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Lord Grey's Bill for the Protection of Wild Birds.

WE have now for many years had legislation in Great Britain for the protection of wild birds, in addition to the much older laws relating only to game. The desirability for such protection has received increasing recognition on humanitarian and æsthetic grounds, and it is also to be hoped that there is a growing realisation of the importance of the subject from an economic point of view. The different Acts which have successively been placed on the Statute Book have had varying merit as judged by the wisdom of their intentions, but where they have all so lamentably failed is in their ineffectiveness. This grave fault has been remedied in the wise measure which Viscount Grey of Fallodon has introduced into the House of Lords, and, although his Bill has many other good points, it is probably on that ground that we should chiefly welcome it. The Bill was read a third time on July 30, and a copy of it, as amended in committee, is before us. It is greatly to be hoped that the House of Commons will similarly pass the measure next session.

The Bill aims at the repeal of all existing enactments on the subject, and at making complete provision on the new lines recommended in 1919 by the Departmental Committee on the Protection of Wild Birds. All birds to which the Bill applies—that is to say, all wild birds other than grouse, ptarmigan, partridges, pheasants, and black game—are divided into three categories, each of which is to receive its appropriate degree of protection, as follows:

Category I.—Birds in this group, and their nests and eggs, are to be protected absolutely at all times and places.

Category II.—Birds in this group, and their nests and eggs, are to be protected absolutely during the close season from the 1st March to the 31st July. (The Woodcock is to be protected from the 1st February to the 31st August, and the owners or occupiers of land may take the eggs of the Lapwing thereon up to the 15th April.)

Category III.—Birds in this group, but not their nests and eggs, are to be protected during the close season from the 1st March to the 31st July except against the owners or occupiers of the land concerned and their accredited agents.

The birds included in the first and second categories respectively are listed in the schedules to the Bill, and the third category includes all the other birds. Roughly speaking, the birds in the first category are either species which are relatively rare or species of great usefulness, such as the owls, which it is desirable to encourage. Those in the second category are species which have not been considered quite worthy of the first but require special protection during the breeding

season. The Home Secretary or the Secretary for Scotland, as the case may be, is to be given power to transfer birds from one category to another or to change the dates of the close season. He may do this by general order or, with the consent of the local authorities, by local order affecting only a particular district; and with the consent of the owner and occupier of the land he may make a special order in support of an endeavour to create a bird sanctuary, even to the extent of giving all birds in the sanctuary the full protection of Category I. In exercising these functions the Secretary of State is to be assisted by an advisory committee.

The Bill also contains a number of special provisions, some of which are new and others of which are retained from existing enactments. The use of certain types of trap is to be prohibited altogether; the use of mechanically propelled boats or of aircraft is to be prohibited as an aid to killing or capturing birds; the capture of birds on highways, commons, and public places is to be prohibited; the killing or capture of birds on Sunday is to be prohibited; and the catching of birds alive is to be prohibited except under licence granted by the competent local authority. Lastly, the liberation of imported birds is to be permissible only with the authority of the Secretary of State, a wise provision aimed at the prevention of interference with the balance of nature.

The great advance in legislation of this kind which is marked by this Bill, however, lies in its application not only to offenders caught red-handed but also to all persons found in possession of birds, parts of birds, nests, or eggs which may be presumed to have been illegally taken. The onus of proof is to be thrown wholly on the possessor in the case of birds, nests, or eggs in Category I. and nests or eggs in Category II., and also in other cases during the whole of the close season except its first fortnight. Further, every taxidermist and dealer is to be compelled to keep a register giving all particulars of specimens passing through his hands which come under Categories I. and II. If this measure becomes law we may therefore hope to see an end of the scandal that the skins and eggs of some of our rarest and most strictly protected birds may be seen openly displayed in the taxidermists' windows or publicly advertised in the catalogues of dealers. Similarly, it will become an offence to sell or possess "plovers' eggs" after April 20 (allowing five days' grace from the beginning of the close season specially determined as regards the taking of these eggs).

The Secretary of State is to be empowered to grant special licences to kill or take protected birds or to take their eggs or nests either for scientific purposes, for the protection of crops, property or fisheries, or for other special reasons. The potential exemption from the law in favour of scientific purposes is a useful new provision, but it is to be hoped that the power will be very sparingly exercised in view of the great amount of useless collecting, especially of eggs, which masquerades under the name of science.

The Capillary Blood-Vessels.

The Anatomy and Physiology of Capillaries. By Prof. August Krogh. (Silliman Memorial Lectures.) Pp. xvii+276. (New Haven: Yale University Press; London: Oxford University Press, 1922.) 13*s.* 6*d.* net.

EVERY cell of the body is brought into material relationship with all other cells in virtue of the existence of a common medium, the blood, which is maintained in constant circulation throughout the body. Substances absorbed into the blood from the exterior, either through the external or internal surfaces of the body, are thus brought round and presented to every cell, to be taken up or rejected according to the needs of the latter. In the same way the products of the chemical changes occurring in any cell are distributed to all other cells, so that the blood represents the internal environment integrating the metabolic activities of all parts of the body. The interchange between blood and tissues takes place only in the capillaries and smaller veins, so that we may say that the whole vascular system—heart, arteries, and veins—exists to ensure an adequate passage of blood through the capillaries. It is therefore rather surprising that the physiology of the capillaries has been comparatively neglected until the last few years. There have been isolated observations with regard to their structure and contractility and the properties of their walls. Some twenty-five years ago, when the question of lymph production and absorption was brought into prominence by the researches of Heidenhain, the functions of the cells forming the capillary walls were hotly debated, but after a few years, interest in the matter died down, and physiologists failed to appreciate or to follow up the many other problems concerning the capillaries which were implicit in the problems of lymph production.

By a study of injected specimens, or of the circulation in the lung or web of the frog, it can be seen that an arteriole breaks up into a large number of capillaries, each of which may have a diameter approximating to that of the arteriole. The relations in this part of the circulation have thus often been compared to those in a narrow stream flowing into a lake, and it has been tacitly assumed that the circulation through the capillary network as well as the state of dilatation

of the vessels forming this network were simply functions of the general blood pressure driving blood through the arteriole and of the state of contraction of the arteriole itself.

In reading the views on the circulation which were general before the discoveries of Harvey, we are often filled with astonishment that men endowed with mighty intellects, like Leonardo da Vinci, could not see what seems to us so self-evident. It is difficult to comprehend how any one could dissect the heart and be familiar with the effects of wounds of different parts of the body and fail to perceive the meaning of the valves in the heart and the course of blood through this organ. Yet we ourselves every day are equally blind. It is self-evident that the colour, say, of the skin, depends not on the amount of blood in the small arterioles but on the fulness of the capillaries. Every one knows that the capillaries may be overfilled together with constricted arterioles, giving rise to blue cold skin, or that the capillaries may be less full but with a vigorous circulation through dilated arterioles, so that the skin is warm and of the normal colour. These two observations should be sufficient to show that the state of dilatation of the capillaries is not dependent only on the condition of the arteries. Even a lifetime devoted to science and research seems incapable of preventing us from accepting familiar appearances without trying to understand them. It is not until some one puts a definite question and our curiosity is aroused that we become aware of a problem to be solved. In science it is the question that matters: the solution can always be found.

The recrudescence of interest in the capillaries occurred suddenly, many observers being led to the subject by the most diverse considerations. Among these Ebbecke was perhaps the most directly interested in the capillaries themselves. H. H. Dale was led to infer independent changes in the capillaries from his observations on the effects of histamine. Krogh, continuing his researches on respiration, found it necessary to consider the volume of the capillary circulation required for supplying sufficient oxygen to the working tissues. Then, during the War, the committee appointed by the Medical Research Council to investigate the causation of surgical shock was led to ascribe the main part in the production of this condition to the abnormally dilated state of the capillaries. Thus from all sides the attention of physiologists was focussed on these structures. As a result we can boast of a very large accession to our knowledge not only of the capillaries but also of the factors determining the supply of blood to the tissues under varying conditions.

The volume under review, by the man who has perhaps done more than any single physiologist to advance our knowledge of the capillaries, not only gives a connected account of our present knowledge, but also adds to this a large amount of original work which has been previously unpublished. Prof. Krogh starts with an account of the anatomy and distribution of the capillaries. He shows that in muscle, for example, the number of capillaries which are open varies from time to time according to the activity of the muscle. In a muscle of the horse there are about 1350 capillaries in every square millimetre of transverse section. The transverse section of an ordinary pin is about half a square millimetre. We get an idea of the extraordinary subdivision of the blood supply within a working tissue when we consider that within a structure of the size of a pin there are 700 parallel tubes carrying blood, in addition to about 200 muscle fibres. In smaller mammals, such as a guinea-pig, the maximum number of capillaries per square millimetre is about 4000. This means that an enormous surface of blood is available for interchange to take place with the tissue cells. Krogh makes the following calculation: "Supposing a man's muscles to weigh 50 kilograms and his capillaries to number 2000 per square millimetre, the total length of all these tubes put together must be something like 100,000 kilometres or two and a half times round the globe, and their total surface 6300 square metres."

The author makes a plea for further work on these lines. There is a rich field for the anatomists in such quantitative anatomy, especially if the problems attacked are chosen according to their importance for the normal functions of the body.

Krogh then shows by various means that the capillaries are endowed with an independent power of contractility, and that this is due to the existence of special kinds of muscle cells present in all capillaries and apposed to the outside of their thin endothelial wall. It is noteworthy that these cells were described so long ago as 1873 by Rouget, but the observation was disregarded and soon forgotten.

In the following lecture the author deals with the innervation of the capillaries. Here again histologists long ago described a rich supply of fine non-medullated nerve fibres, but the physiological significance of these fibres has been revealed only in the last few years. The innervation of the capillaries is of two kinds. In most cases stimulation of the sympathetic provokes contraction. They are also under the influence of the antidromic impulses, which cause dilatation, and, as Bayliss has shown, can be excited in the sensory fibres of the posterior root

and peripheral nerves. It seems that at their periphery these sensory fibres form a branching network, which in some of its functions resembles the diffuse superficial nerve network so widely distributed in the invertebrata. Stimulation of the surface, especially if painful, causes a dilatation of capillaries and small arteries which spreads for some distance round the stimulated spot. There is no evidence that nerve cells are involved in this local reflex, which is therefore regarded as an 'axon reflex.' The redness produced by the application of mustard to the skin is an example of this kind of reaction. If pronounced it may go on to the production of increased transudation of fluid from the affected capillaries and to the appearance of a blister.

After dealing with the local response of the capillary wall to mechanical and chemical stimulation, Krogh proceeds by a series of carefully thought out experiments to the demonstration that, throughout life, the calibre of the capillaries is regulated by some diffusible substance present in the blood, and he tracks this substance finally down to the internal secretion of the posterior lobe of the pituitary body. Perfusion of a frog's limb with Ringer's fluid causes wide dilatation of the capillaries and production of dropsy. If, however, the minutest trace of the pituitary hormone is added to the perfusion fluid, the capillaries retain their normal size and no œdema results.

Having arrived in this way at a knowledge of the factors affecting the calibre of the capillaries and the volume of the flow through the capillaries in any part, Krogh then proceeds to consider the bearing of these results on the main functions of the capillaries, namely, the nutrition of the tissues, the giving off of oxygen from blood to tissue cells, the taking up of carbon dioxide, the exchange of dissolved substances, and the production and absorption of lymph. In a final chapter he deals with various miscellaneous questions closely associated so far as regards their mechanism, such as the production and absorption of intra-ocular fluid, the condition known as surgical shock, and the causation of weals and urticaria under the influence of poisons or in persons of the so-called 'vaso-neurotic' disposition.

It is impossible within the limits of a review to do justice to the wealth of new facts and points of view brought out in the course of these lectures. We feel from the outset that we are starting on a voyage of exploration with the author. In every new step our curiosity is aroused before we are presented with the solution. At the same time we are conscious of the intellectual dangers which beset the explorer in these fields. The author states: "The problems of physiology are so complicated that, to put it tersely, one cannot expect to be able to reason correctly from the facts for more than five minutes at a stretch"—a healthy state of mind and very similar to that expressed by Harvey when he says that he "began to think with Frascatorius that the movement of the heart was known to God alone." But such difficulties and dangers only add to the joy of the chase, and we read the book with somewhat the same fascination and interest that our forefathers must have felt when presented with the immortal treatise of Harvey.

The book is written clearly and simply. We can conceive no better book to put into the hands of a student to arouse his interest in the advancing fringe of physiological knowledge and to acquaint him to some extent with the joy and spirit of research.

E. H. STARLING.

Thermodynamics and Chemistry.

(1) *Thermodynamics and the Free Energy of Chemical Substances*. By Prof. Gilbert Newton Lewis and Prof. Merle Randall. Pp. xxiii+653. (London: McGraw-Hill Publishing Co., Ltd., 1923.) 25*s*.

(2) *Theoretical Chemistry from the Standpoint of Avogadro's Rule and Thermodynamics*. By Prof. W. Nernst. Fifth edition. Revised in accordance with the eighth-tenth German edition, by L. W. Codd. Pp. xx+922. (London: Macmillan and Co., Ltd., 1923.) 28*s*. net.

(1) FOR many years back the published researches of G. N. Lewis and his collaborators have occupied a prominent place in the branch of science dealing with the application of thermodynamics to the solution of chemical problems. The book now under review, of which he and his co-worker, Merle Randall, are joint authors, collects and summarises these researches and places them in position in the general framework of thermodynamics. For this alone all interested in matters pertaining to physico-chemical theory would owe them thanks, but the debt is increased by the fact that no better account of modern chemical thermodynamics than appears in this book can be placed in the hands of advanced students.

The treatment, while remaining in some ways conventional, has an individual freshness which makes the volume much more readable and interesting than most treatises on the subject. The material is divided into three parts, the first treating of the foundations of thermodynamics, the second dealing with the special methods of applying the fundamental principles to chemical problems, and the third being devoted to a systematic consideration of the data of thermodynamic chemistry. As might be expected, the notions of

"fugacity," "escaping tendency," and "activity" play a great part in the authors' development of the thermodynamics of simple substances and solutions, both non-conducting and electrolytic. The galvanic cell and single potentials receive adequate treatment, and a long chapter is devoted to the Third Thermodynamic Principle and the Chemical Constants of Nernst. The chapters of the last section of the book deal systematically with the entropies or free energies of chemical elements and their chief compounds. It is in this section that the book differs essentially from all its predecessors. So far as data are available they are utilised to calculate the changes in free energy attending important chemical reactions. Thus, under the heading "water" there is discussed the free energy of formation of water (*a*) from measurements of its dissociation at high temperatures, (*b*) from the dissociation of silver oxide, (*c*) from the dissociation of mercuric oxide, and (*d*) from the equilibrium of the Deacon process. Based on the mean of the independent and concordant values obtained by these four methods, a final value for the free energy of formation of liquid water is given. The free energy changes in the vaporisation and solidification of water are discussed, and finally the free energy of formation of the hydroxide ion. A table is given of standard free energies of formation at 25°, together with instructions for its use and numerous examples.

While admiring the skill and clearness with which many abstruse conceptions are brought before the reader, we must direct attention to a statement which, if not exactly erroneous, is certainly misleading. The authors (p. 115), after defining change of entropy, say: "Thus entropy has the same dimensions as heat capacity, and may be expressed in calories per degree." Again (p. 144), calculating the difference of entropy between solid and liquid mercury at the constant temperature of its freezing-point, they say: "We have from Equation (1) $\Delta S = \Delta H/T$. If ΔH is the heat of fusion of one mol, namely 560 cal., and T is 234·1, we may write $\Delta S_{234\cdot1} = 560/234\cdot1 = 2\cdot39$ cal. per deg." Surely there is an essential difference between $\Delta H/\Delta T$ (heat capacity) and $\Delta H/T$ (entropy); and surely the words "per degree" imply that the temperature is variable, which is here not the case. Such minor lapses as the above are most infrequent, and we have nothing but praise for the book in general. The formulæ are clear, and the notation employed is consistent, although not always in accordance with the table of International Physico-chemical Symbols. A good index is a valuable adjunct to the volume.

(2) A cordial welcome will be given to the new edition of Nernst's "Theoretical Chemistry." Written by one who is a master of research and of exposition, the book has been the guide of many generations of serious physico-chemical students, and nothing better of its type is ever likely to appear. It is not everywhere easy reading, but close study of the text will always provide an ample reward. In the present edition the chapters on radioactivity and the theory of the solid state have been largely rewritten, and sections have been added dealing with the structure of atoms and the application of X-rays to the determination of molecular dimensions. The translator, by not following the German text too slavishly, has provided a version which is both readable and accurate, though finer shades of meaning are not always faithfully reproduced: thus (p. 767) *Zusammenbacken* is translated by *solidification*, (p. 885) *Wechselwirkung* by *conversion*, (p. 874) *höchstwahrscheinlich* by *certainly*. It might be worth the attention of the publishers to consider the use in future editions of italic letters for algebraic quantities, as in the German original, instead of Roman letters, as in this translation. The former catch the eye better and facilitate reading.

