystal Structure of some Biological Objects.—C. Andrews: Demonstration of The Seriascope, a New Instrument for Serial Radiography.
ROYAL ANTHROPOLOGICAL INSTITUTE, at 8.30.—Miss M. A. Murray: Recent Excavations in Malta.
ROYAL SOCIETY OF MEDICINE (Orthopædics Section), at 8.30.—S. L. Higgs, Prof. Noordenlos, Sir Charters Symonds, Mr. Openshaw, H. Groves, Mr. Elmslie, M. Redding, E. M. Cowell, Mr. Bristow, Mr. Fairbank, Mr. Todd, and others: Discussion on The Treatment and Results of Fracture of the Upper End of the Femur in Adults (Excluding the Shaft).

WEDNESDAY, DECEMBER 8.

SOCIETY OF CHEMICAL INDUSTRY (Glasgow Section) (at Royal Technical College, Glasgow), at 3.—F. H. Carr: Insulin.
ROYAL INSTITUTE OF PUBLIC HEALTH, at 4.—Lt.-Col. F. E. Fremantle: The Rôle of Parliament in regard to Health Legislation.
INSTITUTION OF CIVIL ENGINEERS (Informal Meeting), at 6.—A. H. Dykes: The Circumstances in which Small Private Electric Generating Stations may have Advantages over Public Stations.
SOCIETY OF CHEMICAL INDUSTRY (South Wales Section, jointly with Institute of Chemistry, South Wales Section) (at Swansea Technical College), at 7.30.—E. Le Q. Herbert: Lubricating Oils: their Manufacture, Properties, and Examination.
ROYAL SOCIETY OF ARTS, at 8.30.—Rev. Père De Cleyn: The Port of Antwerp.
EUGENICS SOCIETY (at Royal Society), at 8.30.—Prof. Carr-Saunders: Migration in relation to Racial Problems.
SOCIETY OF CHEMICAL INDUSTRY (Newcastle-upon-Tyne Section) (at Newcastle-upon-Tyne).—Discussion on The Possibility of the Introduction of New Chemical Industries into the District.

THURSDAY, DECEMBER 9.

LONDON MATHEMATICAL SOCIETY (at Royal Astronomical Society), at 5.—T. Esterman: On Certain Functions represented by Dirichlet Series.—R. M. Gabriel: Some Theorems for Integrals of Moduli of Regular Functions.—U. S. Haslam Jones: An Extension of Hadamard's Multiplication Theorem.—Prof. H. Hilton and Sybil D. Jervis: On the Real Foci of Plane Algebraic Curves.—S. Pollard: On Plane Curves.—E. C. Titchmarsh: A Consequence of the Riemann Hypothesis.—Prof. H. W. Turnbull: Double Binary Perpetuants.
ROYAL INSTITUTION OF GREAT BRITAIN, at 5.15.—Sir Squire Sprigge: Early Medical Literature.
BRITISH PSYCHOLOGICAL SOCIETY (Industrial Section) (jointly with the National Institute of Industrial Psychology) (at Royal Society of Arts), at 5.30.—Discussion on The Attitude of Management to Industrial Psychology.
SOUTH LONDON ENTOMOLOGICAL AND NATURAL HISTORY SOCIETY, at 7.—Dr. H. B. Williams: Rumicia phlœas: Random Notes on Breeding and Collecting.
INSTITUTION OF ELECTRICAL ENGINEERS (Dundee Sub-Centre) (at University College, Dundee), at 7.30.—Prof. A. R. Fulton: Tidal Power from the Tay.
INSTITUTE OF METALS (London Local Section, jointly with Institute of British Foundrymen) (at 83 Pall Mall), at 7.30.—H. C. Dews: Contraction and Alloy Casting.
ROYAL SOCIETY OF TROPICAL MEDICINE AND HYGIENE (at 11 Chandos Street, W.), at 7.45.—Demonstration on Some Tropical Liver Infections.—At 8.15.—Dr. H. S. Stannus: Tropical Neurasthenia.
OIL AND COLOUR CHEMISTS' ASSOCIATION.
INSTITUTION OF THE RUBBER INDUSTRY (Manchester Section) (jointly with Society of Dyers and Colourists, Manchester Section) (at Manchester).—H. L. Hocknay and C. W. Bancroft: Cloth Dyeing suitable for Rubber Proofing.

FRIDAY, DECEMBER 10.

INSTITUTION OF WATER ENGINEERS (at Geological Society), at 10.30 A.M.—A. W. Kenyon: Water Supply Finance.—J. P. Hallam: Recent Developments in the Design and Application of Centrifugal Pumps.—J. K. Swales: Repair Works in Connexion with the Belmont Reservoir of the Bolton Corporation.—E. J. Silcock: The History of an Artesian Bore-hole.
ROYAL SOCIETY OF ARTS (Indian Section), at 4.30.—C. H. Bompas: The Calcutta Improvement Trust.
ROYAL ASTRONOMICAL SOCIETY, at 5.—A. Stanley Williams: A New Variable Star in Taurus.—R. H. Fowler: On Dense Matter.—W. M. Smart: The Constants of the Star Streams from Photographic Proper Motions.
ROYAL SOCIETY OF MEDICINE (Ophthalmology Section) (at Central London Ophthalmic Hospital), at 5.—Clinical Meeting.
PHYSICAL SOCIETY OF LONDON (at Imperial College of Science), at 5.—Dr. F. Wenner: The Principle Governing the Distribution of Current in a System of Linear Conductors.—A. Campbell: A Capacitance Bridge of Wide Range, and a New Inductometer.
MALACOLOGICAL SOCIETY (at Linnean Society), at 6.
INSTITUTION OF MECHANICAL ENGINEERS, at 6.—Marine Oil Engine Trials Committee: Report No. 5.
NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS (at Newcastle-upon-Tyne), at 6.—H. I. Brackenbury: Workshop Methods in Heavy Engineering.
INSTITUTION OF ELECTRICAL ENGINEERS (London Students' Section) (at Automatic Training School, G.P.O., E.C.), at 6.30.—F. I. Ray: Automatic Telephony.
INSTITUTE OF METALS (Swansea Local Section) (at Swansea University College), at 7.15.—C. A. Seyler: The Application of Metallographic Methods to Coal.
JUNIOR INSTITUTION OF ENGINEERS, at 7.30.—C. E. Foster: A Method of Measuring Temperatures in the Cylinders of Internal Combustion Engines.
INSTITUTE OF METALS (Sheffield Local Section) (at Sheffield University), at 7.30.—A. E. Nicol: The Conductivity of Silver Plating Solutions.
INSTITUTION OF MECHANICAL ENGINEERS (Liverpool Branch) (jointly with Liverpool Engineering Society) (at Liverpool).—Marine Oil Engine Trials Committee: Report No. 5.

SATURDAY, DECEMBER 11.

INSTITUTION OF MUNICIPAL AND COUNTY ENGINEERS (South-Western District Meeting) (at Vestry Hall, Dawlish), at 2.15.—S. F. C. Church: Twenty Years in an Urban District.
ROYAL INSTITUTION OF GREAT BRITAIN, at 3.—Dr. C. Rootham: Henry Purcell and his Contemporaries (1).
BRITISH PSYCHOLOGICAL SOCIETY (Annual General Meeting) (at University College), at 3.30.—J. C. Flugel: Practice, Fatigue, and Oscillation.
NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS (Graduate Section) (jointly with Institution of Mining Engineers) (at Newcastle-upon-Tyne), at 7.15.—Discussion on The Production and Transport of Coal by Machinery.
MINING INSTITUTE OF SCOTLAND (at Glasgow).
OIL AND COLOUR CHEMISTS' ASSOCIATION (Manchester Section) (at Manchester).—R. S. Horsfall: Modern Industrial Chemistry.
PHYSIOLOGICAL SOCIETY (at London Hospital Medical College).