A Scientific Introduction to Biology.

Elements of Plant Biology. By A. G. Tansley. Pp. 410. (London: G. Allen and Unwin, Ltd., 1922.) 10*s*. 6*d*. net.

TO write a text-book of botany is nowadays no easy task. The subject itself has grown in many directions, and it demands some knowledge of all the main branches of science as a preliminary to tackling even the simpler problems with which it confronts the student. A book intended for use in junior classes in a university must obviously then be the outcome of careful sifting and artistic synthesis of raw material if it is to be of any real value, and especially is this true when the demands of the student of medicine have to be satisfied. Botany, properly presented, forms perhaps the best introduction to biology for the purpose of the medical student, but how often when he has asked for bread has he been put off with unprofitable and altogether unattractive stones!

A modern introduction to botany ought to aim at affording some real insight into the working mechanism of life, and to make it possible to understand, at any rate, the more outstanding features of that mechanism as it behaves when in action. The machinery is vastly complex, and we have only been able as yet to certainly know fragments of the factory-processes that go on so swiftly and so smoothly within the plant cell. But it is possible, even now, to pick out and illustrate those processes by judicious selection of material, and so vividly to portray them in their larger outlines.

In his "Elements of Plant Biology" Mr. Tansley has certainly achieved a great measure of success in discharging a task beset with difficulties, and his book deserves to be widely read, for it possesses a certain indefinable, but none the less real, quality of distinction. The author has thought out his subject-matter well, and he has succeeded better, we think, than any of his predecessors in giving, on elementary lines, a clear and comprehensive account of the main features of plant life regarded from a truly scientific point of view. His mode of exposition is clear and his choice of material admirable, and thus, with remarkable freedom from esoteric technicality, he has produced a volume that really does provide the student with what will stand him in good stead, no matter what branch of biology he may ultimately elect to follow up. Furthermore, the book may be recommended with no less confidence to those who want to know something of some of the most important tendencies in modern biology, even if their main interests happen to lie in quite other fields.

The opening chapters touch briefly, and very clearly, on those physical and chemical aspects of the subject which are so essential to any real understanding of the living organism. The cell, its structure, its modes of reproduction, and so on, is sufficiently described, and its marvellous variety, both in form and development, is illustrated by well-chosen examples, special prominence being accorded to essentials, whilst details which, for the purpose of this book, are of less moment have been wisely passed over. A good account is then given of the leading and most generally interesting facts of structure and function as displayed in the various main groups of the vegetable kingdom, the whole treatment being so worked out as to enable the reader to obtain a comprehensive, if elementary, grasp of the chief evolutionary story of plants.

It is possible that a chapter on genetics might lend more completeness to this admirable volume; but with the object the author had more especially before him when writing it, possibly the omission was deliberate. Moreover, he does, in his closing chapter, briefly discuss the larger aspects of evolution, and the present writer especially welcomes the expression of opinion that "there is no bar to the appearance of characters which are of no *use* to the organism, nor even of characters which are disadvantageous to it, *provided they do not handicap the organism sufficiently to destroy its chances of continued existence.*" This sentence (the italics are the author's) is in real accordance with the facts as they may be gathered from a study of plants actually growing in the open, and it represents a point of view which it is well to emphasise in the face of much false doctrine based on fanciful teleology. Lucretius, regarding the matter from a somewhat different angle, has well said in his "De Rerum Natura" (iv. 834-5):

> Nil ideo quoniam natumst in corpore ut uti
> Possemus, sed quod natumst id procreat usum.

J. B. F.

Kamerlingh Onnes and his Laboratory.

Het Natuurkundig Laboratorium der Rijksuniversiteit te Leiden in de Jaren 1904–1922. Gedenkboek aangeboden aan H. Kamerlingh Onnes, Directeur van het Laboratorium bij gelegenheid van zijn veertigjarig Professoraat op 11 November 1922. Pp. iv+458. (Leiden: Eduard Ijdo, 1922.)

At a recent lecture given in London by Prof. H. A. Lorentz, Sir William Bragg made the happy remark that Holland, per square mile of its land—and water!—produced more eminent physicists than any other country. Amusing, and true. The appearance of the volume with the above title is another reminder of how true it is. Surely it is almost, if not quite, without precedent that it should fall to the lot of the same scientific investigator to have his work commemorated twice during his lifetime. Yet this is what has happened here. In 1904 there appeared a book, produced by his colleagues, to celebrate the twenty-fifth anniversary of the bestowal of the title of doctor on Heike Kamerlingh Onnes. The name of that book is identical with that of the present one, except for the dates—1882 to 1904; and in its introduction, if a free translation from the Dutch may be permitted, its purpose is described as "a review of what by him—through his inspiration, under his direction, by means of the apparatus he has assembled, and from his learning—has been added to the advancement of science."

It has appeared to the committee responsible for the new commemoration—Prof. Zeeman being the chairman and Prof. Lorentz himself a member—that the occasion would be served best by bringing out what Prof. Lorentz calls a "second edition," dealing with the work in Prof. Onnes' laboratory during the period 1904–1922, a period which includes the successful liquefaction of helium in 1908 and the well-known subsequent advances in the attainment and use of low temperatures. The cryogenic laboratory at Leyden has for some years become "an international institution for scientific investigations at very low temperatures"—a fact made evident by the names of those who have worked there and contributed papers to this volume. The description given by Dr. Crommelin indicates what a magnificent and well-organised laboratory it now is; but, until the enlarged building was completed and opened in January

1921, lack of space apparently added great difficulties to the work, and it is significant of the capacity of Prof. Onnes and those who have laboured with him that the output of valuable results has been so profuse. The new laboratory is indeed a fitting monument to a great man.

The book is, appropriately enough, mainly in Dutch, but each contributor has, in fact, written in his own language. Prof. Lorentz has contributed the foreword, in which he pays glowing tributes to his colleague. There are five chapters, of which the first contains articles descriptive of the laboratory itself. The late Prof. Kuenen describes the international character of the work, and Dr. Crommelin, upon whom seems to have fallen a lion's share of the labour of production, gives a very complete picture of the buildings, equipment, apparatus, and methods of work. Each of the four remaining chapters deals with a special field in which low temperatures have been applied. W. H. Keesom and E. Mathias, among others, contribute papers on thermodynamic investigations with gases. Researches on magnetism at low temperatures, carried out by himself and Prof. Onnes, are described by P. Weiss. Chapter IV. is entitled "Investigations in Optics, Magneto-optics, and Radioactivity," and contains papers by Zeeman, Jean Becquerel, Ehrenfest, and Mme. Curie. The last chapter, which refers mainly to the super-conductivity displayed by metals at very low temperatures, and contains a paper by Einstein, includes also reviews of results connected with the Hall effect, piezo-electricity, and other electric phenomena. There are numerous illustrations and diagrams; a few sketches appear also, including a frontispiece portrait of Prof. Onnes, drawn it is not clear whether by himself or by a near relative of the same name.

It is altogether a book worthy of the occasion; it properly impresses one with the exceptional greatness of the work and of the man. Strictly, of course, it is a tribute from his colleagues and students, but it is one in which, without distinction of nationality, we should all be ready to join unreservedly.

Thirty Years of Public Health Work in Manchester.

Observations on the History of Public Health Effort in Manchester. By Dr. James Niven. Pp. vii+230. (Manchester and London: John Heywood, Ltd., 1923.) n.p.

THE retirement of Dr. James Niven, the medical officer of health of Manchester, has led to the preparation by him of an intensely interesting account of public health effort in Manchester since 1894, when he first became responsible for the official health work of this city. The story is one which will be read with interest and admiration, not only by those colleagues in the public health service who for many years have looked to Dr. Niven for light and guidance in the application of science to preventive medicine, but also by many others who know that sanitary progress in this period has been as great as, or even greater than, the progress in life-saving surgery.

Here we can merely direct attention to a few salient points, advising all who can obtain a copy to study the report in detail.

In the stride forward of preventive medicine, there has been a tendency to have regard solely to specific infection as a source of disease; but Dr. Niven wisely, in the outset of his report, expresses the well-founded view that by far the most important influence which has governed the improvement of the public health in Manchester, apart from economic conditions, has been the removal of organic filth, whether within or without the habitations of the people. The story of improvement in this respect is vividly told, the region of least success being that of emission of smoke from chimneys.

The general result of all the reforms achieved, as shown in vital statistics, comparing the period 1891–95 with 1916–20, is that the general death-rate has declined 40 per cent., typhus fever is extinct, the death-rate from enteric fever has declined 92 per cent., diarrhœal diseases 74 per cent., the rate of infant mortality 44 per cent., and pulmonary tuberculosis 42 per cent. The story as regards enteric fever and diarrhœa is especially impressive. The abolition of pail-closets, the reform of stable-yards, the aid furnished by bacteriology in the diagnosis of enteric fever, the recognition of carriers and shell-fish as important sources of infection, and steady action against the domestic fly, have all borne their share in securing the vast improvement which is recorded.

Dr. Niven was the pioneer of administrative control of tuberculosis in Great Britain, and his review of progress made is especially important. In defending direct action against the disease as distinguished from indirect action against slum dwellings, he holds the balance very fairly. He agrees that history and experience alike point to the relief of economic pressure as the most powerful weapon in combating tuberculosis; but attack solely from this point of view erroneously assumes that economic conditions can be altered at will. This being so, there is no excuse for neglecting direct action founded on an intimate knowledge of the disease. There is the further point that we are concerned with a vicious circle. Not only does poverty favour tuberculosis, but it is itself a poverty-

making disease, some 40 per cent. of existing poverty having been estimated to be due to it. In a full discussion of housing difficulties, Dr. Niven points out the impossibility of securing satisfactory housing in central districts on economic lines, and in this connexion suggests that the necessary expenditure might be diverted from what is wasted on alcoholic drinks. He asks, "Can there be any doubt that the liquor trade paralyses the hands of the social reformer and keeps the people poor?"

Only a few of the important subjects discussed in this valuable review of public health progress have been mentioned; but we trust that the attention now directed to it may lead to its study by many who at present realise inadequately the vast strides already made in the prevention of disease and in the improvement of the public health.

The Ichthyosaurians.

Die Ichthyosaurier des Lias und ihre Zusammenhänge. Von Friedrich von Huene. Pp. viii + 114 + 22 Tafeln. (Berlin: Gebrüder Borntraeger, 1922.) 25*s*.

BARON F. VON HUENE is well known by his numerous writings on fossil reptiles of strange and rare types which are represented by more or less fragmentary specimens. He has now turned his attention to the comparatively familiar ichthyosaurians, of which, perhaps, more nearly complete skeletons occur in museums than of any other reptiles. As he remarks, the osteology of this group is now rather well known. He therefore devotes his work chiefly to a definition of the species, with an attempt to arrange them in genera and to determine their relationships. He has made many new observations on the specimens from the Lias of south Germany, of which he publishes important illustrations. In this research he acknowledges especially the valuable help of Dr. Bernhard Hauff, of Holzmaden, whose fine preparations of Liassic reptiles and fishes are now scattered through many museums.

Baron von Huene adopts the usual classification of the ichthyosaurians into those with the fore paddles broad and those with the paddles long and narrow. He also considers that these two groups remain distinct from the beginning to the end of the career of these marine reptiles. He recognises and names more genera, however, than have hitherto been supposed to occur, and his taxonomy is not likely to meet with general approval. Ichthyosaurus, for example, altogether disappears as a generic name; and other generic names already exist having priority over some of the new names proposed. The taxonomy is indeed the least acceptable part of the work.

The stratigraphical distribution of the ichthyosaurians in the Lias of south Germany is shown in a table, and it would be interesting to make an equally detailed study of the distribution of the species in the several zones of the Lias in England. Except the typical species of Ophthalmosaurus from the Oxford Clay, the later ichthyosaurians are still known only by comparatively fragmentary specimens.

The author concludes his work with a large table of outline sketches to illustrate the evolution of the ichthyosaurians from their first appearance in the Middle Trias to their disappearance in the Upper Cretaceous. At the beginning he places the small Mesosaurus, of Permian age, which he considers may be related to the semi-aquatic primitive ancestor of the whole group, which still remains unknown. The Triassic forms are represented as long-bodied, with the backbone only slightly bent downwards where a small caudal fin arises. The caudal fin is completed before the end of the Liassic period; and it becomes more effective as a propeller by the shortening of the caudal pedicle in the Upper Jurassic forms. The only Cretaceous species sufficiently well known for restoration is represented as again slender, with a comparatively small though complete caudal fin.

The volume is excellently printed and illustrated, and we commend it to the notice of all students of vertebrate palæontology. A. S. W.

Our Bookshelf.

Die steinzeitlichen Stationen des Birstales zwischen Basel und Delsberg. Von Fritz Sarasin. Prähistorischer und anthropologischer Teil von Fritz Sarasin. Paläontologischer Teil von H. G. Stehlin, unter Mitwirkung von Th. Studer (Aves). Mit 32 Tafeln und 20 Textfiguren. Neue Denkschriften der Schweizerischen Naturforschenden Gesellschaft. Band liv. Abh. 2. (Basle, Geneva und Lyons: Georg und Co., 1918.) n.p.

THE above volume, only recently issued though dated 1918, contains some 290 pages of text, with 32 full-page illustrations at the end. There are also some 20 figures in the text giving sections, maps, and the like. A full and careful account of a number of diggings just south of Basle is given, including a description not only of the archæological finds, but also of the mammalian and bird remains. The whole forms a useful addition to our knowledge of prehistoric times in this region.

The first part of the volume is devoted to a description of finds from a number of caves. The industries recognised are Neolithic, Azilian, and Magdalenian. Owing to the area being outside the region of glaciation, the determination is done on purely typological grounds. A Neolithic burial (with skeleton complete) was unearthed, and a full account is given. In one instance "painted pebbles" were discovered in an Azilian layer. It is interesting to find these typical Azilian objects so far north. There is evidence of Azilian culture as far

north as West Scotland, but hitherto "painted pebbles" have only been found farther south. The latter part of the book is concerned with an account of some open-air Neolithic stations. The whole is completed by the inclusion of a very full bibliography, referring both to the archæology and to the palæontology.

The authors are to be congratulated on their explorations and on the publication—especially on having managed to include so many and such excellent plates. The area under discussion is of course restricted, but it is exceedingly important that the results obtained in various diggings should be carefully published, and not, as is, alas, so often the case, be either not published at all or merely noted briefly in some obscure review. The finds described in the above work are preserved in the museum at Basle. M. C. B.

The Practical Applications of X-rays. By Dr. G. W. C. Kaye. Pp. viii+135. (London: Chapman and Hall, Ltd., 1922.) 10*s.* 6*d.* net.

THIS book is based largely on a course of Cantor Lectures given by the author, and is primarily concerned with the many practical applications to which X-rays are put at the present time; this term is, however, not meant to include their medical applications.

Rather more than one-half of the book is devoted to a description of the methods of production of X-rays and of their measurement; such a liberal proportion of space will generally be welcomed by those seeking to apply X-rays for themselves. During the War, X-rays were used successfully to detect flaws in aeroplane parts, and the author shared very largely in this work, of which some good illustrations are shown. The main industrial application may perhaps be said to be in the examination of metal castings, and the recent technical developments, whereby X-rays of very short wave-length may be obtained, should see a widening range of application here.

X-ray examination shows some very striking differences between ancient and modern pictures; these differences are mainly due to the pigments and primers employed by the artists; present-day pigments are not nearly so opaque to X-rays as the metallic pigments used by the earlier painters. Some illustrations from the work of Heilbron will convey sufficiently well to the expert the assistance he may expect from the radiologist in detecting the work of the vandal.

The volume contains in one appendix the two memoranda which have been issued by the X-ray and Radium Protection Committee on methods of safety, and in a second appendix a useful list of definitions of terms in common use in X-ray and electro-medical literature.

Principles and Practice of X-ray Technic for Diagnosis. By Dr. John A. Metzger. Pp. 144. (London: H. Kimpton, 1922.) 14*s.* net.

THE author's aim is "to put into the hands of the student and operator a formula on which to base his work in order that he may obtain better results and thus be able to reach a more correct diagnostic interpretation."

We must confess to a failure in finding the "formula." The book opens with a glossary of terms and this is scarcely reassuring; for radiography we read "same as skiascopy," which is not defined; X-rays are said to be rays of unknown quantity; tension is defined as the tendency of electricity to overcome resistance.

On the second page of the first chapter the author discusses the use of gas and Coolidge tubes, but we are left wondering at what is meant by the following statement: "The difference between the tubes used with the high-frequency machines and the induction coil is one of the vacuum, and the additional cathode of the former to care for the inverse, while the difference between those for the induction coil and the transformer is that of a heavier target construction and lower vacuum of the one to care for the additional voltage and absence of an inverse."

The book is profusely illustrated, mainly in order to show the various positions of the patient which the author advises for different diagnostic purposes. Many of these are quite unnecessary, and three of them are duplicated in the text.

A Text-book of Intermediate Physics. By H. Moore. Pp. ix+824. (London: Methuen and Co., Ltd., 1923). 22*s.* 6*d.* net.

THIS is a very complete text-book for intermediate students in universities. It is well printed, has many original illustrations, and is provided with an exceptionally good index of thirty-nine pages. Block type is used for the principal laws and conclusions, so that revision of his work on the part of a student is facilitated. The author has, however, unfortunately reproduced a number of the mistakes and incomplete statements of his predecessors. He confuses surface energy and surface tension, and on p. 149 he speaks of the weight of the liquid below the meniscus in a capillary tube being supported by the surface tension. He devotes more space than is desirable to old and discarded methods, *e.g.* Laplace and Lavoisier's expansion apparatus, p. 173, and specific heat apparatus, p. 218, while no information is given as to how the expansion coefficient of a gas is calculated from observations with accurate apparatus, p. 191. On p. 254 the saturation vapour pressure over a solid is incorrectly shown. The part on light is good, but there seems no reason for omitting old sight from the list of defects of the eye on p. 458. There appears to be no mention of the magnetic circuit, and the diagrams of dynamos on pp. 739 and 741 may account for the necessity of silence on the subject.

Abriss der Biologie der Tiere. Von Prof. Dr. Heinrich Simroth. Vierte Auflage, durchgesehen und verbessert von Prof. Dr. Friedrich Hempelmann. Teil 1. Entstehung und Weiterbildung der Tierwelt. Beziehungen zur organischen Natur. (Sammlung Göschen Nr. 131.) Pp. 147. (Berlin und Leipzig: Walter de Gruyter und Co., 1923.) 1*s.*

THIS is a revision of Simroth's "Sketch of the Biology of Animals," and a very interesting little book it is. We do not think that the text corresponds particularly well with the sub-title, which might be translated "Rise and Progress of the Animal Kingdom: Relations to Organic Nature"; and in the catalogue these are the titles of two separate volumes. But that is a trivial detail. The little book before us deals mainly

with the following subjects—the relations of animals to gravity and their locomotion in various media; light, colour, and luminescence; equilibration, hearing, and touch; chemical influences; the influence of heat and cold; animal electricity; and respiration. This is a lot to cover in 150 small pages, but we are bound to say that the treatment is very effective. The chapters are simply illustrative, and thus they remain interesting. Most of the illustrations are fresh.

Origine de la vie sur le globe. Par Julien Costantin. (Bibliothèque de Culture générale.) Pp. 192. (Paris: Ernest Flammarion, 1923.) 4.50 francs net.

THE problem of the origin of organisms upon the earth continues to attract and to defeat the inquisitive spirit. Prof. Julien Costantin discusses it in various aspects: Had living creatures a beginning at all? If they had, what were the first organisms like? Did plants come before animals? Is there any clue in the so-called "life of crystals"? He also inquires into the meaning of animate organisation, the importance of colloids, the chemistry of the cell, the puzzle of cell-division, the processes of growth and development.

The chapters are all careful and clear, but they do not lead us to any solution. The author concludes that there must have been pre-Cambrian spontaneous generation, that it is very improbable that it ever occurred again, that there is no hint of its occurring now, that green algæ were the first organisms, and that there is nothing to show that they were preceded by bacteria, that the hypothesis of cosmozoa only shelves the problem, and that their hypothetical arrival on the earth should have been followed by several distinct lines of evolution, which is not what the facts indicate. To expect to effect the synthesis of living matter in the near future is "perfectly ridiculous."

University of Oxford: Institute for Research in Agricultural Economics. An economic survey of a rural parish. By J. Pryse Howell. Pp. 31. (London: Oxford University Press, 1923.) 1*s*.

THIS little survey, extending to 25 pages only, is quite useful as an example of the kind of inquiry that could well be made in many more of our country parishes. We are told nothing of the location of the particular parish, not even its county, and the work loses much of its value in consequence. But the survey gives a picture of a village, presumably in Wales, where the houses are let at annual rentals of 25*s*. upwards, and where the inhabitants apparently produce most of what they need for themselves, since the sales from the farms work out to about £50 per annum only per person employed. It is interesting and should prove instructive to any rural or urban dweller interested in the human side of agriculture.

Tychonis Brahe opera omnia. Edidit I. L. E. Dreyer. Tomi quinti, fasciculus posterior. Pp. 217-343. (Hauniae: Libraria Gyldendaliana, 1923.) n.p.

THIS is a supplement to vol. v. of Tycho's collected works. It contains several examples of Tycho's observations of the sun and planets, and his discussion of them, assuming that the sun (the centre of the planetary motions) itself goes round the earth. These will always remain classic, from the part they played in establishing Kepler's Laws, and later Newton's law of gravitation.

A map of Huen is reproduced.

The table of longitudes and latitudes reminds us how inaccurate the knowledge of longitude was in Tycho's time; for example, Alexandria is placed 36° east of London.

The volume closes with twenty-five pages of useful editorial notes. A. C. D. C.

Scientific Method: an Inquiry into the Character and Validity of Natural Laws. By A. D. Ritchie. (International Library of Psychology, Philosophy, and Scientific Method.) Pp. viii+204. (London: Kegan Paul and Co., Ltd.; New York: Harcourt, Brace and Co., Inc., 1923.) 10*s*. 6*d*. net.

MR. RITCHIE'S book being a dissertation for the examination for a fellowship at Trinity College, Cambridge, is primarily designed to prove the extent and depth of the writer's reading. It leads us to hope much from Mr. Ritchie when he no longer needs credentials. The main scientific value of the book is perhaps that it reveals the type of mind the present Cambridge teachers are nurturing and the direction of research they are encouraging.

Traité de Psychologie. Par Prof. Georges Dumas. Tome 1. Pp. xiv+964. (Paris: Félix Alcan, 1923.) 40 francs net.

THE work under notice partakes more of the nature of an encyclopædia of psychological science than of a treatise on psychology. It is a reminder of the exuberant growth of the subject in our own time. It was designed by the late Théodule Ribot, and his preface is retained, but the present edition is under the direction of Prof. Georges Dumas, and he has secured as his collaborators a number of most distinguished workers, every one eminent in some branch of psychological science.

The Amateurs' Book of Wireless Circuits. By F. H. Haynes. Pp. 107. (London: The Wireless Press, Ltd., 1923.) 2*s*. 6*d*. net.

THE amateur radio engineer will find Mr. Haynes's little work most instructive. The author begins with the simplest possible circuits and then introduces elaborations step by step until he arrives at many of the complicated arrangements used in practice. Standard symbols are employed and the diagrams are beautifully clear, so the gradual evolution of the systems can be very readily followed.

Questions and Problems in Chemistry. By F. L. Darrow. Pp. vii+177. (London: G. Bell and Sons, Ltd., 1923.) 3*s*. 6*d*. net.

THIS book consists of a large number of very simple questions on chemistry, and may be found useful to teachers in schools. It is, however, more adapted for use with an American text-book, and adopts American spelling—"sulfuric," etc. The examination papers at the end are American, and in many ways the book will not fit in with English school methods.

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.*]

Light and Electrons.

SIR OLIVER LODGE, in his survey of the problems connected with Ether and Electrons (NATURE Supplement, August 4), propounds the interesting question: "Does light generate an electron?" The hypothetical conversion of radiation into matter may, as he points out, accord with observed results as to the photo-electric emission of electrons. In particular the striking reciprocal relation between the energy of an electron and the energy of X-rays seems to justify his statement: "It is as if the same beta particle, that is, the same electron, had gone out of existence at one place, and been recreated at another, the intermediate link being constituted by specific radiation of a perfectly definite wave-length." Sir Oliver Lodge says further: "I know that the Bohr Theory of the Atom seems at first against these speculations. Electrons do appear to jump from one orbit to another, and thereby give out a certain quantum of energy. But this may be a supplementary, and not a contradictory statement."

In this connexion I should like to direct attention to a suggestion made by Prof. E. T. Whittaker in his paper on the quantum mechanism in the atom (Proc. Roy. Soc. Edin. vol. 42, p. 141, 1922). He points out that Bohr's theory of series spectra can be assimilated to the theory advanced in his paper in the following way. "In Bohr's theory let a negative electron E fall from an orbit of radius a_1 (position P_1) to an orbit of radius a_0 (position P_0). Now in the initial state of this system, which consists of the electron E at P_1, let us introduce two coincident electrons E′ and E″ at P_0, one positive and one negative, so that they annul each other; and let us replace Bohr's conception of the fall of the electron from E at P_1 to E′ at P_0, by the conception of the discharge of a condenser whose charges are E and E″; the discharge annihilates E and E″, and so leaves E′ surviving alone at the end of the process, and is therefore equivalent to Bohr's notion of a translation of E to the position of E′."

The suggestion is easier to visualise if instead of the circling electrons of Bohr's theory we employ the stationary electrons obtained by introducing Langmuir's "Quantum Force" (*Phys. Rev.*, vol. 18, p. 104, 1921). The conception of the discharge of a condenser is not essential to the picture, and Sir Oliver Lodge may prefer to replace it by a mechanical vibration of the column of ether between E and E″, resulting in the production of what Silberstein has called a "light-dart." In speaking of the discharge of a condenser, as in speaking of the vibration of a medium, we are using figurative language, which is meant only to suggest an illustration of a process which is beyond the range of our experience.

One of the difficulties in Bohr's theory is to understand how the frequency of the radiation emitted in accordance with his fundamental frequency condition can be fixed as soon as the electron quits the first stationary state and before it has reached the final state. As Silberstein puts it: "Needless to say the founder of the new theory and his followers do not attempt to describe the mechanism of such an extraordinary performance, one, that is, that enables the atomic system to hit precisely upon the frequency required." Again in a recent letter Prof. C. G. Darwin (NATURE, vol. 111, p. 771, June 9) refers to the difficulty "that the quantum conditions determining the permissible Bohr orbits can only be explained physically by attributing to the electrons a knowledge of the future."

This difficulty—and the similar one which arises in connexion with absorption—seems to be diminished, if not entirely removed, by the suggestions put forward by Prof. Whittaker. On this view the emission of light originates not so much at the position P_1 as at the position P_0, where we may imagine an incipient crack in the ether developing under the influence of some external disturbance, say the approach of some other atomic system. There is here a suggestion of a discrete structure for the electromagnetic field (or ether) in the space surrounding an atom such as I have previously attempted to indicate in speaking of Faraday's magnetic lines as "Quanta."

In the present stage of the development of physics, when we seem forced to believe in two mutually contradictory theories of light (the undulatory and the corpuscular theory) at the same time, the wildest guess at a solution may be permitted. This must be my excuse for hazarding the suggestion that conceivably the "head" of the disturbance (derived from the negative electron E) spreads out as the light advances—the amount of spreading involved being a question requiring further investigation—whilst the "tail" (derived from a positive electron) retains to a greater extent its corpuscular character, and plays the part of one of Sir J. J. Thomson's "specks" as it follows the advancing wave-front. On this view absorption of radiation takes place when an electron grasps the light—in this revised version of Little Bo-Peep—by its "tail"!

H. S. ALLEN.

The University, St. Andrews.

Continental Drift and the Stressing of Africa.

As one among many geologists who (so it would seem) would welcome proof of an hypothesis of continental drift, but who cannot accept Dr. Wegener's peculiar opinions with regard to it, I recognise that we owe a debt of gratitude to Dr. J. W. Evans for showing us an ingenious way out of some of the difficulties that Wegener, albeit unintentionally, demonstrates rather than removes; none the less, the views of Dr. Evans on this subject appear to be open to question.

Dr. Evans states (NATURE, March 24, p. 393) that "there seems reason to believe that Africa is in the main the centre of a region of tension, due to the outward drift of continental masses," which, as he points out, is explicable as "drift from a region of comparatively low gravity to one of higher gravity." Following Osmond Fisher and Pickering, Dr. Evans sees no objection to the view that the Pacific depression is the scar left by the separation of the moon from the earth—a phenomenon which Sir George Darwin attributed to tidal action—and is inclined to follow Prof. Sollas in regarding the African protuberance as an unsuccessful attempt on the part of the earth to produce another satellite.

The birth of the moon is a piece of extremely ancient history, and the consequent stressing of Africa, if indeed there be any such consequence, must have started as soon as the moon's mass was lost, or, in the event of excessive resistance of sima to sial—an unlikely event if the postulated circumstances of the moon's origin be correct—as soon as

the rise in temperature resulting from the blanketing of the sea bottom, by sedimentary deposits, in the neighbourhood of land masses became sufficient considerably to reduce the rigidity of the basic sima beneath the continental shelves. The great thickness of the earliest sedimentary strata suggests that this condition was attained in very remote geological times; and in view of the slow progress the continents would make by this process of drift, it would appear that the degree of separation now attained by these land masses may be taken to point to a similar conclusion, even though a liberal allowance be made for lateral collapse along the margins of the separated tracts. According to this view, tensional structures should be dominant throughout the geological history of Africa.

Of other African territories I will say nothing, but with regard to Uganda, which lies, be it noted, in the heart of the continent and between two great rift valleys, tensional structures are astonishingly absent, or, at any rate, difficult to find.

Deposited on a basement of crystalline rocks which represents, in all probability, a great accumulation of archaic sub-aqueous deposits intruded upon and largely metamorphosed by ancient acid magmas that have incorporated much of the sediments, is a very thick series of shales and sandstones (usually more or less altered) of great antiquity but of undetermined age. These are part of what we once called the Argillite series (a tentative term now abandoned, see Ann. Rept. Geol. Dept. Uganda, 1920, p. 10); they constitute what we now call the Ankolian system. These rocks have suffered much from folding and are sliced up by tremendous faults. Owing to the want of easily recognised horizons within the system, it is usually very difficult to demonstrate the nature of these faults. There can be little doubt, however, that they are essentially compressional structures, and in every instance where the fracture contacts have been seen they have revealed overthrust faults. After this great phase of faulting, the Ankolian beds have been thrown into a series of complicated domes, the eroded remains of which were first described by me as *arenas* (*loc. cit.* p. 14). Some of these have been the subject of careful study by Mr. A. D. Combe (Field Geologist, Uganda Service), who has mapped them in detail. It is quite certain that these do not give evidence of tension, but quite the reverse.

Above the Ankolian, and deposited unconformably upon that system, is the Mityana series, consisting of thick accumulations of sandstones and conglomerates; these, too, have suffered from faulting, but to a lesser degree than the Ankolian. The nature of these faults is as yet undetermined. The Ankolian and the Mityana series have together been thrust up by an enormous bathylith (the Mubendi bathylith), the denudation of which has exposed the newer granite: this does not look like tension. Deposits revealing plant-impressions, possibly of Jurassic age, which appear to be the next in order of sequence, have been located in eastern Uganda; they occur in a syncline of no great size: the significance of this structure is uncertain. No other tectonic movements are as yet known in this country until we come to (probably) late Cretaceous and Tertiary times, when we have the doming of Uganda (the Uganda-Congo dome lying to the west of the syncline of Lake Victoria, which itself lies to the west of the Kenyan dome or anticline). This structure can scarcely be interpreted as tensional; yet at the time of its inception continental drift, if drift there has been, should surely have been well advanced. The first structures of more than purely local significance that have been interpreted as tensional do not make their appearance until about middle tertiary times, though the action which they signify continued until much later: I mean, of course, the rift valleys, and even these, at any rate so far as their first inception is concerned, are more easily accounted for by compression than by its opposite.

Here, with the Semliki (Semaliki the natives call it) and the Congo rift-scarp to my left, the Toro-Bunyoro escarpment to my right, and the Ruwenzori range behind me, I write sitting on the evidence, as it were, that proves, perhaps for the first time conclusively, the tectonic origin of the Albertine depression, and demonstrates beyond all doubt the amazing fact that early man knew the lake when it stood more than 1000 feet higher than it does now. A thousand-foot head on Lake Albert is impossible to-day, and has been ever since the differential drop of the Bunyoro scarp not only released the pent-up waters of Lake Albert, but gave birth to the Victoria Nile that connects, through Lake Chioga, the great Nyanza with the Albertine depression. All this is, in my opinion, more easily accounted for as a necessary consequence of compressional activity than as the direct result of tension.

The tectonics of the rift is too big a question to discuss in a letter, but it may be noted that all the evidence that I have been able recently to obtain in Toro and in the Bwamba country supports the view, generally held, that Ruwenzori is an upthrust mass. It is directly connected with the rift but very probably pre-rift in age. Now there is evidence to show that since the inception of the Albertine rift the bottom of the valley has sunk by two distinct major movements well separated in time. The sinkage has been pivotal with a maximum downthrow to the north-east, as has the subsidence of Bunyoro. That which has remained firm and helped in marked degree to hold the sinking bottom of the rift valley is the great faulted upthrust of the Ruwenzori range: this does not look like tension anyway.