PUBLIC LECTURES.

SATURDAY, DECEMBER 4.

HORNIMAN MUSEUM (Forest Hill), at 3.30.—Miss M. A. Murray: Egyptian Hieroglyphs.

SUNDAY, DECEMBER 5.

GUILDHOUSE (Eccleston Square), at 3.30.—Sir George Newman: The Contribution of Medical Science to Human Life.

MONDAY, DECEMBER 6.

ROYAL COLLEGE OF SURGEONS, at 4.—F. W. Twort: Influence of Environment on Bacteria. (Succeeding Lectures on December 7, 9, 13, and 14.)

WEDNESDAY, DECEMBER 8.

INSTITUTION OF CIVIL ENGINEERS, at 5.30.—F. E. Smith: Physics in Navigation (Public Lectures of the Institute of Physics on Physics in Industry).
LONDON SCHOOL OF ECONOMICS AND POLITICAL SCIENCE, at 6.—F. Hutchinson: Office Machinery in the United States (2).

THURSDAY, DECEMBER 9.

IMPERIAL COLLEGE OF SCIENCE AND TECHNOLOGY, at 5.30.—Air Vice-Marshall H. R. M. Brooke-Popham: Air Warfare.
KING'S COLLEGE, at 5.30.—M. Beza: Sacred Marriage in Roumanian Folklore.
FULHAM CENTRAL PUBLIC LIBRARY, at 8.—Dr. D. Ward Cutler: Charles Darwin and Human Progress.

FRIDAY, DECEMBER 10.

UNIVERSITY COLLEGE, at 5.30.—L. S. Jast: The Planning of a Library Building.

SATURDAY, DECEMBER 11.

HORNIMAN MUSEUM (Forest Hill), at 3.30.—M. A. Phillips: The Nursery Life of Animals.

SUNDAY, DECEMBER 12.

GUILDHOUSE (Eccleston Square), at 3.30.—Viscount Grey: The National Genius of England.

CONFERENCES.

DECEMBER 8, 9, AND 10.

INSTITUTION OF CHEMICAL ENGINEERS (at Science Museum, South Kensington).
Wednesday, December 8, at 5.30.—R. G. Parker and D. N. Jackman: The Measurement of Mechanical Power absorbed by Driven Machines. A Recording Torsion Dynamometer.
Thursday, December 9, at 3 and 5.30.—Symposium on Statistical Methods in relation to Industrial Efficiency:—D. Rider and T. C. Finlayson: The Control of Chemical Plant Operation by Statistical Methods.—H. C. Marris: Statistics in Industry—Some Uses and Limitations.—E. Cooke: Statistical Methods in Connexion with Plant Construction.
Friday, December 10, at 3 and 5.30.—Dr. G. Martin: Researches on the Laws of Air Elutriation.—H. M. Dunkerley: Refrigeration in Chemical Manufacturing Processes.

DECEMBER 10.

ROTHAMSTED EXPERIMENTAL STATION, HARPENDEN, at 11.30 A.M.—Green Manuring: its Possibilities and Limitations in Practice:—H. J. Page and others: Green Manuring.—H. Upcher, H. Drewitt, and others: Practical Experiences of Green Manuring.

Supplement to NATURE

No. 2979 DECEMBER 4, 1926

Recent Developments of Cosmical Physics.[1]

By J. H. JEANS, Sec. R.S.

UNTIL recent years astronomy was concerned almost entirely with the sun, moon, and planets; the stars were mere points of light so inconceivably remote as to be of only minor interest. To-day Urania has wearied of the speck of dust we call the solar system, and claims the whole universe for her playground; the astronomer's interest centres almost exclusively on the stars. The dynamical astronomer, for example, having lost interest in the motions of the planets and their satellites, studies the arrangement and motions of the stars in the hope of discovering the general plan at least of the architecture and mechanism of the universe; for him the whole universe is a single dynamical system formed of innumerable particles—the stars—each of which attracts each other according to the universal law of gravitation.

The physical astronomer finds a different interest in the stars. For him each separate star is a complete physical system: it is a crucible in which matter is subjected to temperatures and pressures far beyond any available to the terrestrial physicist. From a study of the radiation emitted by the stars, the physical astronomer tries to unravel their physical structure, to discover how they generate their energy, and by what mechanism this energy is transmitted to their surfaces and discharged into space as radiation. In this way he may perchance happen upon properties of matter which have eluded the terrestrial physicist owing to the small range of physical conditions at his command. If the simile may be pardoned, on the plea that it is at least true to scale, the animalculæ which inhabit a raindrop may learn something of the properties of water by manipulating the particles of the raindrop with their puny strength, but they may also learn something by watching the uncontrollable fall of torrents over Niagara. The primary study of the physical astronomer is precisely this external fall of torrents over Niagara; his ultimate aim is to weld cosmical physics on to terrestrial physics so as to form one all-embracing science. Only when this has been done will it be possible to understand the main trend of events in the physical universe.

[1] A lecture delivered at University College, London, on November 9, 1926.

THE INTERPRETATION OF STELLAR SPECTRA.

There is only one method available to this end, namely, a study of the radiation emitted by different stars. Apart from unscientific speculations, physical astronomy may be said to have come to birth in 1863, when Huggins attached a spectroscope to a telescope and found that certain lines in the spectra of the stars were identical with lines emitted in the laboratory by the known chemical elements. The early stellar spectroscopists believed that they were investigating 'the chemistry of the stars' although we know now that they were merely opening up a fundamental problem of the physics of the stars. The spectrum of Sirius, for example, was found to exhibit hydrogen lines very strongly and calcium lines very weakly; in the solar spectrum the relative strength of these two sets of lines was reversed, calcium being strong and hydrogen weak. They concluded that hydrogen was specially prominent in the constitution of Sirius and calcium in that of the sun. Believing that Sirius must one day develop into a star similar to our sun, they conjectured that its substance must gradually change from hydrogen into calcium and other more complex elements, thus finding support for the long-established hypothesis that the more complex elements were formed by gradual evolution out of the simplest.

The true interpretation of these early observations, as the investigations of Saha, R. H. Fowler and Milne have abundantly proved, is merely that the surface of Sirius is at a temperature at which hydrogen is specially active in emitting and absorbing radiation, while the sun's surface is at a lower temperature at which hydrogen is comparatively inert, calcium, iron, etc., having become active in its place. Just as the laboratory physicist can produce different spectra from the same vacuum-tube by varying the mode and conditions of excitation, so Nature produces different spectra from the same stellar material by varying its temperature.

Clearly this circumstance robs stellar spectra of all direct evolutionary significance. The spectra of the stars merely tell us their present surface temperatures, so that even if we could arrange the stars in order of age, a comparison of their spectra would only show whether their surfaces were becoming hotter or cooler; it would give no information as to chemical changes occurring in their substance.

The Sizes of the Stars.

The knowledge of a star's surface temperature nevertheless opens the door to further valuable knowledge. The hotter a surface is, the more energetically it radiates heat, and from a knowledge of a star's surface temperature it is easy to calculate its radiation per square inch of surface—the sun, for example, radiates approximately 560,000 calories a minute, which is about the energy output of a 50 horse-power engine, from each square inch of its surface. The hottest stars of all probably radiate at least a thousand times as much per square inch of surface.

In this way we can estimate a star's radiation per square inch of its surface. We can also estimate the radiation from its whole surface; this can be calculated at once from its distance and apparent brightness. Simple division gives the area of the star's surface, and hence its radius and volume. Calculated stellar radii range from about 300 times the sun's radius for Betelgeux to about 0·03 times the sun's radius for the companion of Sirius.

As is well known, the diameters of certain stars have recently been observed directly with the Michelson interferometer, and the measured values agree almost perfectly with those calculated in the simple way just explained. The interferometer method is only available for the largest stars, but at the extreme other end of the scale the theory of relativity has come to the rescue. The shift of spectral lines toward the red, which Einstein predicted to be a necessary consequence of the theory of relativity, has been observed in the light received from the companion of Sirius, and its amount corresponds exactly to the radius calculated for the star in the way just explained. So much of a sensational kind has been written about the observational measurements of the diameters of Betelgeux and of the companion to Sirius, that it may be well to remember that, while the *methods* were novel and of the greatest interest and importance, the *results* were precisely those that were generally expected, and such as a simple arithmetical calculation showed to be practically inevitable. Indeed, this calculation could only have failed in one way. It is based on the assumption that the surfaces of the stars emit their full temperature-radiation like the surface of the sun. If the stars had been transparent bodies like the planetary nebulæ, or solid bodies like the moon, this assumption would have been false, and the observations would have revealed its falsity.

Our gain of positive knowledge from these observations is that Betelgeux and the companion to Sirius are neither transparent nor solid bodies, but full radiators like the sun. Moreover, as the three stars just mentioned are about as different as any three stars possibly could be, representing approximately the two extreme ends and the middle of the scale in almost any ordered arrangement we please to make, it seems reasonable to suppose that all stars are full radiators and so, as regards their mechanism of radiation, are essentially similar structures.

The Physical State of Stellar Interiors.

What, then, is this mechanism of radiation? And what, as a preliminary question, is the physical state of stellar matter? In the early days of spectroscopy it was commonly supposed, from a faulty analogy with laboratory experiments, that a hot gas always gave a line spectrum, and that a continuous spectrum, such as is exhibited by the stars, could be emitted only by a solid or a liquid body. It is now generally conceded that this view was erroneous, and it is recognised that the continuous spectrum of a star merely indicates that the star is not transparent, thus leaving the question of stellar structure almost entirely open.

The view of stellar structure now universally accepted is that stars are formed of matter which, as a consequence of its high temperature, is to a very large extent broken up into its constituent electrons and nuclei, these all moving about independently like the molecules of a gas. The electrostatic attractions which in more peaceful surroundings would rapidly unite the wandering nuclei and electrons into complete atoms and molecules, are powerless in the general whirl of rapidly moving projectiles and in face of the shattering blows of the quanta of high-frequency radiation which the high temperatures of the stellar interiors generate. When I first put forward this view in 1917 (Bakerian Lecture, *Phil. Trans.*, **218**, p. 209), I thought it was entirely novel, but I have since found that in 1644 Descartes had conjectured that the sun and fixed stars were made of matter "which possesses such violence of agitation that, impinging upon other bodies, it gets divided into indefinitely minute particles." My own suggestion was not conjecture, being based on incontrovertible scientific grounds. In 1907 Emden had published calculations ("Gas Kugeln," p. 96) on the interior states of the sun and stars, in which he assumed the stars to be masses of gas resting in an equilibrium similar to that of the lower strata of the earth's atmosphere—the so-called 'adiabatic' equilibrium in which there are assumed always to be sufficient currents to keep the constituent gases thoroughly mixed by a process of stirring. On this supposition he found that if the sun were composed of air or other diatomic gas of equal molecular weight, its central temperature would be 455 million degrees, while if it consisted of hydrogen, or other diatomic gas of molecular weight 2, its central temperature would be 31·5 million degrees. These temperatures are so high that no atom or molecule could survive them; at 31·5 million degrees the quantum of radiation has energy $2{\cdot}1 \times 10^{-8}$ ergs, which is sufficient to move an electron through a potential difference of 13,500 volts. Even with such quanta flying about, the atomic nuclei are still safe, far higher than stellar temperatures being needed to dissociate these into their constituent electrical charges, but the electrons must of necessity nearly all be torn off atoms of moderate atomic weight and the nuclei left almost or entirely bare.

To a first rough approximation we may regard stellar matter, at any rate in the star's hot central regions, as consisting of a mixture of bare nuclei and free electrons. Passing outwards towards the star's surface, the temperature falls, and we come to atoms which are more and more fully formed, until finally, close to the surface, we meet atoms which are completely formed except perhaps for one or two of their outermost electrons. In the surfaces of the coolest stars of all, we even find complete molecules, as, for example, the molecules of titanium oxide and magnesium hydride, which appear in the spectra of certain classes of stars.

The Mechanism of Stellar Interiors.

The mixture of free electrons and bare nuclei or imperfectly formed atoms will behave like a mixture of monatomic gases. In completely broken-up hydrogen, each hydrogen molecule gives rise to four flying units—two protons and two free electrons—so that the effective molecular weight of the mixture will be 0·5. The corresponding figure for helium is 1·33, for calcium 1·90, for iron 2·07, and for lead 2·50, but since atoms of lead would not be completely broken up at stellar temperatures, the actual value for stellar lead would be somewhat higher. If we momentarily adopt 2 as a mean molecular weight of stellar matter, we find that Emden's calculations give 31·5 million degrees for the central temperature of the sun if formed of hydrogen molecules (mol. wt. 2). Various adjustments must be made in this figure, but they are of comparatively minor importance, and Emden's original figure of 31·5 million degrees is probably not very far from the actual temperature of the sun's centre. Indeed, Russell has recently suggested that the great majority of stars have central temperatures fairly close to 32 million degrees (Nature, Aug. 8, 1925).

One of the necessary adjustments arises from Emden's calculations having neglected the pressure of radiation in stellar interiors.[2] At 31·5 million degrees the pressure of radiation is about 2500 million atmospheres. Huge though this is in comparison with terrestrial pressures, it is only some five per cent. of the ordinary gas-pressure of the broken-up atoms and electrons at the sun's centre. We could allow for its dynamical effects by decreasing our assumed mean molecular weight by 5 per cent., but this mean molecular weight is not in any case known to within 5 per cent. In exceptionally massive stars, the pressure of radiation assumes somewhat greater importance. For example, at the centre of a star of some ten times the sun's mass, radiation pressure is about equal to gas-pressure. To allow for its effects in this case we should have to suppose the assumed mean molecular weight halved—reduced perhaps from 2 to 1. In every case we shall get a true picture of stellar structure if we think of the layers of stellar matter as held up against gravitation by the incessant impact of a certain number of atomic nuclei or partially stripped atoms, the 'molecular weight' of which is practically the same as that of the corresponding complete atoms, together with a far greater number of free electrons of standard 'molecular weight' 0·00055, and a rather small number of 'molecules' of radiation the molecular weight of which is negligibly small. The combined impacts of these three types of projectiles prevent the star from falling in under its own gravitational attraction.

This gives us, I think, the best snapshot picture of a star's structure. The corresponding picture of its mechanism is obtained by thinking of the nuclei as α-ray particles, of the free electrons as β-ray particles, and of the radiation as γ-rays (although in most stars the main bulk of the radiation has the wave-length of X-rays); and, precisely as in laboratory work, the β-rays are more penetrating than the α-rays, and the γ-rays are more penetrating than either.