I am afraid that exception must be taken to Dr. Evans's use of the term rift as applied to the separation tract between drifting continents. Thus used, the term is most applicable, but it has priority in Prof. Gregory's usage, which, though it may be less apt, is now unalterable. E. J. WAYLAND.

The Semliki Plain,
May 1.

Protozoa and Virus Diseases of Plants.

ATTEMPTS to discover the presence of a foreign organism in such diseases as tobacco-mosaic, tomato-mosaic, leaf-roll of potato, and numerous other similar infectious diseases have been the concern of botanists for many years. Although considerable knowledge has been gained as to the distribution of these diseases by insects such as Aphides, yet no causal organism has been observed with certainty, and the diseases have been classed accordingly as virus diseases. The failure to detect the presence of a foreign organism has naturally been a serious handicap in combating these diseases, many of which are of serious economic importance.

The appearance of a paper by R. Nelson entitled "The Occurrence of Protozoa in Plants affected with Mosaic and Related Diseases" (Agric. Expt. Station, Michigan, Bull. 58, 1922) is thus of great interest.

In this paper Nelson claims that protozoa are to be found in the phloem of plants affected by bean-mosaic and tomato-mosaic, and also in potato plants affected by leaf-roll, while such organisms are absent from the phloem of healthy plants.

Some of these organisms are described as possessing a single flagellum and an undulating membrane, others as biflagellate; their general resemblance to trypanosomes is also claimed.

When Nelson's paper was received in this country some few months ago, I was engaged in a study of the mosaic of hops, a disease probably to be classed as a virus disease. A search for protozoa similar to those described by Nelson was accordingly made in the phloem of hops thus affected. No such organisms were to be observed, but elongated deeply-staining structures having a marked resemblance to those figured by Nelson and described by him as protozoa were found, as shown in Figs. 1a, 1b. *In the case of the hop-mosaic these structures were undoubtedly degenerate nuclei*, for all transitions could be observed between them and the normal nuclei of the phloem. These degenerate nuclei were not observed in the phloem of healthy hop plants, but they were to be seen in the phloem of an unhealthy bean plant that had been kept some time in the poor light of a laboratory and the leaves of which were attacked by Botrytis (Fig. 1, *c*).

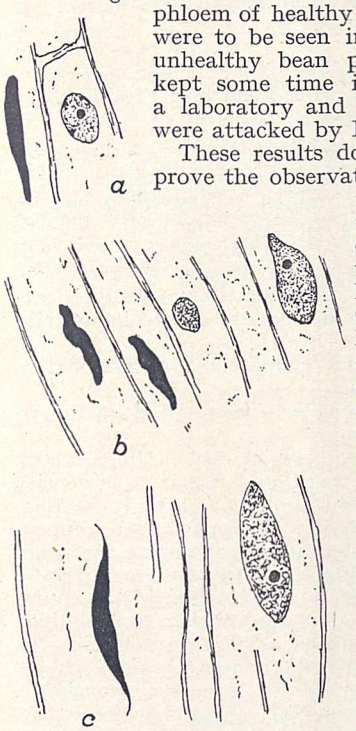

FIG. 1.—Longitudinal sections of the phloem. *a* and *b*, a mosaic hop stem. ×1000; *c*, an unhealthy bean plant. ×600.

These results do not, of course, disprove the observations of Nelson as to the association of protozoa with virus diseases, for the diseases which he investigated have not been studied. Considering, however, how important the discovery of a causal organism in virus diseases would be, it seemed advisable to put on record the results obtained with diseased hops and beans.

Such results indicate clearly that the theory of the association of protozoa with virus diseases requires fuller evidence than has yet been supplied. It is to be noted that Nelson describes the protozoa in the plants he examined as usually existing singly in the cells, and as always elongated in the direction of the axis of the stem, *i.e.*, the organisms stand permanently on end in the plant. These somewhat remarkable results would find an easy explanation if the structures in question were no more than the degenerating nuclei of the elongated cells of the phloem.

M. S. LACEY.

Department of Plant Physiology and Pathology,
Imperial College of Science and Technology,
South Kensington, S.W.7, August 8.

The Scattering of Light by Liquid and Solid Surfaces.

IT is a well-known fact of observation that most reflecting surfaces usually also scatter a little light and are thus rendered visible. The effect is usually dismissed, however, as due to dust or imperfect polish of the surface, and little attention has been given to the problem of determining whether, when these disturbing factors are eliminated, any scattering by the surface persists. Experiments carried out by the writer in collaboration with Mr. L. A. Ramdas to test this matter have led to some interesting results.

Freshly split cleavage faces of crystals show extraordinarily little scattering. In fact, it is found that a clean good piece of mica has surfaces which are invisible even when placed at the focus of a lens illuminated by sunlight against a dark background. This is what one would expect theoretically. Cleavage surfaces of rock-salt and Iceland spar are also good, though not so perfect. The conchoidal fracture-surfaces of quartz are relatively very imperfect optically. Blocks of thick plate glass when freshly broken open exhibit surfaces which apparently are quite smooth, but when illuminated by sunlight they show a blue superficial opalescence. Freshly-blown bulbs of glass when held in a strong light also show this surface opalescence very well.

Coming to liquids, the most interesting case is that of metallic mercury. After carrying out a series of chemical purifications, washing and drying the mercury and then distilling it in vacuum from one bulb to another and transferring it back again repeatedly, Mr. Ramdas succeeded in obtaining surfaces which were dust-free and chemically clean. When sunlight is concentrated on such a mercury surface in a vacuum, the focal spot shows a bluish-white opalescence, the scattered light when observed in a direction nearly parallel to the surface being very strongly polarised with the electric vector perpendicular to the surface and of nearly similar intensity in all azimuths. The opalescent spot when examined under a microscope appears perfectly structureless, showing that it is a true molecular phenomenon.

To test whether the surface-opalescence exhibited by mercury is due to the mobility of the dispersion-electrons usually assumed to exist in metals, or whether it is due to the rugosities of the surface caused by molecular bombardment, observations were also made with transparent liquids in enclosed bulbs made dust-free by repeated distillation. Various liquids tried, *e.g.* ether, alcohol, benzene, carbon tetrachloride, liquid carbon dioxide, all showed the surface-opalescence conspicuously under strong illumination. The character of the effect in these cases was, however, quite different from that shown by a clean mercury surface.

The surface-scattering by transparent liquids is undoubtedly due to the effect of molecular bombardment of the surface. It is much more intense when observed in directions adjacent to that of regular reflection and refraction than in other directions. It is less blue than the internally-scattered light, and shows remarkable changes in its state of polarisation with varying angles of incidence and observation. There were notable differences in this respect between the cases in which the light is incident respectively within and outside the liquid on the interface. There is a rapid falling off in the intensity of the surface opalescence when the angle of incidence is increased much beyond the critical angle. These facts clearly indicate that the effect shown by transparent liquids is essentially due to the imperfect planeness of the surface. The scattering by a metallic liquid surface, on the other hand, has probably a different origin, as suggested above.

The interface between two non-miscible dust-free liquids also shows strong opalescence under illumination. For the particular case in which the interfacial tension is very small or negligible, the opalescence becomes greatly exaggerated. Some observations by Mandelstamm (*Ann. d. Phys.* vol. 41, 1913) on the critical state of liquid mixtures are of interest in this connexion.

The experimental observation of the surface-opalescence of *water* presents special difficulties owing to the great ease with which this liquid catches dust and grease. The difficulties have, however, been successfully overcome and the effect satisfactorily demonstrated, both with water rendered dust-free in sealed bulbs and with the water-film on a clean block of melting ice kept free of dust by a gentle stream of gas blowing upon it.

C. V. RAMAN.

210 Bowbazaar Street, Calcutta,
June 28.

On Continuous Radiation from the Sun.

PROF. J. Q. STEWART recently published in these columns (NATURE, February 10, p. 186) a very interesting communication on the optical and electrical properties of ionised gases. For some time past I have been engaged in investigations on similar lines, and I wish to direct attention to one important side-result. It is well known that in estimating the surface temperature of heavenly bodies (as has been done by Coblentz, Abbot, Wilsing and Scheiner, and others), from their continuous spectra, it is always tacitly assumed that they radiate like perfectly black bodies. Several investigators have pointed out that this assumption does not tally with experimental results. The temperature obtained by applying the total radiation law and the method of isochromatics to the spectral-energy curve are at variance with each other. They are also different from the temperatures obtained from the ionisation-theory.

The best example is afforded by the sun, which, according to the careful measurements of Abbot and Wilsing, shows a spectral-energy curve considerably deviating from that of a black body (see E. A. Milne, Phil. Trans. vol. 223, p. 218); the fact has been discussed by many investigators, including Schwarzschild, Groot, Milne, Dietzius, and others. There are very weighty reasons why the sun would not radiate like a black body. A black body or a full radiator is one which absorbs all the radiant energy which falls on it, reflecting none. Such an ideal body is nowhere met with in the world, but Wien and Lummer realised it by making use of a hollow enclosure maintained at a constant temperature, and provided with a small hole, the idea being that a beam of radiation within the enclosure would describe an infinitely circuitous path, and what the emission lacks in fullness will be made up by repeated reflections.

It is clear that none of these conditions is fulfilled in the case of the sun. The surface of the sun contains a large percentage of free electrons, and positive charges, which endow it with a large reflecting power. This point will be clear if we remember the analogous case of metals. According to the electromagnetic theory, metals derive their high reflecting power from the presence in them of a large number of free electrons, or rather electrons which are easily excited to vibration by incident radiation. A theory of emissivity of metals on this basis was worked out by Aschkinass in 1905, and has been verified by the experiments of Rubens and Hagen, Langmuir, and others.

The presence of a large percentage of free electrons on the surface of the sun would, thus, endow it with a high reflecting power. The surface being an open one, the hollow enclosure condition is not realised. Thus the conclusion seems to be irresistible that the total emission from the surface would fall far short of that of full radiator. The form of the spectral-energy curve suggests the emissivity E_λ varies as $\frac{A}{\lambda^{5+x}}\phi(\lambda\theta)$ where $1 > x \geqq \frac{1}{2}$, but about this point judgment should be reserved now.

Turning to the stars, it is easy to see that similar conditions would hold. The analogy with metals enables us to say that the emission from low temperature stars would fall far short of that from a full radiator at the same temperature, while for stars with very high temperature, emissivity may approach that of a black body.

Prof. Eddington's work on the constitution of stars is based on the assumption that inside the stars total emissivity varies as T^4; this assumption is probably not affected, for, inside the stars, the hollow enclosure condition is largely fulfilled.

MEGH NAD SAHA.

University College of Science, Calcutta,
July 5.

Separation of Common Lead into Fractions of Different Density.

BY fractional crystallisation of lead assay foil, about 300 grams in all, two end fractions, each weighing about 60 grams, were obtained. These fractions were then purified according to Stas's method. For the density determinations, about ten grams of each was melted in an atmosphere of hydrogen and allowed to solidify in a vacuum. The densities of samples prepared in this way were determined in specific gravity bottles.

Density of lead from *crystals* end of fractionating series :—11·345±0·005.

Density of lead from *mother liquor* end of fractionating series :—11·313±0·005.

A sample of Stas lead, which Mr. C. T. Heycock very kindly gave me, was found to have the density 11·328 in one experiment and 11·326 after re-melting.

The difference in density between the above-mentioned fractions persisted after granulating the metal and also after re-melting the granulated metal under potassium cyanide. It was discovered in the course of these experiments that lead which has solidified slowly is not homogeneous as regards density,—the parts which freeze first being denser.

Out of eleven experiments, only one was inconsistent with the view that the original lead had been separated into two fractions which had different densities.

The work is being continued.

R. H. ATKINSON.

Goldsmiths' Metallurgical Laboratory,
University Chemical Laboratory,
Cambridge, July 18.

Proposed International Survey of the Sky.

ON the initiative of the French National Meteorological Service, it has been decided to take photographs of the clouds three times daily during the week September 17-23, inclusive, at as many stations as possible throughout the countries of western Europe. As the number of official meteorological stations is limited, it has been proposed to enlist the services of those professional and amateur photographers who are willing to co-operate voluntarily in the work. The photographs should be taken as nearly as possible at 7 A.M., 1 P.M., and 6 P.M. G.M.T. (not summer time). The photographer should make a note of the direction in which the camera is pointing when the photograph is taken (*e.g.* north, south-west, etc.); if more than one photograph is taken at any

hour it will be advantageous to take them in opposite directions (*e.g.* south-west and north-east). A reseau of five photographs would practically cover the whole visible sky when an average lens is employed, and it is accordingly recommended that, when possible, one photograph should be taken towards each of the points north, east, south, and west, and one towards the zenith. Photographers should be particularly careful to mark their plates in some way, so that the photographs in the different directions may be readily recognised after development; the inclusion of a small strip of horizon might be advisable for this purpose. In the case of the zenith photograph, a small part of some object might be included (*e.g.* the top of a tree or the corner of the roof of a house) to indicate the orientation of the plate.

The main object is not to secure artistic effects, but rather to obtain clearly defined records of the cloud forms present, and therefore "contrasty" results are preferable.

Photographers who are willing to take part voluntarily in this work are invited to send their names to one of us at Stoner Hill, Petersfield, and these volunteers will be supplied with the necessary instructions when these are ready for distribution. At the request of Col. Delcambre, of the French Meteorological Service, instructions for taking the photographs have been drawn up by one of us and are to be circulated internationally.

C. J. P. CAVE.
G. AUBOURNE CLARKE.

An Einstein Paradox: an Apology.

ALLOW me to express regret for having misinterpreted Prof. Einstein's symbols. My mistake was caused by the fixed idea that it was impossible for K_1 *in motion* to learn anything about the signal at L *until the light reached him.*

I owe to Mr. C. O. Bartrum the explanation that there are three events, namely, (1) the emission of light-signal at L; (2) its reception by K_1; (3) its reception by K; and that each requires its own double set of space-time co-ordinates; thus (x_1, t_1), (x_2, t_2), (x_3, t_3) in K's system and the same letters with accents for K_1's. There will then be three pairs of Einstein equations.

I find, however, from letters received, that opinions differ as to the interpretation of the t's. Some think that they are the actual times recorded by the clocks; others that they have to be corrected by allowances for the passage of light. Some think that a body in motion actually contracts and that a carried clock goes slow; others that the body only seems to contract and that each of the two observers thinks that the other's clock goes slow. The latter have a difficulty in explaining the constant c.

The simple problem of which the Newtonian solution was given in NATURE of June 2 ought to admit of a solution by relativity methods. I should be greatly obliged to any of your readers who would send me one showing the time on K's clock when the signal reaches K, viz. $x_1/v + x_1/c$.

R. W. GENESE.
40 London Road,
Southborough, Kent.

Colour Vision and Colour Vision Theories.

PROF. PEDDIE, in NATURE of August 4, p. 163, has dealt with some of my strictures of the trichromatic theory. Whilst nothing can be said against his mathematical presentation of the theory, it can easily be shown that, when a case of colour blindness is fully and carefully examined, the mathematical presentation will not account for the facts. All the facts which are explained by the trichromatic theory are, however, consistent with my theory.

The trichromatic theory becomes more and more complicated with subsidiary hypotheses, inconsistent with each other. I have examined a man stated to be completely red blind, but tested with my lantern he recognised red as easily as a normal-sighted person. How do 50 per cent. of the dangerously colour blind get through the wool test? The trichromatic theory completely fails to explain the trichromic class of the colour blind. The trichromic have no yellow sensation, regarding this region of the spectrum as red-green and marking out in the spectrum a monochromatic division including yellow, orange-yellow, and yellow-green.

If the trichromatic theory were true the point where the hypothetical curves cut should be shifted towards the defective sensation; this is not found. Let the trichrome now be examined by colour-mixing methods, and he may make an equation $R + G + V = W$, with too much red in the mixed light, and then make an equation with too much green in the mixed light. Again, he may agree with the normal match, or in other cases only agree with the normal match when the comparison white light is diminished in one case or increased in another, thus matching two white lights of different luminosities.

F. W. EDRIDGE-GREEN.

London, August 7.

Stirling's Theorem.

THE recent correspondence in the columns of NATURE on this subject prompts me to add to the collection a formula which I deduced about three years ago. It was then communicated to a mathematical friend, but has not otherwise been published.

The ordinary Euler-Maclaurin series for $\log_e n!$ is

$$\log\sqrt{2\pi} + (n+\tfrac{1}{2})\log n - n + 1/12n - 1/360n^3 + 1/1260n^5 \ldots$$

It is easily shown that the last three terms printed above are reproduced exactly by the first three terms of the binomial

$$\frac{1}{12n}\left(1+\frac{113}{210n^2}\right)^{-7/113};$$

while the simpler binomial

$$\frac{1}{12n}\left(1+\frac{8}{15n^2}\right)^{-1/16}, \text{ or } \frac{1}{12n}\left(\frac{15n^2}{15n^2+8}\right)^{1/16},$$

reproduces exactly the terms in $1/n$ and $1/n^3$ and very approximately the term in $1/n^5$. Adopting the simpler form, we have

$$\log n! \fallingdotseq \log\sqrt{2\pi} + (n+\tfrac{1}{2})\log n - n + \frac{1}{12n}\left(\frac{15n^2}{15n^2+8}\right)^{1/16},$$

or passing to common logs (M = modulus),

$$\log_{10} n! \fallingdotseq 0{\cdot}39908993 \ldots + (n+\tfrac{1}{2})\log_{10} n - n\mathrm{M} + \frac{\mathrm{M}}{12n}\left(\frac{15n^2}{15n^2+8}\right)^{1/16}.$$

This formula gives for 1! (true value 1), 1·00007 . . .; for 2! (true value 2), 2·000002 . . .; for 3! and 5! no discrepancy is shown by 7-figure logs and 9-figure logs respectively. The degree of approximation is therefore high and even remarkable; but it may be doubted whether this formula or any of those under discussion is really to be preferred to the direct use of the series of which we can easily take as many terms as may be required for the order of accuracy desired.

G. J. LIDSTONE.
9 St. Andrew Square, Edinburgh,
July 24.

The Growth of the Telescope.[1]

By Dr. WILLIAM J. S. LOCKYER.

IN the beginning of the year 1608, that is, 315 years ago, or about ten generations, telescopes did not exist. The main work of astronomers before the year 1608 was, therefore, concentrated upon observing and recording the positions of the heavenly bodies from day to day and from year to year. The early (1587) instruments for observations of position took the form of graduated quadrants mounted in a vertical plane capable of rotation about the centre of a horizontal divided circle. The direction of a heavenly body could be indicated only by pointing at it; so every quadrant was furnished with a pointer pivoted at the centre of the quadrant. The adjustments of the instruments were made by using a plumb line for the determination of the vertical, and a level for placing the azimuth circle horizontal.

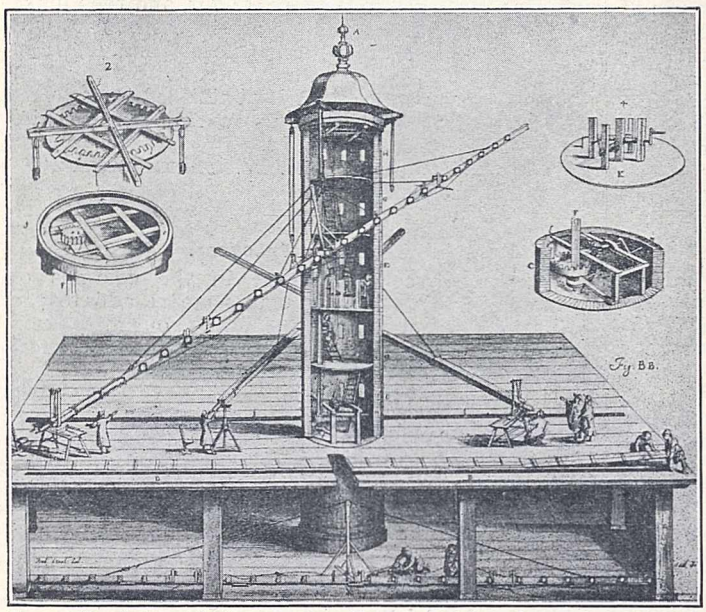

FIG. 1.—Hevelius's aerial telescopes mounted by suspension from the roof of a tower which can be rotated by gearing.

Tycho Brahe, the famous Danish astronomer (1546–1601), constructed many elaborate instruments of this nature for his observatory at Uraniberg, but his most important instrument was the large quadrant fixed in the meridian with which he observed transits of the heavenly bodies through a hole in the south wall. This instrument was the forerunner of the modern transit circle.

Galileo was the first to use the "optik tube" for the study of the heavenly bodies, and in consequence made a series of important discoveries. Thus, he found that the number of stars was enormously increased; the "wandering stars" were really planets; the moon displayed mountains; Jupiter possessed a family of satellites; Saturn exhibited curious features which were eventually identified as a ring system; Venus appeared as a crescent; spots were visible on the solar surface, etc. The lens combination employed by Galileo underwent changes as time advanced. In 1620 Kepler suggested the use of two double convex lenses, and this was actually carried out by Scheiner in 1637. Astronomers had to wait nearly 100 years before Chester More Hall, in 1733, put forward the idea of making an object-glass of two different kinds of glass—crown and flint—placed close together, thus establishing the so-called achromatic lens. It was not, however, until another quarter of a century had passed that John Dollond in 1758 rendered this discovery effective, thus heralding the dawn of what may be termed modern astronomical observation.

In the year 1639 the discovery of another form of telescope was made, namely, the reflecting telescope; but it was not until the year 1663 that the principle was described in practical form by James Gregory. It was left, however, to Sir Isaac Newton in 1668 actually to construct an instrument of this nature, and the telescope he made, which is quite small, is to-day in the rooms of the Royal Society of London. Like the refracting telescope, the reflecting telescope underwent various changes in the optical train; thus we have the forms now known as the Newtonian, Gregorian, Cassegrainian, and Herschelian.

As soon as the refracting telescope became a practical instrument it was at once brought into commission for instruments employed in the measurements of the positions of the heavenly bodies. In fact, it at once replaced "pointers." Tycho Brahe's great quadrant was soon superseded by a type of instrument similar to that made in 1770 by Sisson for the Kew Observatory. This was an 8-foot quadrant, mounted in the meridian, with a finely divided scale and vernier. The quadrant form developed later into a complete graduated circle read by several microscopes after the type of Gambey's mural circle, made in 1819 for the Paris Observatory.

The acme of perfection in accuracy is reached to-day by such an instrument as the present Cape Observatory transit circle. In this the telescope has an objective of 6 inches aperture of the finest construction, two very finely graduated circles are attached, and several micrometers are employed for reading each circle. Many other refinements, too numerous to mention here, are included to attain the highest accuracy.

In order to follow the developments of the two kinds of telescopes, namely the refractors and reflectors, it is best to deal with each kind separately. Returning to the epoch many years before John Dollond made the achromatic lens effective, it was found that an object glass, which then consisted of a single lens only, formed images at the focus which were highly coloured and spoilt definition. The only method of securing greater magnifying power, with increase of aperture or diameter of lens, was to make the lenses of great

[1] From a discourse delivered at the Royal Institution on Friday evening, April 20.

Current Topics and Events.

ATOMIC projectiles have been used by many investigators to batter down the defences which have guarded so well the innermost mysteries of the structure of matter. The α-particle, liberated spontaneously in radioactive transformations, has, thanks to its enormous velocity, been of special service in elucidating the constitution of the atom. In these investigations no one has played a more important part than Sir Ernest Rutherford, and it is, therefore, appropriate that in the address which appears as a supplement to this issue of NATURE he should give an account of the life history of such a high-speed α-particle. When the particle is expelled from a radioactive substance, it has been proved to be the nucleus of a helium atom of mass 4 carrying two positive charges of electricity. Recent experiments by Henderson have shown how, by the successive capture of electrons, the α-particle becomes a neutral helium atom. The experiments, which were carried out by observing the deflexion of a narrow pencil of α-rays in a magnetic field, have been confirmed and extended by Sir Ernest Rutherford. It appears that not only may the doubly charged helium nucleus remove and capture an electron from the outer electron structure of the atoms in its path, but the converse change may also take place. In passing through other atoms this electron may be knocked off, and the singly charged α-particle revert back to the doubly charged type. The somewhat unexpected conclusion is reached that this process of capture and loss may repeat itself more than a thousand times in the flight of the particle. Similar considerations apply in the case of singly charged and neutral helium particles. Though the results of these encounters may be less startling than those in which disintegration of an atomic nucleus like that of nitrogen or of aluminium occurs, it seems probable that the study of these rapid interchanges of charge will yield information of great value to the theoretical physicist.

THE attempt to restrict the spread of epidemic disease amongst plants is creating a phytopathological service of inspection in many countries, and legislation is gradually restricting the free movements of plants and plant produce in and out of the various countries. In a paper under the title "The Biological Basis of Plant Quarantines" contributed to *Phytopathology* for June, W. A. Orton and R. Kent Beattie attempt to get down to the first principles underlying such legislation, and their views deserve careful study in Great Britain, both by growers and students of pathology, as, if the conclusions arrived at find favour in the United States, the British exporter of plants may experience increasing difficulties in the way of export trade with that country. The authors draw a fundamental distinction between communications between countries that are close neighbours, and traffic in plants across the ocean barriers that separate continents. They conclude that within the area of a continent the cultivated host plants and their parasites will in most cases have fought out their battle and arrived at an approximate equilibrium, the issue of the conflict varying of course each season, but without violent fluctuation. When, however, a parasite crosses an ocean barrier, then its arrival in the new continent may be followed by incalculable results, and a cultivated crop may almost be exterminated before selection of more resistant forms, or other factors operating over a space of time, have again produced an equilibrium in which the cultivation of the crop is economically possible, allowing for the average loss produced by this parasite. These results may follow, even when the parasite thus introduced is one regarded as relatively innocuous in the continent where it has long been known. For example, chestnut bark disease, *Endothia parasitica*, though a relatively minor trouble in Asia, has, since its introduction to America, bid fair to destroy all the chestnut forests of the country. The author's arguments bring them into disagreement with the conclusion of the last International Phytopathological Convention, held in Rome in 1914, as they emphasise the importance of "common species of long-standing dispersion" which inspecting officials naturally tend to overlook, and lead them to the very important general principle that "inter-continental trade in plant propagating material is fundamentally dangerous, and to be held within the narrowest limits compatible with economic need."

ONE of the best-known German scientific workers, and at the same time one of the founders of modern physical chemistry, Wilhelm Ostwald, who was born September 2, 1853, at Riga, is about to celebrate his seventieth birthday. After having studied at Dorpat he was appointed, in 1883, professor of chemistry at the Baltic Polytechnical School of Riga, and, in 1887, professor of physical chemistry in Leipzig. Here he developed a great ability as an investigator as well as a teacher. His work gave a firm experimental foundation to the theories of van 't Hoff and Sv. Arrhenius. There, scientific workers from all over the world assembled round the master, and built up, in a short time, the edifice of modern physical chemistry. Besides this work, Ostwald produced a number of valuable text-books, including his large "Outlines of General Chemistry," "The Fundamental Principles of Chemistry," "The Principles of Inorganic Chemistry," and "Scientific Foundations of Analytical Chemistry." At the end of last century Ostwald devoted himself more to questions of natural philosophy, such as the energy resources of the world. These studies, the fight against scientific materialism, and the propagation of Haeckel's monistic philosophy so occupied his mind that he gave up his professorial duties in 1906 and retired to his country seat in Grossbothen, Saxony. It was a token of the breadth and productivity of Ostwald's mind that even then he created for himself quite a new sphere of activity. Starting from the art of painting, which he had loved and cultivated since his youth, he worked out a new system of colour, by which every tint can be

characterised by exact figures. He has expounded the system in various works on colours, and it has already led to the foundation of an institute for colour investigation in Dresden. The numerous pupils and friends of Ostwald rejoice in the work of their leader and offer him their tribute of esteem.

THE second triennial Pan-Pacific Science Congress, which opened at Melbourne on August 13, is being held under the auspices of the Australian National Research Council and with the support of the Commonwealth and State Governments. The first congress was held in Honolulu in 1920, and the third will be held in some other country bordering on the Pacific. The object of these congresses is the promotion of the study of scientific problems of common interest, and the meetings form part of a general plan aiming at the maintenance of harmonious relations between all the countries within and bordering the Pacific region. In addition, therefore, to representatives from Great Britain and various parts of the Empire, distinguished men of science from the United States, Japan, and Formosa, the Netherlands, Dutch East Indies, and other countries are attending the Melbourne congress. Among the subjects under discussion are: irrigation problems; agricultural education and research; genetics, with special reference to the improvement of farm animals; organisation of research among the natives of the islands of the Pacific. (A strong effort will be made to obtain from ethnologists agreement as to a definite and practical scheme for the investigation at once of the fast-disappearing races in those islands in which Australia is especially interested. If such a scheme can be devised it will be laid before the Commonwealth Government with an urgent plea that it be put into effect at once); introduced pests and natural enemies; paper pulp: Australian possibilities; meteorology of the Pacific; terrestrial magnetism in Pacific regions; value of hydrographical work of the Royal Navy, and Australia's responsibility to continue it; survey of the Great Barrier Reef; international notification of animal diseases; hygiene of Pacific Region; fisheries and marine biological stations; parasitological problems, etc. We hope to give an account of the proceedings of the congress in a future issue.

A SPECIAL number of the *Revue Scientifique* was published on July 28, under the title of "L'Œuvre de Pasteur et ses conséquences." We may regard it as the complement of the special Pasteur number of NATURE: but it goes further afield. It contains many articles by writers of great authority: and it represents the devotion of all France to Pasteur's memory. He lived and worked for France, and wore out his life for her. His work was for the good of the world. Still, it was for the honour and glory of France: that was his revenge, after 1870, to set France high above Germany in a vast domain of science. Every year we in Great Britain, though we are grateful to him, are living under this disgrace, that we have no monument or memorial to him, to show our sense of gratitude for all that we have learned from him. Among the articles in this number of the *Revue Scientifique* are two of remarkable interest. One is on the predestined course of his discoveries, "L'Enchaînement des découvertes de Pasteur." There is no end to the wonder of this orderly and inevitable enchainment of discoveries. The other article is "Pasteur et la Maternité." It tells the story of Semmelweis and his defeat: and the story of Tarnier's work, who in one year saw, in the Maternité de Paris, 132 women, out of 2237, die of puerperal fever: indeed, in May, out of 31 admitted for confinement, 30 went out dead. Then, the wearisome debating and theorising, up to that day in 1879, March 11, in the Académie de Médecine, when Hervieux poked fun at the notion that puerperal fever was caused by germs, and Pasteur went up to the blackboard and sketched *streptococcus* on it, saying, "Tenez, voici sa figure." We see, by an advertisement in the *Revue Scientifique*, that copies of Aronson's bust of Pasteur can be had at prices according to size. Surely, some English shops ought to stock this bust. But where is our proper memorial of Pasteur in London?

A SEVERE typhoon was experienced at Hong-kong on Saturday, August 18, and much damage occurred, accompanied with loss of life. The wind is said to have attained a velocity of 130 miles an hour, which is stated to be the highest on record, and the barometer fell to 28·66 in., said to be the lowest reading on record at Hong-kong. In two hours, from 9 to 11 A.M., during the height of the storm the rainfall amounted to about 5 inches. Good notice was given of the approach of the typhoon, which was first reported on August 11, from Guahan, Ladrone Islands, in the North Pacific. The progress of the typhoon was about 270 miles a day to the west-north-west. Later reports fortunately state that Hong-kong has suffered far less than might have been expected, but the typhoon warning was again hoisted on August 20. Typhoons are regularly warned at Hong-kong by those in charge at the Royal Observatory.

IN the *General Electric Review* of America for August there is a complete technical description of the latest broadcasting station in New York. It is termed "Broadcast Central" and operates under the call letters WJY and WJZ. It was opened on May 15 and can be heard by radio listeners on the eastern side of the United States. It has "two channel" operation, so that it transmits two different programmes simultaneously. WJY, called the "jazz" channel, operates on a wave-length of 405 metres and broadcasts popular music, news, lectures, etc. The WJZ channel operates on a wave-length of 455 metres and broadcasts operatic and classical music. Both the studios are on the sixth floor of the Æolian Hall, which is in the centre of New York City. As concerts and recitals are always being given in this hall, arrangements have been made to broadcast them. Special line wires also have been run to the more important theatres and hotels, so that outside performances can be readily transmitted. The antennæ are strung from two 120-foot towers located on the roof at a distance of 175 feet apart and form two

separate four wire horizontal systems separated by ropes and insulators. The length of the wires forming one system is 45 feet, and the length of the other system is 55 feet. As the output of a high-quality microphone seldom exceeds a few millivolts, considerable amplification is necessary. A three-unit motor generator set is used. One of the generators has a 1000-volt commutator at each end, thus giving 1000 volts for the amplifier plate filter and 2000 volts for the transmitter. The equipment is all duplicated, one set being in reserve, so as to reduce the risk of a breakdown to a minimum. From the listener's point of view, this alternative choice of programmes is an attraction, and the operation of Broadcast Central has been extremely successful.