The Transport of Energy inside a Star.

In ordinary kinetic theory of gases, conduction of heat is studied by regarding the molecules of the gas as carriers of energy; each molecule has a carrying power which is jointly proportional to its heat energy, its velocity and its free-path. In the interior of a star there are, as we have seen, three distinct types of carriers—the nuclei (or atoms), the free electrons, and the radiation. We can compare the relative carrying capacities of these three types of carriers by multiplying up the energy, velocity, and free-path of each.

[2] I first directed attention to this in reviewing Emden's book (*Astrophys. Jour.*, 30 (1909), p. 72, and gave a reasonably accurate estimate of the ratio of this pressure to ordinary gas-pressure in stellar interiors in 1917 (Bakerian Lecture, May 17, 1917, p. 209). Some months previously Eddington had given an estimate which made this ratio some hundreds of times too large. He corrected this at the earliest opportunity (*Mon. Not. R.A.S.*, June 1917), but not in time to overtake sensational statements, still occasionally encountered, that pressure of radiation is of predominant importance in the dynamics of stellar interiors.

The nuclei and the free electrons have, of course, quite definite free-paths. The same is true of the radiation if this is regarded as consisting of discrete quanta; when a quantum is emitted a free-path begins, and when it is re-absorbed the free-path ends. Whether we think in terms of undulatory theory or quanta, we may suppose that a beam of radiation is reduced in intensity by a factor $e^{-k\rho x}$ on passing through a thickness x of matter of density ρ, where k is the 'coefficient of opacity' of the matter. By comparison with the kinetic theory formula $e^{-x/\lambda}$ for the reduction in strength of a shower of moving molecules, we see that the 'free-path' of the radiation must be taken to be $1/k\rho$. When we use this value for the free-path of radiation and calculate carrying capacities in the way already explained, the carrying capacity of both nuclei and electrons is found to be insignificant in comparison with that of the radiation. The nuclei and electrons may have the greater amount of energy to carry, but the distance over which they carry it, their free-path, is far less than that of the radiation, and their speed of transport is also less, since radiation transports energy with the velocity of light. In this way it comes about that practically the whole transport of energy from the interior of a star to its surface is by the vehicle of radiation.

This general principle was first clearly stated by Sampson in 1894 (*Mem. R.A.S.*, 51, p. 123), but his detailed applications were vitiated by his using an erroneous law of radiation. Twelve years later, Schwarzschild independently advanced the same idea (*Gött. Nach.*, 1906, p. 41); he showed how the temperature of any element of a star's interior must be determined by the condition that it received just as much radiation as it emitted, and gave accurate equations of radiative equilibrium which have formed the basis of every subsequent discussion of the problem.

The Configurations of a Star in Equilibrium.

As a consequence of radiation completely outstripping the material carriers in the transport of energy to the star's surface, the build of a star is entirely determined by the values of k, the coefficient of opacity in its interior. If this coefficient is everywhere zero, the star is entirely transparent, and so cannot retain any heat; we now have a star of zero temperature and therefore of infinite extent. If, on the other hand, the coefficient of opacity is everywhere infinite, the star is completely opaque, so that all radiation accumulates where it is generated until the star's temperature becomes infinite, and we have a star of infinite temperature but of infinitesimal radius. It is, of course, the intermediate values which are of practical interest, but the two extreme cases just mentioned show how the whole build of a star depends on the value of the opacity coefficient k. So much is this the case that all attempts to investigate the build of stars before the value of this coefficient was known can only be regarded as speculation.

The first attempt to evaluate it theoretically by Eddington in 1922 (*Mon. Not. R.A.S.*, 83, p. 32) proved unsuccessful and was withdrawn. In the next year Kramers (*Phil. Mag.*, 46, p. 836) put forward the theory of opacity which has now gained general acceptance. Using the value of the opacity coefficient given by this theory, it is possible to determine the complete build of a star having any given mass and any given rate of generation of energy. In this way I have shown (*Mon. Not. R.A.S.*, 85, pp. 196 and 394) that a star of given mass can rest in equilibrium with any radius from zero to infinity, different radii corresponding to different rates of generation of energy from zero to infinity by the star. A star adjusts its radius to suit its rate of generation of energy, and in so doing fixes its surface temperature and spectral type. If a star's rate of generation of energy were suddenly to change, the star would expand or contract until it had assumed the radius and temperature suited to its new rate of generation of energy. Contrary to common belief, an increase in a star's rate of generation of energy causes it to contract its radius and increase its temperature, while a slackening in its generation of energy is found to result in expansion and cooling. Thus we see the giant red stars such as Betelgeux do not owe their immense size to their radiating so much energy, but to their radiating so little; indeed, comparatively compact stars such as Plaskett's star and V Puppis are radiating far more in proportion to their masses. The general theoretical principle can be verified by the examination of pairs of stars of approximately equal mass, as for example the two pairs in the following table. The surface temperatures are here deduced directly from the observed spectra, the radii then being calculated in the way already explained.

Star.	Mass (in terms of sun).	Generation of energy per gram (ergs per second).	Observed temperature.	Radius (in terms of sun).
Sun	1·00	1·9	5750	1·00
α Cent. B	0·97	1·4	3700	2·03
Procyon	1·13	10·2	8300	1·17
α Cent. A	1·14	2·3	5000	1·56

Stellar Evolution.

There is not likely to be any abrupt change in the rate of generation of energy of an actual star. There will be a slow secular decrease, but this will be associated with a slow secular decrease of the star's mass resulting from its continual emission of radiation. For example, the 560,000 calories of radiation which stream out every minute from each square inch of the sun's surface have a mass of $2 \cdot 5 \times 10^{-8}$ gm., whence it is readily calculated that the sun's mass must diminish by 250 million tons every minute. After millions of millions of years this rate of wastage produces an effect even on the gigantic mass of the sun. To trace the changes in the radius and temperature of an actual star we must study the sequence of configurations assumed in turn as the mass and the rate of generation of energy change together. In this way I have found (*Mon. Not. R.A.S.*, January 1925) that a normal star would first decrease in size and get hotter, but would ultimately expand and get cooler again. This result provides a simple dynamical interpretation of the sequence of 'ascending and descending temperatures' which was first suggested by Lockyer, and formed the outstanding feature of Russell's 1913 theory of stellar evolution—although our physical interpretation is very different from that suggested by Russell.

The Atomic Weight of Stellar Matter.

In the simplest case, in which energy is generated uniformly throughout a star's mass, the surface temperature T assumed by a star of mass M and of given luminosity (or rate of generation of energy) is given by the equation—

$$\text{Star's luminosity} = C\left(\frac{N^2}{A}\right)^{-0 \cdot 8} T^{0 \cdot 8} \mu^{6 \cdot 8} f(M).$$

Here C is a known constant, N and A are the atomic number and atomic weight of the stellar atoms, and μ the effective molecular weight (about 2) of the broken-up stellar material; T is the temperature of the star's surface and $f(M)$ is a quantity I have calculated and tabulated, which depends only on the star's mass (*Mon. Not. R.A.S.*, 85, p. 395).

The quantity N^2/A necessarily occurs in the foregoing formula, because the coefficient of opacity, by which the star's whole structure is determined, is proportional to N^2/A. If a Maxwell demon could cut every atomic nucleus in a piece of matter into two equal halves, he would halve both N and A and so also N^2/A, with the result that the substance would become twice as transparent as before. This shows that a large clot of matter in the form of a massive nucleus is far more effective in absorbing X-radiation than a large number of small clots of equal total mass. It is for this reason that the physicist and surgeon both select lead as the material with which to screen their X-ray apparatus; a ton of lead is far more effective in stopping unwanted X-rays than a ton of wood or of iron. If we knew the strength of an X-ray apparatus, and the total weight of shielding material round it, we could form a very fair estimate of the atomic weight of the shielding material by measuring the amount of X-radiation which escaped through it.

A very similar method may be used to determine the atomic weight of the atoms of which the stars are composed. A star is in effect nothing but a huge X-ray apparatus. We know the total mass of many stars, and we can readily calculate the rate at which they are generating X-rays—it is merely the rate at which they are radiating energy away into space. If we could shut our Maxwell demon inside a star and make him cut each atomic nucleus in half, keeping the star's mass and rate of generation unaltered, we should halve the coefficient of opacity of the star. This would necessitate a change in the star's build: in actual fact its radius would increase fourfold while its surface temperature would be halved. We could follow the progress of the demon's work by watching the changes in the surface temperature of the star. Hence from the observed surface temperature of any star the mass and luminosity of which are known, it must be possible to estimate the atomic weight of the atoms of which the star is composed. The formula given above provides the means.

I ought perhaps to mention in passing that Eddington and others have approached this question from the other end, assigning conjectural values to N^2/A from our knowledge of the elements which occur in the atmospheres of the sun and stars. Such a course appears to be very risky. A star's spectrum gives no indication of the selection of elements which occur in its interior; and there is at least an *a priori* possibility that the elements occurring there may be entirely different from those which appear in its surface; consider into what errors an extra-terrestrial observer might be led if he assumed that the earth contained no chemical elements beyond those appearing in its atmosphere.

When, however, the risk has been taken, and such values assigned to N^2/A, all the quantities which occur in the luminosity formula are known, and the only question which remains is whether the values calculated for the luminosity agree with those observed through the telescope. They do not.

It is clear that the value of N^2/A must be adjusted until agreement is obtained, and this amounts to precisely the same thing as determining N^2/A, directly and at once, from the luminosity formula. On doing this for a series of stars, I have found (*Mon. Not. R.A.S.*, June 1926) that two very significant facts emerge. First, most of the values so determined prove to be higher than the value for uranium, the heaviest element known on earth. Second, the different values of N^2/A show an ordered arrangement, the youngest stars generally giving the highest values for N^2/A, and this value falling as we pass to older stars.

The second of these results has far-reaching implications. Contrary to the views of the early spectroscopists, and contrary to what is still probably the prevalent belief, it now looks as though the atoms in a star become simpler as the star grows older; evolution appears to be from complex to simple, and not, as in biology, from simple to complex. There is at present no direct experimental evidence bearing on this question except that provided by radioactivity, where evolution is certainly from complex to simple, atoms of lower atomic weight being continually produced by the disappearance of atoms of higher atomic weight.

The evidence of physical astronomy, pointing to an evolution of matter in the same direction, suggests that the main evolution of matter in the universe may be of the same type as, but a generalisation of, the radioactive processes as they occur on earth. The evidence so far given has been based entirely on Kramers' theory of opacity for X-radiation. This theory has been found to agree very well with the observed absorption in the laboratory of radiation of about the wavelength which occurs in stellar interiors, while its theoretical basis has been discussed fully and critically by Eddington, Milne, and others, who have been unable to suggest any substantial alteration. Still, if the evidence from Kramers' formula were the only evidence available, our conclusions would be open to the charge of resting, if not on a slight, at least on a single, foundation. But there is plenty of further evidence, as we shall now see.

Distribution of Chemical Elements in a Star.

A star necessarily arranges itself so that there is a great concentration of matter near its centre. This is primarily a consequence of the inverse square law of gravitation, although the opacity law is involved also to some extent. With Kramers' formula for the opacity the arrangement is such that the central density is 100 or more times the mean density, while at least some 90 or 95 per cent. of the star's total mass is concentrated in a sphere of half the radius, and so of only one-eighth the volume, of the star. But the degree of central condensation is rather insensitive to changes in the opacity formula, and any reasonable formula would still give very high central condensation. A strict mathematical argument based on this circumstance (*Mon. Not. R.A.S.*, June 1926, p. 561) enables us to rule out the possibility of convection currents stirring up a star's interior in the way in which boiling water is stirred up in a kettle. Convection occurs in a kettle because the hot water at the bottom is of lower density than the cool water at the top; it is absent in a star because the hot matter near the centre, notwithstanding its intense heat, is still far, far denser than the cool matter near the surface. Thus, the mixture of matter in a star's interior is not analogous to that in the earth's lower atmosphere, where the constituent gases are kept thoroughly mixed by winds and storms, but rather to a serene upper atmosphere in which the lightest elements float to the top while the heaviest sink downwards under gravity.

Such considerations as these suggest at once that the elements which indicate their presence in the spectra of the outermost layers of the sun and stars are only the very lightest of the series of elements existing in the star. It is natural that the earth, formed originally out of the sun's outer layers, should contain precisely the same chemical elements as these outer layers, but it now appears that there ought to be heavier elements inside. The calculation which assigns to stellar matter atomic numbers higher than that of uranium no longer looks suspicious or paradoxical; it begins to look natural, and indeed almost inevitable.

The Generation of Energy in a Star.

Further evidence that the atomic weights of stellar atoms are higher than those of any known terrestrial atoms may be obtained by considering the rate of generation of energy inside a star. The sun radiates energy at about 2 ergs per second for each gram of its mass, and so must generate energy at this rate in its interior. To the best of our knowledge it has generated and radiated at this, or a greater, rate for some millions of millions of years. Could the sun have any such radiating capacity if its interior were formed of the common terrestrial elements, calcium, iron, silicon, etc.?

One's first impulse is to say, No. Even if the sun were built of pure uranium, its radiating power would be only about one-half of that observed, and would only last for a minute fraction of what is believed to have been the sun's life. A sun of pure radium would radiate more than enough for the moment, but its life would be limited to a few thousand years. No possible combination of terrestrial elements can give the combination of high radiation and of staying power which is observed in the sun and stars.

We must, however, remember that stellar interiors are at pressures and temperatures which are quite unattainable in our laboratories. We are led to wonder whether our terrestrial elements would behave quite differently if they were exposed to stellar conditions. Is it possible, for example, that the sun's interior is formed of ordinary terrestrial elements, which owe their high generation of energy merely to their high temperatures and pressures?

A general survey of astronomy throws a good deal of light on this question. We find immediately that the stars which radiate most energetically (per unit mass) are not, broadly speaking, the hottest stars, and neither are they the densest. Some of the hottest and densest stars are entirely put to shame in the matter of radiation by very cool stars of low density such as Antares and Betelgeux. If we arrange the stars in order of radiation per unit mass, we shall find that we have arranged them neither in order of temperature nor of density, but very approximately in order of age; the youngest stars radiate most energetically, regardless of their interior temperatures and density; the older stars appear to be tired out.

The general tendency is shown in the following table:

Star.	Generation of energy (ergs per gram).	Central temperature.	Central density.	Age.
Plaskett's Star	1000	500,000,000	Very great	
V Puppis	640	300,000,000	More than 1,000	Less than 10^{11} yr.
Antares	320	1,000,000	0·005	
Capella A	50	8,000,000	0·5	Less than 10^{12} yr.
Sirius	21	150,000,000	1,000	10^{12} yr.
Sun	1·88	70,000,000	300	7×10^{12} yr.
α Cent. B	1·39	15,000,000	10	7×10^{12} yr.
Kruger 60 B	0·02	70,000,000	30,000	Very old.
Sirius B	0·003	Unknown	More than 53,000	Unknown.