THE *New Phytologist* (vol. 22, No. 3) contains a very stimulating article by Dr. F. E. Clements under the title of "The Ecological Method in Teaching Botany," in which the author's ecological outlook is applied to the problems of teaching with the insistence upon quantitative study of environment, and the response thereto, that has proved so fruitful in his studies of vegetation. This paper should do good if only for its challenge to the traditional methods which hold such unquestioned sway, though many teachers will feel Dr. Clements's ideals—that the student's education should be based mainly upon first-hand investigation, brought into an ordered and correlated form by the method of group discussion, all the work being done "where the plants are, whether this be the greenhouse, garden, field or (much less satisfactory) the ordinary laboratory"—make demands which the staffing and accommodation of most British departments of botany would render impossible. Dr. Clements's distrust of the efficacy of lectures, his challenge to the professors' insistence upon principles as apart from facts, his criticism that the laboratory notebook, save for its indifferent quality, is more suitable to a drawing class, and his objection to the content of the typical elementary class in which morphology is paramount, are points in his paper which might well provoke animated discussion; but there can be little question that a new generation will do well to take a critical survey of the methods and results of the formal lecture and laboratory courses of their predecessors.

APPLICATIONS are invited by the Admiralty for a Junior Scientific Assistant in the Experimental department of the Signal School, the duties being concerned with the application of W/T devices; also for a Junior Scientific Assistant having a good knowledge of general physics, possessing an honours degree in physics or its equivalent, and with some experience in research. Applications for the posts should be sent to the Secretary of the Admiralty (C.E.), Admiralty, S.W.1.

REFERRING to the letter of Dr. G. D. Hale Carpenter on a waterspout with a sheath or sleeve, published in NATURE of September 23, 1922, p. 414, and one on the same subject by Dr. Willard J. Fisher in the issue of November 18, p. 669, Dr. Fisher writes to say that the same sort of sleeved tornado pendant seems to be described by R. Abercromby, in the Quart. Jour. Roy. Met. Soc., 16, pp. 119-126, 1890, as having been observed by Mr. S. Elson, a Calcutta pilot. Possibly the phenomenon is not very uncommon.

THE British Research Association for the Woollen and Worsted Industries announces the following awards for the year 1923–24: Research Fellowships: Mr. Robert Burgess, of Nottingham, to carry out investigations on the damage and deterioration caused by bacteria and fungi on woollen goods and yarns during storage; and Mr. H. E. Farrar, of Leeds, to conduct research on the dyeing of wool with acid and mordant colours. Advanced Scholarships: Mr. S. Menzer, tenable at the University of Leeds; Mr. T. N. T. Graham, tenable at the Scottish Woollen Technical College, Galashiels; Mr. P. M. Redman, of Keighley, and Mr. W. Lee, of Halifax, tenable at the Bradford Technical College.

WE have received from British Drug Houses, Ltd. (16-30 Graham Street, N.1), a specimen of their standard lactose B.D.H., which has been prepared of guaranteed purity for the particular requirements of bacteriologists and biologists. We have tested it with several strains of *Bacillus typhosus*, *B. paratyphosus*, *B. dysenteriæ*, and other micro-organisms, and find that it gives the characteristic and typical fermentation reactions of the respective organisms. One gram incinerated on platinum gave no weighable amount of ash. We therefore believe that the claim made as to the purity of this lactose is substantiated. It is supplied in 1 lb. sealed tins, price 3*s*. 6*d*. each.

THE Nouvelle Société Helvétique, 28 Red Lion Square, London, W.C.1, has just issued a useful bibliography of books dealing with Switzerland which have appeared in English since 1880. The list includes not only guide-books and tourist literature but also those on historical, constitutional, and social subjects, and in addition works by Swiss writers translated into English, as well as books in English on such pioneers as Rousseau and Pestalozzi in education and de Saussure in science. All lovers of Switzerland and its people will find the bibliography helpful and interesting. Copies may be obtained upon application to Dr. Paul Lang, Secretary of the Society, at the above address.

THE names of the green pheasant, the copper pheasant, and the golden pheasant were added to the Schedule to the Importation of Plumage (Prohibition) Act, 1921, by virtue of the Importation of Plumage (No. 2) Order, 1922, dated June 12, 1922. As was announced in the Press at the time, the Advisory Committee appointed under the Act, in recommending the addition of the names of these birds to the Schedule, further recommended that the matter should be referred to them again for review after the expiration of twelve months. The Committee has now reconsidered this question and has recommended that the golden pheasant should be included in the Schedule for a further period of twelve months, but that the copper and green pheasants should be removed from the Schedule at the end of the present year.

The Board of Trade accordingly desires it to be known that an order will be made in due course, removing the names of the copper and green pheasants from the Schedule, with effect from January 1, 1924.

Science announces that the committee of the Daniel Giraud Elliot Medal desires to receive nominations for the awards of the years 1921 and 1922, which are still open, because the committee has not been able to reach unanimous conclusion on any work thus far brought to its attention. The Elliot Medal is awarded for some especially great contribution, not for general accomplishment, in the field of either zoology or palæontology. It is not restricted in either branch to the vertebrates, but may be made in either the vertebrate or invertebrate field and is open to scientific workers of the world. The award of the gold medal is accompanied by a generous honorarium. Nominations for the two years mentioned, namely, 1921 and 1922, and also for 1923, can now be received. Communications should be addressed to the Secretary of the National Academy of Snccices, Washington, D.C.

THE eleventh meeting of the Indian Science Congress will be held at Bangalore on January 14-19, 1924. H.H. the Maharajah of Mysore will be patron of the meeting, and Sir Asutosh Mookerjee will be president. The following sectional presidents have been appointed :—Mr. B. C. Burt (agriculture) ; Prof. C. V. Raman (physics and mathematics) ; Dr. E. R. Watson (chemistry) ; Prof. K. N. Bahl (zoology) ; Prof. Agharkar (botany) ; Mr. H. Bosworth Smith (geology) ; Lieut.-Col. Christophers (medical research) ; Mr. J. Hornell (anthropology). The honorary local secretaries will be Prof. F. L. Usher, Central College, Bangalore, and Mr. S. G. Sastry, Secretary, Board of Scientific Advice, Bangalore. Further information can be obtained on application to the hon. general secretary, Dr. J. L. Simonsen, Forest Research Institute and College, Dehra Dun, U.P. India.

THE Journal of the Röntgen Society (the oldest radiological society in the world) for July (vol. xix. No. 76) contains an account of the twenty-fifth anniversary dinner of the Society held in March last, and a translation of Röntgen's first and second memoirs on X-rays, entitled "Concerning a New Kind of Ray," which are interesting reading.

THE latest catalogue (No. 378) of Messrs. Bernard Quaritch, Ltd., 11 Grafton Street, W.1, is of a miscellaneous character, but of the 1399 second-hand works offered for sale many deal with science, and, as is usual with the lists issued by this firm, some are very scarce and choice. The catalogue also comprises a list of selected new and recent publications.

THE McGraw-Hill Publishing Co., Ltd., announces an interesting new series of books under the title of "Concise Studies in Economic Problems," which will embody the results of research studies made by the Institute of Economics of Washington, D.C., U.S.A. The first volume will be "Germany's Capacity to Pay." Succeeding works will deal with International Economic Reconstruction, International Commercial Policies, Industry and Labour, and Agricultural Economics.

Our Astronomical Column.

THE DENSITY OF THE CORONA.—The question of the density of the corona is of interest both with regard to possible refraction of starlight in the investigation of the Einstein light-deviation, and with regard to the amount of resistance met with by comets of small perihelion distance. *Astr. Nach.*, 5238, contains a discussion of the subject by B. Fessenkoff, of Moscow.

The author assumes that the total light of the corona is equal to that of the full moon, and that the light intensity varies (1) as the inverse square, (2) as the inverse fourth power, of the distance from the sun's surface. He utilises some studies of his own on the light-reflecting powers of the terrestrial atmosphere at various heights, obtained from measures of the brightness of twilight for different angles of depression of the sun. He calculates that the light given by a small volume of the corona, 5′ from the sun's limb, in terms of the light given by an equal volume of terrestrial atmosphere, of the density and composition that exist at a height of 100 km., placed in the same situation as the coronal volume, is :— on supposition (1) $0{\cdot}52 \times 10^{-3}$; on supposition (2) $0{\cdot}27 \times 10^{-4}$. The density of the corona at 5′ from the limb is that of hydrogen at pressures $0{\cdot}43 \times 10^{-5}$ mm. and $0{\cdot}22 \times 10^{-6}$ mm. (temperature 0° C.) on the two suppositions. It will be remembered that the nearest stars that have been observed in the Einstein investigation were considerably further from the limb.

REPORT ON THE KAPTEYN SELECTED AREAS.—Prof. Van Rhijn, of Groningen, has issued a useful report on the progress of researches on these areas. They are distributed on a uniform plan over the celestial sphere, and are to be studied in an exhaustive manner by a number of co-operating observatories. The first step is the formation of a photographic Durchmusterung of the stars in the areas ; this is being done at Harvard and Arequipa, with apertures of 16 and 24 inches, and limiting magnitudes 15·9 and 16·3 respectively ; these plates are being measured at Groningen. It is estimated that the number of stars is about a quarter of a million, the total area being 225 square degrees, or 1/183 of the sphere. The positions are determined to an accuracy of half a second, the magnitudes to 0·1 mag. The centennial proper motions of the stars of mag. 12 and brighter are determinable to a third of a second with the aid of the *Carte de Ciel* plates ; those of the fainter stars will not be obtainable for some years with the necessary accuracy.

The best methods of determining absolute motions and eliminating magnitude error are discussed ; the author hopes that Kapteyn's plan for a photographic parallax Durchmusterung will not be abandoned. He admits that the results are illusory for particular stars, but he thinks that they will serve to compare the parallaxes of stars of the same magnitude with large and small proper motions. The colour-indices are being determined by Seares by comparison of photographs on ordinary and orthochromatic plates. Altogether the report gives a hopeful summary of the results already attained and those to be looked for in the near future.

Research Items.

TESTS OF NATURAL AND CULTURE PEARLS.—A simple optical method of distinguishing the Japanese "culture" pearls from wholly natural pearls is described by Dr. F. E. Wright in Journ. Washington Acad. Sci., 1923, vol. 13, p. 282. In a bead of mother-of-pearl, such as is always used for the nucleus of the "culture" pearls, the nacreous layers are not concentric to the surface, but are approximately plane, being parallel to the surface of the shell from which the bead was cut. Now normal to this surface the reflecting power, and consequently also the opacity, is at a maximum; whilst at 90° from this direction (that is, looking along the laminæ) there is a minimum of reflection and of opacity. A "culture" pearl when viewed in a strong reflected light (for example, with the observer's back to the sun) shows at the opposite poles of one diameter a small bright spot due to the light reflected from the laminæ of the enclosed bead of mother-of-pearl. In a strong beam of transmitted light (arranged in a closed box with lens and mirror, the pearl resting in a circular aperture) the "culture" pearl shows two positions of maximum opacity, whilst the natural pearl is the same in all positions. A third method, which is applicable also to "culture" pearls containing a real pearl as nucleus, is given by an examination of the walls of the hole drilled through the pearl. The pearl is illuminated by a strong side light and a minute bead melted on the end of a gold wire is inserted in the bore to act as a reflector, which is viewed under the microscope.

CONDENSED MILK.—An important report by Dr. Savage and Mr. Hunwicke on the manufacture, condition, bacteriology, and spoiling of commercial sweetened and unsweetened condensed milk has been issued by the Food Investigation Board (Special Rep. No. 13). The changes in the condition of the milk as a result of its concentration are profound, and not merely those caused by deprivation of water. It is, for example, a much worse conductor of heat than unconcentrated milk. While sporing aerobic bacilli are present in a considerable proportion of samples, decomposition and spoiling are nearly always due to non-sporing bacteria, particularly certain micrococci, which either survive the preliminary pasteurisation of the raw milk in the course of manufacture, or after canning are admitted to the tins through minute leaks. The sources of bacterial contamination and multiplication are mainly from the original milk, from the air of the factory, and particularly from dirty pipes and apparatus. As regards the viability of the micrococci which cause spoiling, in unsweetened condensed milk they may survive a temperature of 70° C., but are destroyed at 80° C. in a short time: this suggests that a longer pasteurisation of the raw milk might be an advantage. The best manufacturers appear to have achieved striking success, however, in dealing with such an unstable substance as milk.

RESEARCHES ON MARINE ANIMALS.—We note with pleasure that Prof. M'Intosh—the veteran naturalist—continues to publish his notes from the Gatty Marine Laboratory, the forty-fifth paper of this series appearing in the July number of the *Annals and Magazine of Natural History*. A note on variation in the wild rabbit is included, but the other items refer to marine animals. The results of a comparative study of the British species of Lepadogaster (Sucker-fishes) are set forth, the characters of the young as well as of the adults being contrasted. The sub-fossil skull of a whale found at Airthrey, near Stirling, is described and figured, and Sir William Turner's conclusion that it pertains to Sibbald's Rorqual is corroborated. A fragmentary skull of *Balæna australis*, from the Campbell Islands, is also described. Finally the variation of *Amphinome rostrata*, a Polychæte worm, is considered, and the conclusion is arrived at that the differences said to exist between specimens from the Atlantic and Indian Oceans are not specific, but are largely due to different methods of preservation. Formalin is condemned as an unsuitable preservative for animals of this group.

VIRUS DISEASES OF POTATOES.—A valuable addition to knowledge of the virus diseases of the potato (Leaf Roll, Mosaic, etc.) has been made by P. A. Murphy, of Dublin, who publishes an account of his work in the current issue of the *Journal of the Irish Department of Agriculture*. It is now well established that what has hitherto been called degeneration of the potato is not due so much to environmental causes as to the presence of infective diseases of which the perplexing feature is that no visible causative organisms have yet been discovered. The menace of these virus diseases to the economic plants of the world seems to be increasing. Already the maize and sugar-cane crops in America have been attacked over large areas of the country. In addition to the potato these diseases (it may be the same disease) in the British Isles attack the tomato, mangel, and the hop. It was shown some years ago by Quanjer in Holland that the infection is transmitted from plant to plant by species of aphis. Mr. Murphy has now proved that other insects infesting the potato, such as various species of Jassid and Capsid, are capable of transmitting infection. In this connexion it is interesting to learn that potatoes when grown in the North of Scotland are not so liable to infection, and it has been suggested that this is due to the absence of disease-carrying insects at a sufficiently early stage of the growth of the plant. Whatever the reason may be, it is undoubted that tubers imported into the south from this region are generally free from disease and produce a much heavier crop of potatoes than that raised from indigenous "seed." Mr. Murphy also shows that certain varieties of potatoes are less liable to infection than others. One of his most interesting experiments was an attempt to secure healthy tubers for "seed" by "rogueing" out obviously infected plants. The result was unfortunately inconclusive, and it appears doubtful whether immunity from attack can be secured by this means. Another perplexing feature of these diseases probably stands in the way. There appears to be no doubt that certain plants (including Solanaceous weeds) act as carriers of the disease, and may therefore be the means of infecting other plants, while showing no visible signs of infection themselves.

TERMITES OF BARKUDA ISLAND.—In a recent part of the Records of the Indian Museum (vol. xxv. part II.) is a memoir on the Termites of Barkuda Island in the Chilka Lake. The systematic characters of the genera and species are described by Prof. F. Silvestri, the habits by Dr. N. Annandale, and the fungi cultivated by the termites by Prof. S. R. Bose. Dr. Annandale divides these termites biologically into three categories—burrowers, mound-builders, and log-dwellers—a classification which, as he points out, does not correspond with the taxonomic one. He discusses the swarming, the duration of life, the cultivation of fungi and the search for food, and the details of structure of the nests.

PARASITIC NEMATODES.—Dr. H. A. Baylis and Mr. R. Daubeny (*Memoirs Indian Mus.*, vii. pp. 263-347) report on the parasitic nematodes in the collection of the Zoological Survey of India. The material, which includes about eighty species, was collected

from animals, mostly Indian, in the Zoological Garden, Calcutta. One of the most interesting records is that of full-sized specimens of *Ascaris lumbricoides* in squirrels. The authors have compared these specimens with others from man and from an Indian wild pig—paying particular attention to the characters of the lips, of the posterior end of the male, and of the eggs—and they conclude that all belong to the same species. *Ancylostoma duodenale* is recorded from the tiger, the specimens being somewhat smaller than those from man, as has been noted in regard to examples previously found in the tiger. *Necator americanus* was found in a new host, namely, a young African rhinoceros which was captured in Tanganyika Territory and had lived in the Calcutta Zoological Garden only a very short time. Two larvæ taken from a prawn are tentatively referred to the genus Eustrongylides, and are apparently the first examples of the genus to be recorded from an invertebrate.

FOSSIL BARNACLES OF INDIA.—The receipt of fresh material at the Natural History Museum has led Mr. T. H. Withers to undertake a revision of the Fossil Balanomorph Barnacles from India and the East Indian Archipelago (*Rec. Geol. Surv. India*, vol. liv). Five species in all are described, three being new, but amongst them the *Balanus tintinnabulum*, of Linné, although often cited in literature, was not to be found, notwithstanding its occurrence in the modern Indian Ocean fauna. One of the new species, *Balanus javanicus*, is closely allied to a recent South African form, and another, *B. indicus*, to a North Pacific species.

INDIAN TERTIARY GASTROPODA.—A fourth, and unhappily last, contribution on Indian Tertiary Gastropoda comes from the pen of Mr. E. Vredenburg, who did not, alas, live to revise the proofs. This part includes the Olividæ, Harpidæ, Marginellidæ, Volutidæ, and Mitridæ (*Rec. Geol. Surv. India*, vol. liv.), and is on the same lines as its predecessors (*cf.* NATURE, May 6, 1922, p. 594). Most of the species described are new and nearly all are excellently illustrated. By an oversight the pre-Linnean name Turricula of Klein, 1753, has been allowed to stand in lieu of Vexillum, Bolten, 1798.

THE GEOLOGICAL EXPLORATION OF AFRICA.—The progressive work of the Geological Survey of Nigeria has already been referred to in NATURE (vol. 110, p. 91, 1922). The fourth of the quarto bulletins, on "The Northern Tinfields of Bauchi Province," price 10s., has now been issued under the care of Dr. J. D. Falconer, and its finish and style of publication testify to appreciative Government support. The illustrations of heat-weathering and water-weathering in granite increase our knowledge of "inselbergs," and the solution-cave in the granite mass near Gohar (Pl. vi) will be a revelation to most geologists. Dr. Falconer's discussion (p. 41) of the origin of the fissures that carry tin ore in the region is of importance in the question of batholitic intrusion generally. He shows how widely spread fracturing may occur in advance of the magma rising from the depths, and how intrusive breccias result from the breaking off of abundant blocks from the zone of shattering. The tin ore may have been introduced to a large extent by vapours heralding the invasion, rather than during the cooling of the "Younger Granite" mass. In Uganda, where "mineralisation" is not obvious, Mr. E. J. Wayland is not so fortunate; he is of necessity working with a temporary staff, and there is a tendency to regard his Survey as a luxury. The Annual Report for 1922 (Entebbe, 1923) shows a wide range of work, including researches on water-supply, and we hope that it may be realised that a Geological Survey, with a geographical as well as a petrological outlook, forms the basis for the understanding of a country. The Geological Survey of Tanganyika Territory, under Dr. E. O. Teale, has issued (1922) what is called a "Final Report," in which details of mineral samples are given, together with some new points as to the Karroo flora of the district. The recommendations show that hopes are entertained of the establishment of a permanent Survey Department.

CONTACT ANGLES IN CAPILLARITY.—The modern industry of ore flotation has its origin in some of the comparatively obscure laws of surface tension, and any observations which throw light on these laws help to provide the industry with a firmer scientific basis. Mr. R. Ablett's paper in the August issue of the *Philosophical Magazine* deals with variation of the contact angle of water with paraffin wax according to whether the solid is stationary or is moving into or out of the water. The wax is in the form of a horizontal cylinder immersed to such an extent that the two liquid surfaces at its sides are horizontal right up to the solid. The angle of contact is then $104\frac{1}{2}°$. On rotating the cylinder about its axis, the angle at the side where the wax enters the water becomes 113° and where it leaves the water 96°, the wax as it were dragging the meniscus with it. For speeds exceeding 4 mms. per second these angles are constant. The author ascribes the change of angle to absorption or inhibition of the water by the wax.

THEORY OF SHIP WAVES.—A contribution to this subject, by Einar Hogner, has been published in the *Arkiv för Matematik, Astronomi och Fysik*, Band 17, No. 12. (Stockholm: Almquist and Wiksells Boktryckeri A.-B.; London: Wheldon and Wesley, Ltd.) The aim of the paper is to investigate mathematically the waves produced by a "forcive" travelling with uniform velocity over a water surface; the investigation being confined to the waves in the vicinity of two boundary planes radiating from the "forcive" and forming an angle of 19°-28′ with the mid wake plane. The author briefly reviews the mathematical explanation of the system of ship waves developed by previous authors, and points out that the theory so developed is valid only for waves at great distances from the ship, and fails in proximity of the boundary planes, where the wave amplitudes become infinite. Furthermore, no waves exist outside the boundary planes, as the approximations introduced make the surface discontinuous at the boundaries. From his modified mathematical treatment, which is given in full, the author deduces that the resultant wave system inside the boundary planes can be considered as constituted by the superposition of two different wave systems, the "transverse" and "divergent." These two systems have a phase difference of 1/3rd of a wave length at the boundaries, —a fact not hitherto noticed by previous writers on this subject. The highest points of the outermost waves are finite and situated at some distance inside the boundary planes, and the resultant wave crests form angles of 56°-44′ with the mid-water plane. The resultant wave systems inside and outside the boundary planes join without discontinuity. The system outside the boundary planes is simple. The mutual situation and direction of the crests of the different wave systems at the boundary are in general found to be dependent on the acceleration of gravitation, velocity of the forcive, and distribution of pressure within the forcive; and the direction depends also on the distance from the forcive.

The Earth's Magnetic Field for 1922.

By Dr. LOUIS A. BAUER.

THE precise constitution of the earth's magnetic field at any one time, and the causes of the constituent fields, are problems of fascinating interest, the solution of which appears destined to reveal hitherto unknown properties of matter. A most intimate knowledge of the earth's magnetic and electric phenomena, as well as a thorough acquaintance with all the latest developments of theoretical physics, seems requisite to success in the proper interpretation of the mysteries presented. Whatever theory is advanced, either for the earth's magnetic or its electric field, a hypothesis must be introduced somewhere implying new properties of matter, or changes in the classical laws of electro-dynamics, or physical conditions below or above the earth's surface, of which we have no knowledge at present. This being so, it behoves us to keep an open mind with regard to any new magnetic or electric phenomena which may come to light.

We fortunately have now three bodies, vastly differing from one another in their physical constitution, the magnetic and electric fields of which may come within the scope of our investigations and help us in our theoretical views, namely—the earth, the atmosphere, and the sun. To anticipate, we now know that the direction of the magnetic axis of each one of these bodies is related in the same way for all three to the direction of rotation of the body, and that the magnetic axis of each is inclined to the axis of rotation, namely, at present, about 11·5° for the earth, about 14° for the atmosphere, and about 6° for the sun. If f be the physical factor, ω the angular velocity of rotation, r the radius, and D the density of the body, then the strength of the magnetic fields of these three bodies, at their magnetic poles for example, may be expressed approximately by a formula of the following type :

$$F = f.\omega r^2 D.$$

The magnetic field expressed by (1) has thus far defied laboratory detection, because of the size and speed of rotation of bodies we may experiment with, but it becomes readily appreciable when we are dealing with a body of mass, size, and angular velocity of rotation comparable with those of a member of our solar system. If (1) holds universally, Jupiter, for example, would be enveloped by a magnetic field of about the same strength as that of the sun. Thus we may have to look for assistance in making notable advances concerning the structure and properties of matter to experiments performed by Nature at large.

The chief questions pertaining to the earth's magnetic field may be stated as follows : (*a*) Is any appreciable portion of the magnetic force observed on the earth's surface to be referred to a non-potential system N ? (*b*) Is there, besides an internal magnetic potential system, I, also an appreciable external magnetic potential system, E, existing in our atmosphere ? (*c*) If measurable N- and E-systems are disclosed, may any portions arise from relativity effects, R ? (*d*) Is the integral of $d\mu$ over the earth's surface and for all constituent systems equal to zero, where $d\mu$ represents the elemental quantity of magnetism, or any other corresponding physical quantity that may evoke a magnetic field ? (*e*) What physical conditions must the causes for the various systems fulfil to account for the geographic variations, the secular and other variations ?

Any theory of the earth's magnetism and electricity will have to give a complete and satisfying account of these various questions before it can be accepted. Doubtless for some time to come we shall have to be content with trying out working hypotheses and must not permit ourselves to be bound to any one theory. However, encouraging progress has been made, and the object of the present communication is to tell of answers more or less complete to some of our questions.

While the magnetic survey of the globe has been in progress by the Carnegie Institution of Washington and other organisations during the past eighteen years, the writer has published the results of various investigations preparatory to a rigorous and complete analysis of the earth's magnetic field. It thus became possible to decide in what regions of the earth the field work should be intensified, and what additional allied scientific data should be included in the observational programme. Furthermore, to satisfy practical demands for magnetic data, our observational work was so arranged that sufficiently accurate results for magnetic charts could be supplied to leading hydrographic establishments within a few months after the observations had actually been made. Thus for the 1922 magnetic charts of the British Admiralty, as constructed at the Greenwich Observatory, Sir Frank Dyson states that all available material was used, "the greatest source being the observations made by the *Carnegie* and the land observations of the Carnegie Institution of Washington."

Pending more accurate and complete reduction of all observations to a common epoch by the Department of Terrestrial Magnetism than was possible by Greenwich Observatory, a preliminary analysis of the earth's magnetic field for 1922, on the basis of the latest charts and observations, was made by the writer, with the assistance of various members of his staff. The chief results were announced in a lecture entitled "The Greater Problems of the Earth's Magnetism and their Bearings on Astronomy, Geology, and Physics," delivered at the Carnegie Institution of Washington on November 21, 1922. Some later results were also presented at the meetings of the American Physical Society and the American Astronomical Society at Boston on December 30 and 31, 1922.[1] The analysis was made free as possible from assumptions as to the systems composing the entire magnetic field, and was restricted, for the time being, to the region of the earth (86 per cent.) between 60° N. Lat. and 60° S. Lat. Treating the earth as a spheroid of revolution, spherical harmonic series to the sixth degree, and in some cases to the seventh, were established separately for each of the rectangular components: X, positive towards north; Y, positive towards east; and Z, positive towards nadir.

The magnetic data utilised apply in general to longitude-intervals of 10° and latitude-intervals of 5°. Before the polar caps may be safely included in the analysis, the available magnetic data for these regions will require careful examination, and it may be found necessary to await additional data. Some analyses were also made for the regions 30° N. Lat. to 30° S. Lat., and 45° N. Lat. to 45° S. Lat. *There is evidence that the Gaussian coefficients defining the earth's magnetic field, are to be regarded at first as purely empirical quantities and, hence, strictly applicable only to the region of the earth from which they were derived.* It would seem, however, that inclusion of the polar caps will not materially alter the main conclusions given here.

The chief conclusions from our analysis are as follows:[2]

1. For a satisfactory representation of the observed data, it is necessary to recognise the existence of an

[1] *Phys. Rev.*, March 1923, pp. 370-371 and 388 ; also *Pop. Astr.*, March 1923, p. 186.

[2] For fuller details the interested reader may be referred to *Terr. Mag. and Atm. Elect.* for March-June (pp. 1-28), and September 1923.

internal magnetic system, I, an external system, E, and a non-potential system, N, or of three equivalent systems, X, Y, Z. The I-system constitutes about 94 per cent. of the total magnetic field, and E and N, each about 3 per cent. (There is a possibility that relativity effects, R, may play a part in the exact evaluation of the three systems.)

2. As a resultant effect of all systems causing the secular variation of the earth's magnetism, the north end of the magnetic axis of the I-system during the past eighty years has been moving slowly towards the west, and apparently at the same time slowly towards the equator. The indications from all available data are that if the magnetic axis completely revolves around the axis of rotation, regarding the possibility of which there may be some doubt, the period would not be some hundreds of years, but many thousands of years. The magnetic secular variation results from changes, with lapse of time, both in the direction of magnetisation and in the intensity of magnetisation; the latter quantity has been steadily diminishing during the past eighty years at the annual average rate of about 1/1500 part.

3. A suggestive effect, dependent apparently upon the distribution of land and water, has been disclosed, namely, that the average equivalent intensity of magnetisation for corresponding parallels north and south, is generally larger for the land-predominating parallel than for the ocean-predominating parallel. The secular changes, however, are on the average larger per annum for the south, or ocean-predominating, hemisphere than for the north, or land-predominating, hemisphere.

4. For the earth's internal uniform magnetic field, the following data apply for 1922. The magnetic moment, M, is $8{\cdot}04 \times 10^{25}$ C.G.S.;[3] the components of M, respectively parallel and perpendicular to the earth's axis of rotation, are, $M_p = 7{\cdot}88 \times 10^{25}$ C.G.S., and $M_e = 1{\cdot}60 \times 10^{25}$ C.G.S.; $M_p = 4{\cdot}93\ M_e$. Were the earth's magnetism uniformly distributed throughout the earth, which is not likely, the average intensity of magnetisation would be 0·074 C.G.S. The magnetic axis intersects the North Hemisphere in latitude 78° 32′ North and longitude 69° 08′ West of Greenwich.

There has recently appeared an account of an analysis of the earth's magnetic field, also for 1922, by Sir Frank Dyson and Prof. H. H. Turner.[4] These authors reach conclusions which apparently are at variance with mine given in (1) as to the definite existence of the two systems, E and N. However, a critical examination of the residuals obtained by them when they endeavour to represent the rectangular components, X, Y, Z, on the hypothesis of a magnetic potential due alone to systems below the earth's surface, and assuming that a non-potential system does not exist, is found, in fact, to strengthen my conclusions.[5]

Question (*a*) (*Non-potential System, N*).—The existence of the N-system implies the non-vanishing of the line integral of the magnetic force taken around a closed circuit on the earth's surface. Such line integrals have been computed for large land areas, like the United States, and for very large ocean areas, with data from the cruises of the *Carnegie*, both in the Northern and Southern Hemispheres. The results are so consistent that they cannot be accounted for wholly by observational errors. The analysis of the earth's magnetic field shows that the coefficients derived from the east-west component, Y, will not give an entirely satisfactory representation of the south-north component, X. A similar experience has been encountered in recent analyses of the diurnal variation of the earth's magnetic field, of magnetic disturbances, and of eclipse effects. Thus the evidence is in favour of the existence of non-potential magnetic systems. The difficulty has been in the adequate *physical* interpretation of the results. According to classical theory, line-integral values are a measure of electric currents passing perpendicularly through the area enclosed by the circuit. The average strength of such indicated currents for the earth's magnetic field is found to be more than 10,000 times that of the vertical conduction current of atmospheric electricity. The average strength of vertical currents that may in part be responsible for the magnetic diurnal variation is about 2000 times that of the currents causing the diurnal variation of atmospheric electricity. We are then forced to conclude that the magnetic line-integrals are a measure of something else than is recorded by atmospheric-electric instruments. Various suggestions are at present receiving careful consideration. The very interesting point was recently raised by Sir Arthur Schuster that no one, so far as he knew, had experimentally verified the generally accepted hypothesis that the magnetic force was accurately at right angles to the current which produced it, and he further remarked that he had very recently come across the statement that according to Einstein's theory the force and the current should not be exactly at right angles. But there are at present difficulties in trying to attribute the observed non-potential effects wholly to such a possible relativity cause.

The general system of vertical currents for the earth's field is as follows: negative electricity flowing into the earth in polar regions and flowing out in lower latitudes; for positive electricity these directions would of course be reversed. The system of vertical currents is unsymmetrical both about the axis of rotation and the equator. (A similar system of vertical currents will explain the present facts of the annual variation of atmospheric electricity.) Enough has been said to show of what extreme interest the final elucidation of the magnetic non-potential effect is likely to be.

Question (*b*) (*External Potential System, E*).—This system is disclosed by the fact that the coefficients determined from the horizontal components, X and Y, will not reproduce completely the vertical component, Z, but will leave outstanding effects of a character which, according to classical theory, can only be explained by an external system of electric or magnetic forces. However, if any portion of the earth's total magnetic field is to be attributed to causes which involve relativity effects, R, then E, in whole or in part, may have to be regarded as resulting from R. It is hoped that a special investigation now under way will throw further light on this interesting question.

As the result, apparently, of the extensive increase in knowledge of the earth's magnetic field over that at the command of previous analysts, the coefficient of the first degree zonal harmonic is found to be three times that resulting from Schmidt's careful analysis for 1885. The magnitudes of Schmidt's coefficients for the various zonal harmonics were such that he did not deem it safe to draw a definite conclusion as to the reality of an external system. The case is different, however, for our 1922 analysis; as stated under conclusion (1), we can no longer ignore the existence of effects similar to those from an external system.

Question (*c*) (*Relativity Effects*).—This question has already received some attention in the consideration of questions (*a*) and (*b*); it also enters into question (*d*).

Question (*d*) (*Is the Integral of $d\mu$ Zero?*).—All analysts beginning with Gauss have assumed that the integral of $d\mu$ is zero. The assumption enters not only into the determination of the coefficients of the

[3] The value of the magnetic moment frequently found in text-books, as dependent on Gauss's analysis for 1830, is $8{\cdot}55 \times 10^{25}$ C.G.S. The average annual rate of loss between 1830 and 1922 is about 1/1500 part, thus corresponding with the annual average rate as given in (2).

[4] Mon. Not. Roy. Astr. Soc., Geophys. Sup., vol. i. No. 3, May 1923, pp. 76-88.