If it is asked whether densities so high as these can really exist at the centres of the stars, the answer is provided by the companion to Sirius (Sirius B). Direct observation has shown that the *mean* density of this star is about 53,000, and the central density must of course be higher. Incidentally, as Eddington has remarked, this provides striking confirmation of our view that stellar matter consists of atoms broken up into their fundamental constituents. It is impossible to compress matter formed of complete atoms of radii 10^{-8} cm. or more to anything approaching these high densities, but there is no difficulty as regards minute nuclei and electrons of radii of the order of 10^{-13} cm.

It has to be admitted that many of the entries in the table are highly conjectural, and few can claim any great accuracy. But while many astronomers may prefer different values for individual entries in the table, I doubt if any would seriously challenge the general contention that a star's energy-generating capacity depends primarily on its age, and not, at any rate primarily, on its central temperature or density.

No doubt exceptions to the general rule can be found. An extreme example is provided by the earth and sun; the matter of which these two bodies are formed must be of the same ultimate age, yet they radiate at very different rates per unit mass. This is readily explained if we suppose the heavy atoms from which the sun's energy originates to have sunk deep into its interior, and so not to have entered into the composition of the earth and planets: a similar explanation will account for the different radiating capacities of the components of binary systems. But these exceptions result from special conditions prevailing in special cases; they do not affect the general law that a star's generation of energy is not determined by either its density or its temperature.

The accompanying table shows that the law is well supported by observational astronomy; it can also be reached from a theoretical study of the actual process of generation of energy in a star. A mass of evidence, mostly dynamical, indicates that the stars must have existed for millions of millions of years. To take one example, newly formed binary stars have circular, or nearly circular, orbits; this is a consequence of the manner of their formation. Every gravitational pull on a circular orbit tends to make the orbit more elliptical, so that the older a binary star is, the more elliptical its orbit ought to be. This is actually found to be the case. But from our general knowledge of the number and masses of the stars wandering about in space, we can estimate the rates at which the ellipticities of the orbits of binary stars ought to increase, and this in turn makes it possible to estimate the ages of actual stars. It is a mere problem of dynamics, and the answer comes out in millions of millions of years.

We can now estimate the total amount of radiation which must have been emitted by particular stars in the millions of millions of years they have existed; and, except in the case of the youngest stars of all, the total mass of this radiation is found to be far greater than the present mass of the star. We obtain the mass of the star at its birth by adding the mass of all this radiation to that of the matter now remaining in the star. Thus its mass at birth must have been far greater than now. But, as a star's mass at any instant consists almost wholly of the mass of the matter of which it is composed, we see that the greater part of the matter contained in the original star has ceased to exist as matter; it has been annihilated and transformed into radiation which the star has radiated away into space. So far back as 1904 (NATURE, 70, p. 101) I put out the suggestion that energy might be created by the annihilation of matter; it now appears that this process must in actual truth be the source of the energy emitted by the sun and stars. Throughout a star's interior, electrons and protons must at intervals fall into one another and mutually destroy one another, the energy of their fall being set free as radiation.

The energy of this fall is enormous, being sufficient to set both the masses involved into motion with a velocity of 0·866 times that of light. In no other way can a given mass of matter be made to yield energy of amount comparable with this; for example, whereas the ordinary combustion of a ton of coal provides energy enough to drive an express locomotive for an hour, the annihilation of a ton of coal would provide enough energy for all the heating, lighting, power, and transport in Great Britain for a century.

Each proton or atom, as it is annihilated, makes a splash of radiant energy which travels through the star until, after innumerable absorptions and re-emissions, it reaches the star's surface and wanders off into space. Each splash is similar to the splashes produced by radioactive material in the spinthariscope, except for being many thousands of times more powerful. The great energy of the splashes is to some extent counterbalanced by their rarity. In the sun, for example, only about one atom in every 10^{17} annihilates itself each hour. A cubic centimetre of the sun's mass contains, let us say, 10^{22} atoms, and of these about 100,000 are annihilated every hour. The energy produced in a cubic centimetre of the sun's mass is thus not very great, averaging about 9400 ergs or 0·00022 calories per hour; the enormous flow of energy from the sun's surface results from the fact that all the energy produced in a cone 433,000 miles in depth has to stream out through the mouth of this cone.

Such, in brief, is the mechanism by which stellar energy is generated. The question immediately before us is whether this generation of energy proceeds more merrily, whether the electrons and protons fall into one another more frequently, when the stellar matter is in a state of high temperature and high density.

It is a matter of direct observation that ordinary radioactive processes cannot be either inhibited or intensified by such temperatures as are available in the laboratory; the quantum theory provides the reason. Einstein has shown how a sub-atomic generation of radiation can occur in either of two ways, spontaneously or through the stimulus of incident radiation, and it is easy to calculate the temperature at which the second process becomes operative. It is found that the quantum of radiation at this temperature must have energy equal to the energy set free by the sub-atomic change in question. The temperature necessary to expedite the disintegration of uranium is in this way found to be of the order of 120,000 million degrees, and it at once becomes clear why warming up uranium in the laboratory cannot speed up its disintegration. A similar calculation shows that the temperature necessary to influence the rate of sub-atomic annihilation of matter is of the order of 7,500,000 million degrees. It may be argued that a lower temperature, although not adequate to bring about the actual annihilation of matter, might set up sub-atomic processes of adequate intensity. This is true as regards a star's momentary radiation, but such processes cannot provide an adequate duration for the radiation. All processes which are affected by temperatures of less than about 7,500,000 million degrees leave the total number of electrons and the total number of protons in a star unaltered, whereas the whole evidence of astronomy is that the number of electrons and protons in a star must continually decrease.

With this figure before us, it is clear that the comparatively feeble stellar temperatures of less than a thousand million degrees must be quite inoperative in regard to the main generation of stellar energy; indeed the heat of the hottest of stellar interiors can have no more influence on the rate of annihilation of matter than a warm summer's day has on the rate of disintegration of uranium. Thus it seems abundantly clear that what is annihilating the matter of the stars is neither heat nor cold, neither high density nor low, but merely the passage of time.

These considerations notwithstanding, it has been suggested by Russell (NATURE, Aug. 8, 1925), whose ideas were afterwards adopted by Eddington (NATURE, May 1, 1926), that the annihilation of matter (which they agree to be the ultimate source of stellar radiation) may be produced by the raising of ordinary matter to a critical temperature of some 30 or 40 million degrees. Russell suggests that matter is, broadly speaking, inert until it reaches this critical temperature, when an unlimited transformation of matter into radiation suddenly takes place.

In addition to running foul of the physical principles just explained, this suggestion encounters the difficulty that the generation of energy it provides would not only be unlimited but also illimitable; when once it began there would be no stopping it. The proposal of Russell and Eddington would, in effect, make matter thermodynamically unstable at stellar temperatures by endowing it with the properties of an explosive at its flash-point. When once stellar matter reached its flash-point, its resulting annihilation would generate so much heat that the adjacent matter would also in turn be raised to the flash-point, and the whole star would almost instantaneously explode into radiation. The sky would show no steady star-light, but merely a succession of apparitions of novæ of the most terrifying kind, as the various stars reached their flash-points and 'popped off' in turn. In spite of the astronomical eminence of its father and stepfather, I, for one, find it impossible to accept a hypothesis which is not only contrary to the general principles of physics, but also against which the very stars fight in their courses.

A general mathematical discussion of the stability problem shows that a star built of matter the rate of generation of energy of which is absolutely unaffected by changes of temperature and density, will be dynamically stable. But such a star, although stable, has not much stability to spare. If we change the properties of our stellar matter in the sense of making an increase of temperature increase the rate of generation of energy, we lessen the already small margin of stability. Any substantial step in this direction would render the star dynamically unstable.

Combining this purely dynamical result with the physical principles already explained, it becomes clear that we may, to a good first approximation at least, suppose that an increase in the temperature of stellar matter produces no increase at all in its rate of generation of energy.

Stellar radiation must either originate in types of matter known to us on earth or else in other and unknown types. When once it is accepted that high temperature and density can do nothing to accelerate the generation of radiation by ordinary matter, it becomes clear that stellar radiation cannot originate in types of matter known to us on earth. Other types of matter must exist and, unless physics and chemistry have gone very far astray in recent years, these other types can only be elements of higher atomic weight than uranium. The significance of the calculation which showed that stellar atomic weights are, in the main, higher than that of uranium now becomes apparent.

Recapitulation and Interpretation of Results.

We have now reached the conclusion, by three distinct paths, that the atomic weights of stellar atoms must in the main be higher than that of uranium :

(1) By direct calculations from Kramers' formula.

(2) From the consideration that the atoms near the centre of a star must be substantially heavier than those near its surface.

(3) From the consideration that atoms of atomic weight less than uranium, no matter how much they were heated or compressed, could not provide the intense and lasting radiation emitted by the stars.

The atomic weights of stellar atoms are not only found to be higher than that of uranium, but also they vary systematically from star to star. In brief, the youngest stars are found to have the highest atomic weights, and with this clue all the pieces of the puzzle are found to fit together.

We have to suppose that matter in its earliest state consists of a mixture of elements of different atomic weights, those elements the atomic weights of which are highest having the greatest capacity for the spontaneous generation of radiation by annihilating themselves, and, in consequence, having the shortest lives. These elements will be the first to disappear as the star ages, their disappearance reducing not only the mean atomic weight in the star but also the mean rate of radiation per unit mass, since these heavy elements are the most energetic radiators. Just as, on the coast, the hardest rocks survive for longest the disintegrating action of the sea, so in a star the lightest elements survive for longest the disintegrating action of time, so that ultimately the star contains only the lightest elements of all and so has lost all radiating power. Our terrestrial elements have so little capacity for spontaneous transformation that they may properly be described as 'permanent.' Calculation shows that if they underwent any appreciable transformation in periods comparable with the life of a star (say 10^{13} years) the spontaneous generation of heat by the earth's mass would make the earth too hot for human habitation. The radioactive elements are of course an exception; they probably represent the last surviving vestiges of more vigorous primeval matter, and so form a bridge between the inert permanent elements and the heavier and shorter-lived elements of the stars.

An interesting question is whether the heavy atoms change into radiation instantaneously, or only through successive stages of transformation. Astronomical evidence makes it fairly certain that the most massive stars contain more atoms than our sun, there being a wider range in the weights of the stars than in the atomic weights of their atoms. As these stars must in time become reduced to the mass of our sun, the process of evolution clearly calls for an actual annihilation of atoms; it is not enough to postulate a mere gradual decrease in the atomic weight of each atom until it ends as a permanent atom. Radioactivity suggests that this latter process may also occur, but the evidence of astronomy is that it is at best a subsidiary process.

The number of 'permanent' atoms in a massive star such as Antares or V Puppis cannot undergo any perceptible diminution in the next 10^{13} years, so that they must all survive in the final star of mass perhaps only a fiftieth of that of the present star. Thus some ninety-eight per cent. of the present masses of these stars must consist of non-permanent atoms. To put it in another way, the present mass of a star such as Antares or V Puppis must consist, as regards 98 per cent., of atoms which are destined to change into radiation, and as regards only 2 per cent., of atoms which cannot change into radiation. Clearly the primary matter of the universe must be of non-permanent type; our terrestrial atoms are a mere residue of non-transformable ashes. Like the animalculæ of the raindrop looking out on to Niagara, we discern that our physics and chemistry are only the fringes of far-reaching sciences; beyond the seashore we have explored in our laboratories lies the ocean the existence of which we are only just beginning to suspect.

We are thus led to picture the youngest stars as formed of matter practically all of which is unknown on earth, being of atomic weight higher than that of uranium. This possesses the capacity of annihilating itself spontaneously, the energy produced in the process being set free as radiation. Its rate of generation of energy, as estimated from the luminosities of the youngest stars, is of the order of 1000 ergs per gram per second. As the annihilation of 1 gram of matter produces 9×10^{20} ergs of energy, the matter must have a 'period of decay' of 9×10^{17} seconds, or about 30,000 million years. As the star ages, and only less transformable matter remains, the period of decay is correspondingly lengthened. The matter in the sun, radiating 2 ergs per gram per second, must have a period of decay of 15,000,000 million years. It is these periods of decay which determine the rates of evolution and length of life of the stars. Broadly speaking, a star lasts as long as the atoms of which it is composed, and the lives of these atoms are constants of Nature.

We notice that the periods of decay of stellar atoms are long compared with the periods of ordinary radioactive decay, suggesting that the radioactive elements are mere transitory formations in the evolution of the elements.

The Critical Central Temperature.

A group of stars selected for having approximately equal masses—as, for example, the sun, Procyon, and the two components of α Centauri—might be expected *a priori* to have very different rates of generation of energy, with the result that the stars would have very different surface temperatures and also very different central temperatures. Indeed, on first approaching the question, the whole range of temperatures from zero to infinity would seem to be open for each of these quantities. Yet in actual fact the surface temperatures of the four stars mentioned, as also of all stars of the same mass, lie within the narrow range between 3700 and 8300 degrees; their central temperatures probably lie within the range from 15 to 100 million degrees. For stars of other masses the limits are different, and are substantially wider for stars of great mass. But the stars of any definite mass always show a definite upper limit of temperature, both for the surface temperature and for the central temperature. These limits are never exceeded, but the majority of stars of the particular mass in question seem to crowd towards them. The existence of one limit of course implies the existence of the other, and it seems likely that the limit to the central temperature is the more fundamental. Stars having the same mass as our sun never have central temperatures higher than 80 million degrees, while the majority have central temperatures not very far below 80 million degrees. For stars twenty times as massive as our sun, the corresponding limit is probably somewhere about 300 million degrees, while there are intermediate limits for stars of intermediate mass.

This is obviously one of the fundamental facts of physical astronomy: What does it mean? The normal event for a star like V Puppis, losing mass and capacity for generation of energy together, would be a gradual shrinkage of size accompanied by a steady increase of central temperature. What is it that checks this normal course of evolution so soon as the central temperature touches 300 million degrees?

I have recently suggested that the upper limit of temperature for any star is simply that at which its central atoms begin to be stripped nearly or entirely bare of electrons. This is merely a matter of simple calculation, but we have to suppose the atoms at the star's centre to have the high atomic weights which other considerations, as we have seen, assign to them. For example, a temperature of 300 million degrees suffices to strip the last electrons off atoms of atomic weight 300 or more. The fall in the critical central temperature as a star gets older and less massive is, on this view, a direct consequence of the decrease in the atomic weight of the stellar material, which occurs as the heaviest atoms gradually annihilate themselves.

It remains to explain why this temperature constitutes an upper limit, why a star cannot go on getting hotter after its innermost atoms are stripped bare of electrons. So far as I can see, only one answer is possible: the stripping of the electrons from an atom must remove its power of annihilating itself, and so must inhibit its capacity for generating radiation. The central atoms of the star now act precisely like the governor of a steam engine, regulating the generation of energy so that the central temperature is kept close to the critical temperature. If the star begins to get too hot, the central atoms become stripped bare of electrons, and so leave off generating energy. The star then begins to cool off, and as it does so the atoms reform and resume their generation of energy, again heating up the star. The mechanism provides a perfect thermostat, and it is easily shown that its action is stable. As a star ages the heavier atoms at its centre are the first to be transformed into radiation and so to disappear; their place is taken by lighter atoms, and as a lower temperature suffices to strip these lighter atoms bare of electrons, the critical central temperature of the star falls.

An interesting confirmation of this hypothesis is provided by the components of newly formed binaries. These have the high energy-generating capacity per unit mass of young stars, associated with the small mass appropriate to much older stars. Clearly the 'governor' action ought to be particularly active in checking the generation of energy in these stars, so that they ought to have central temperatures close up to the maximum for their mass. This is in actual fact found to be the case.

All the evidence at present available points to the annihilation of matter being a quantum phenomenon; possibly it represents nothing more than the spontaneous drop of an electron to a zero-quantum orbit. This would suggest an explanation of why bare nuclei and free electrons should be immune from annihilation, and hence why atoms stripped bare of electrons cannot generate energy.

Highly-penetrating Radiation.

If our earth exhibits only one end of the chain of chemical elements, where shall we look for the other end? Moving backwards along the evolutionary sequence we come to younger and yet younger stars, containing elements of higher and higher atomic weight. Passing beyond the stars altogether we come to the nebulæ; here we ought to find the elements of highest atomic weight of all, and the matter of greatest radiating capacity.

Visually the nebulæ are extremely faint objects; their emission of visual radiation per unit mass is only about equal to that of our sun. There is, however, an essential difference between the radiation generated in the stars and that generated in the nebulæ. Radiation, when first generated, must have enormous penetrating power; the simultaneous annihilation of a single electron and proton produces radiation of wave-length only $1{\cdot}3 \times 10^{-13}$ cm. The high penetrating power of this short wave-length radiation, nevertheless, only suffices to carry it through a small fraction of the radius of a star, and successive absorptions and re-emissions soften it, by a sort of generalised Compton effect, until it finally emerges from the surface of the star as ordinary temperature radiation. The density of the nebulæ is, however, so much lower than that of the stars that similar radiation, when generated inside a nebula, passes almost unchecked directly into outer space. Here and there the radiation may devastate isolated atoms in its passage, ejecting a few million-volt electrons in the process, but the majority of it will pass on unhindered until it meets a medium of substantial absorbing powers. Thus we should expect the atmospheres of the stars, sun, and earth, and even the solid body of the earth, to be under continual bombardment by highly-penetrating radiation of nebular origin.

Such radiation has been detected in the earth's atmosphere by Kolhörster, Millikan, and many others, who are satisfied that it is of extra-terrestrial origin. If it originated in the stars, the amount received would depend largely upon the position of the sun. As it does not, the radiation must originate in nebulæ or cosmic masses other than stars. Quite recently (Nature, October 9, 1926), Kolhörster and von Salis have found that its intensity varies with the position of cosmic masses, in a way which indicates that the radiation is received largely from regions near the Milky Way, especially the regions of Andromeda and Hercules.

I have calculated that the total amount of highly-penetrating radiation actually received is of the order of twice that which ought to be received from the Andromeda nebula alone (Nature, December 12, 1925) if this consisted solely of matter of the same radiating power as the very youngest of the stars. Clearly the total amount of radiation which is observed to be received on earth is of the right order of magnitude; it is, moreover, so large that it is difficult to imagine any possible origin for it other than that just mentioned. Its penetrating power appears to be rather less than might have been expected if it originated in the actual annihilation of electrons and protons, but I do not think the difficulty, if it exists, is insuperable. Quite recently Rosseland (*Astro. Jour.*, May 1926) has suggested that bombardment by this radiation may be the cause of the observed bright lines in stellar spectra; I had previously (Nature, December 12, 1925) suggested a similar origin for the luminosity of the irregular nebulæ.

There is a temptation to try to probe still further into the physics of the nebulæ, to try to understand the properties of matter in its still earlier forms, perhaps even to get a glimpse of it in the actual process of creation. But to yield to this temptation would carry us too far into the realms of conjecture and speculation. So far the course of our argument has not depended on either conjecture or speculation. Where there has appeared at first to be a choice of ways, all ways except one have proved on further examination to be prohibited either by observational knowledge or by well-established principles of physics or dynamics: there has never been any real choice. For this reason the conclusions we have reached, although certainly novel and perhaps unexpected, appear to me to be, in their main lines, inevitable; I can see no means of escape.

Life and the Universe.

A general survey of the results obtained by cosmical physics has suggested that terrestrial laboratory physics is a mere tail-end of the general science of physics. The primary physical process of the universe is the conversion of matter into radiation, a process which did not come within our terrestrial purview at all until 1904. The primary matter of the universe consists of highly dissociated atoms, a state of matter which, again, was not contemplated before 1917. The primary radiation of the universe is not visible light, but short-wave radiation of a hardness which would have seemed incredible at the beginning of the present century. Indeed, our whole knowledge of the really fundamental physical conditions of the universe in which we live is a growth of the last quarter of a century.

The simple explanation of this situation is to be found in the fact that life, naturally enough, begins its exploration of Nature by studying the conditions which immediately surround it; the study of the general conditions of the universe as a whole is a far more difficult task which life on this planet is only now approaching. Now the physical conditions under which life is possible form only a tiny fraction of the range of physical conditions which prevail in the universe as a whole. The very concept of life implies duration in time; there can be no life where the atoms change their make-up millions of times a second and no pair of atoms can ever become joined together. It also implies a certain mobility in space, and these two implications restrict life to the small range of physical conditions in which the liquid state is possible. Our survey of the universe has shown how small this range is in comparison with the range of the whole universe. Primeval matter must go on transforming itself into radiation for millions of millions of years to produce an infinitesimal amount of the inert ash on which life can exist. Even then, this residue of ash must not be too hot or too cold, or life will be impossible. It is difficult to imagine life of any high order except on planets warmed by a sun, and even after a star has lived its life of millions of millions of years, the chance, so far as we can calculate it, is still about a hundred thousand to one against its being a sun surrounded by planets. In every respect—space, time, physical conditions—life is limited to an almost inconceivably small corner of the universe.

What, then, is life? Is it the final climax towards which the whole creation moves, for which the millions of millions of years of transformation of matter in uninhabited stars and nebulæ, and of waste radiation into desert space, have been only an incredibly extravagant preparation? Or is it a mere accidental and possibly quite unimportant by-product of natural processes, which have some other and more stupendous end in view? Or, to glance at a still more modest line of thought, is it of the nature of a disease which affects matter in its old age, when it has lost the high temperature and capacity for generating high-frequency radiation with which younger and more vigorous matter would at once destroy life? Or, throwing humility aside, is it the only reality, which creates, instead of being created by, the colossal masses of the stars and nebulæ and the almost inconceivably long vistas of astronomical time? There are too many ways even to enumerate of interpreting the conclusions we have reached; I do not, however, think there is any one way of evading them.

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