[5] *Terr Mag. and Atm. Elect.* for March-June 1923, pp. 24-28.

Z-series, but may also require consideration in the derivation of the coefficients of the X-series and of the Z-series, if there is a non-potential system N. So far as the Z-component is concerned, if we do not assume the integral to be zero, a small constant term is added to the Z-series, which slightly improves the mathematical representation. If we have an N-system caused by vertical currents, as already described, then the question arises whether for a limited portion of the earth, for example from 60° N. Lat. to 60° S. Lat., we may legitimately assume that the total amount of electricity leaving the earth equals the total amount entering it in this region; if not, then $\int d\mu$ would not be exactly zero. It is of interest to note that Gauss himself intimated, in his celebrated memoir on the "General Theory of the Earth's Magnetism," that the day might come when it could not longer be assumed that the integral of $d\mu$ is zero. Investigations in progress will further elucidate this matter.

Question (*e*) (*Variations of the Earth's Magnetic Field*).—We now come to crucial tests that may be applied to any theory of the cause of the earth's magnetic field. It would seem as though the surest approach to a solution of the two problems, the origin of the earth's magnetic field and the origin of the earth's electric field, will be by means of the striking variations, geographic, diurnal, annual, sun-spot, and secular, to which they are subject. The two chief sets of variations, which a theory of the earth's magnetic field will have to explain satisfactorily, are: (1) the geographic variations; (2) the secular variations.

Fig. 1 is intended to show how ρ, the equivalent intensity of magnetisation or any other corresponding physical quantity, would have to vary from parallel to parallel in order to produce the portion (about 70 per cent.) of the earth's total magnetic field symmetrical about the axis of rotation, as represented by zonal harmonics to the sixth degree inclusive. If this portion of the field were uniform, then ρ, represented by the radius-vector from O, would be constant; this case is shown by the outer circle. Were the zonal field symmetrical about the equator, then instead of the outer circle we have an ellipse, which has been drawn for each of the two epochs 1885 and 1922 (indicated by broken curves); for this case ρ for the equator would be about 17 per cent. greater than for the combined parallels 60° N. and S. The heart-shaped full curves represent the actual state of affairs for the field symmetrical about the axis of rotation. Comparing the radii vectores, ρ, for corresponding parallels of latitude, north and south, it is seen that for both curves (1885 and 1922) ρ is invariably greater for a land-predominating parallel than for an ocean-predominating parallel, and this fact obtains even for the dotted portions of the curves which apply to the polar regions (see conclusion 3.) It will be noticed that the 1922 heart-shaped curve lies wholly within the 1885 one, just as was the case for the ellipses, and the difference, $d\rho$, between the curves represents, proportionately, the shrinkage in the earth's magnetic moment, or in the equivalent intensity of magnetisation, between 1885 and 1922. It will be noticed that the shrinkage is greater for the south, or ocean-predominating, hemisphere, than for the north, or land-predominating, hemisphere. The effect of the distribution of land and water is one calling for careful examination, and its further study may result in material advancement of our knowledge as to the cause or causes of the earth's magnetic field.

If we wish also to take into account the balance of the earth's magnetic field, about 30 per cent., which is unsymmetrical about the axis of rotation and is represented by the tesseral harmonics, then the pear-shaped solid, obtained by the revolution of the heart-shaped curve about the earth's axis of rotation,

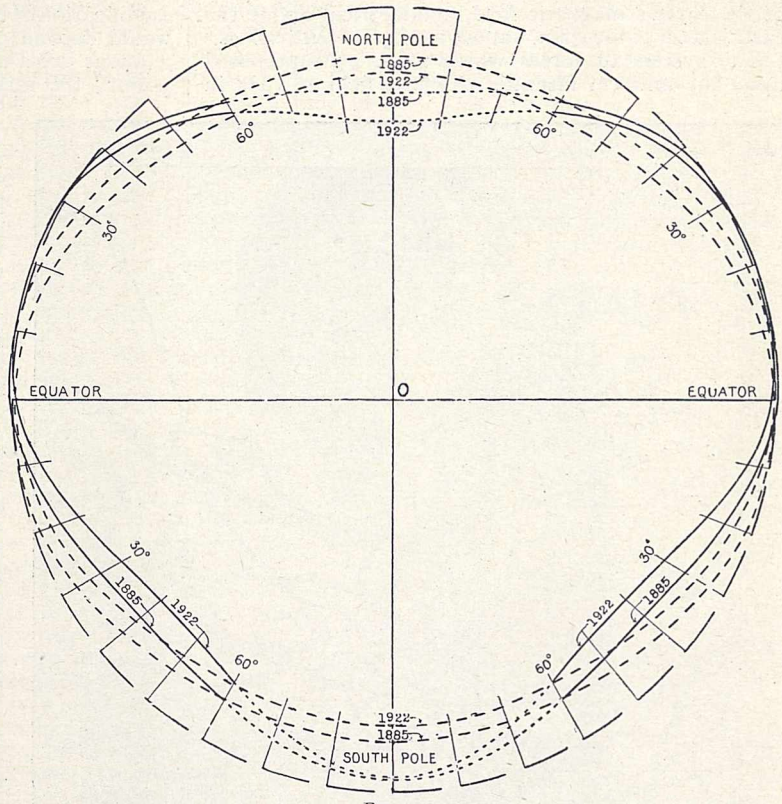

FIG. 1.

would have an irregular surface with specially pronounced humps at the magnetic poles. The radius vector to this somewhat irregular pear-shaped solid would serve to represent the volume or surface distribution of the physical quantity entering into, or evoking, the observed magnetic field. It is clear that no approximately homogeneous spherical iron core inside the earth could produce such a magnetic field as that actually observed.

Now consider the shrinkage in the earth's magnetic moment. The average annual rate of shrinkage was 1/1000 part between 1885 and 1922;[6] it was found to be 1/2170 part between 1890 and 1900, and about 1/2580 part between 1843 and 1883.[7] Whether the annual rate of shrinkage varies as greatly from time to time as is apparently indicated by these figures is open to question and subject to further investigation with sufficiently trustworthy magnetic data. The steady diminution in the strength of the earth's magnetic field, averaging during the past 80 years about 1/1500 part annually, presents one of the greatest difficulties in the theory as to the cause of the earth's field, the surmounting of which may prove to be the key to the sought-for secret. It should be borne in mind that the annual loss is

[6] *Terr. Mag. and Atm. Elect.*, March-June 1923, pp. 15, 22, and 23.
[7] *Terr. Mag. and Atm. Elect.*, vol. 9 (1904), p. 183.

quite comparable with that of well-seasoned magnets. The loss occurs practically all in the uniform portion of the earth's magnetic field, parallel to a diameter, inclined at present to the axis of rotation about 11·5°; the loss is not made up by any material gain in the non-uniform, heterogeneous portion of the earth's magnetic field.[8] The annual percentage loss is nearly the same for the polar and equatorial components of the uniform magnetic field; and as the equatorial component is only about one-fifth that of the polar component, the absolute annual loss in the earth's magnetic moment results almost entirely from the polar component, *i.e.* the uniform portion of the earth's magnetic field, symmetrical about the earth's axis of rotation, suffers nearly the entire loss.

The system of forces which must be superposed upon the uniform internal magnetic field of 1885 in order to obtain the observed field for 1922 proves to be a demagnetising system, the magnetic axis of which is directed almost diametrically opposite to that of the primary uniform field. A similar result was found in 1904[9] for the period 1890–1900. In brief, the secular-variation system shows the characteristics of the self-induced field of a uniformly magnetised body.

Let us next inquire briefly into which of the quantities in formula (1) so large an annual rate of change for the earth's field as 1/1500 part is to be attributed? Certainly not to the angular velocity, ω, or to the radius, r, or to the density, D, since changes on the order of 1/1500 part in one of these quantities, or in their combined product, would not escape detection by other means. We must conclude that the physical factor, f, contains within itself the kernel for the observed change, but what does this imply?

Let us suppose next that in the factor f we have embodied some physical relation upon which both the earth's magnetic field and its gravitational field depend. Then on the basis of the large average annual loss during the past eighty years in the strength of the earth's magnetic field, we can immediately say that magnetism and gravity are not related to each other as the first power of the factor, for otherwise a correspondingly large annual change in gravity would likewise have been observed. Again, while gravity is greater over the oceans than over continents, the equivalent intensity of magnetisation is, on the average, somewhat less for ocean areas than for continental areas, so here again there is no immediate relation between gravity and magnetism. According to Sutherland's theory[10] which was based on a slight modification of the laws of electrodynamics, magnetism would depend on the first power of a small fraction β (about $2{\cdot}6 \times 10^{-22}$), and gravity upon the second power; this quantity β would enter into the factor f of formula (1). Accordingly the annual decrease of 1/1500 part in magnetism would imply, on Sutherland's theory, only a decrease of the square of 1/1500 part, or about one-half of a millionth part in gravity, and this is a quantity which may readily escape detection with our present gravity appliances, unless the accumulative effect over many years be carefully observed at several standard stations. Hence, a theory involving gravity and magnetism in the manner prescribed by Sutherland's hypothesis might be admissible. But the observed decrease in the earth's magnetic field-strength would then have to be referred to a corresponding change in β. But what makes β change? It was only meant to represent a very slight variation in the law of action between electric charges; if β changes, so must the new assumed law of electro-dynamics. We have under investigation various hypotheses to account for the observed secular changes in the earth's magnetic field.

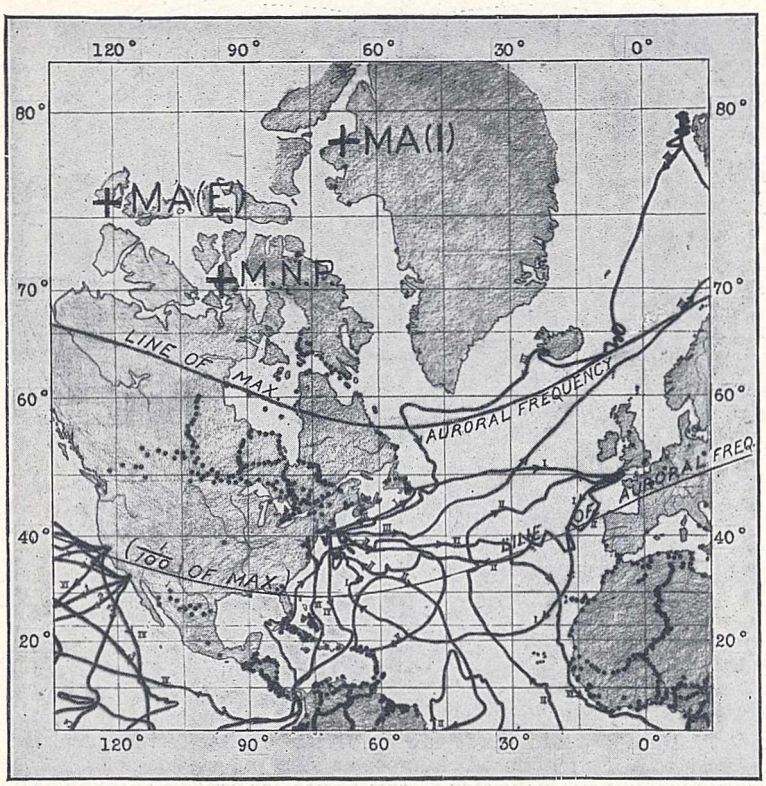

FIG. 2.

Sufficient has been given to show with what extreme care a theory of the earth's magnetic field will have to be formulated and how exhaustively it will have to be examined in the light of the data now known to us. No one who will familiarise himself with the facts will lightly announce the discovery of a new theory of the origin of the earth's magnetism. New and interesting matters may confidently be expected from the discovery of the true cause.

In conclusion, Fig. 2 is presented to show the positions of the following points: MA(I), north end of magnetic axis of the earth's uniform internal magnetic field in 1922, latitude 78° 32′ N., and longitude 69° 08′ W.; MA(E), north end of magnetic axis of the earth's uniform external magnetic field in 1922, latitude 76·8° N. and 121·4° W.; and N.M.P., the approximate position of the North Magnetic Pole in 1904, latitude 70·5° N., and longitude 95·5° W. As will be seen, the line of maximum auroral frequency passes to the south of the three positions. (The other lines shown are the routes of the *Carnegie*.) It will be noticed that the displacement of the E-axis is about 52° west of that of the I-axis, and that the N.M.P. is about midway in longitude between I and E. From the amount and direction of displacement of the E-axis with reference to the I-axis, we may deduce further important facts bearing upon the theory of the earth's magnetic field and the possible conductivity of interplanetary space.

[8] *Terr. Mag. and Atm. Elect.*, vol. 8 (1903), p. 107, and vol. 28 (1923), p. 21.
[9] *Terr. Mag. and Atm. Elect.*, vol. 9 (1904), pp. 181-186.
[10] *Terr. Mag. and Atm. Elect.*, vol. 9 (1904), pp. 167-172.

Lichens and their Action on the Glass and Leadings of Church Windows.

By Dr. ETHEL MELLOR, University College, Reading.

THE gradual deterioration and destruction of the stained glass of church windows is a subject of general and scientific interest. It will, therefore, probably be admitted that the technical and practical knowledge of the stained glass artist should be reinforced by the theoretical and laboratory studies of the scientific worker. One of the several possible lines of research was approached nearly three years ago at the Sorbonne under the direction of the late Prof. Matruchot and afterwards of the late Prof. Bonnier.

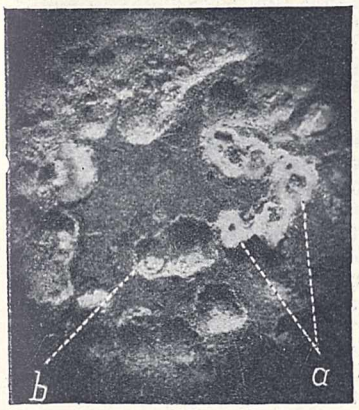

FIG. 1. (×36.)

(*a*) Opaque discs with beginnings of pits; (*b*) pit bordered by opaque glass.

The deteriorated glass is scaly and iridescent, or pitted and opaque. Both surfaces are attacked, and though the outer shows the greater alteration, it is on the inner that the action is sometimes first apparent. The opacity may extend over the whole surface, but more frequently appears as scattered disc-like points; these gradually get bigger and frequently run together. Meanwhile, the glass at the centre of the original opaque discs disappears and so arise the beginnings of the pits, each bordered by opaque glass and later lined by iridescent scales visible under the binocular lens. As the alteration of the glass continues, the pits increase in diameter and often unite, forming channels of diverse outline and length (Fig. 1). The maximum breadth measured was 5 mm., and depth 1·9 mm. Two pits on opposite surfaces will sometimes increase in depth until the separating wall disappears and a perforation of the glass results. Microscopical examination of the opaque glass shows markings and surfaces similar to geographical contours, and the contortions and cleavages of rocks.

In some cases there is no opacity, and there are no pits. The surface is iridescent and may appear slightly irregular over more or less extended areas. The alteration here takes the form of scaling in thin horizontal plates shown under the microscope to consist of several superposed layers variously cleft and resembling a crazy-tiled garden path.

Unstained and stained glass are similarly deteriorated, but certain colours show more susceptibility to alteration than others. Purple, green, blue, red, amber, and particularly amethyst glasses, are all deeply corroded, while grey tones are less so, and the golden-yellow glass resulting from the vitrification of the silver salts is more or less immune. This immunity is well illustrated in the reproduction of a fragment of fifteenth-century glass (Fig. 2); the surface of the grey and colourless portions is corroded and opaque, and outlines clearly the golden-yellow border and leaf.

There is little reason to believe that the glass of any century is the more frequently or gravely attacked. The glass of the twelfth to the fifteenth centuries is more refractive than that used later and shows a slower rate of alteration, but the cumulative destructive effects are great. The extent of the corrosion does not depend upon age—portions of fourteenth-century glass are still unaltered; specimens of nineteenth-century glass are sometimes badly pitted. The corrosion is of considerable importance æsthetically, but, though it continue until perforation occurs, it does not affect the actual duration of the window; this depends upon the leadings.

The oldest leadings are heavy and have well resisted chemical change; the lighter lead used since the fifteenth century is much more liable to conversion into carbonate of lead, friable and unstable. The transformation is often completed in less than fifty years. This is a matter of supreme importance, for the leadings constitute the skeleton of the window and their appearance remains reassuring after the chemical change has taken place. They are, however, no longer solid, and the crucial moment arrives when an external condition, such as a gust of wind, causes them to disaggregate and allow the glass to fall. It is in this way that so many of the marvellous windows of the last few centuries have perished. This destructive process has been studied and pointed out repeatedly during the last thirty years by M. Félix Gaudin of Paris, a well-known *peinte-verrier*; it cannot be emphasised too much that it is through the leadings and not through the glass that historic windows are often lost.

The alteration of the lead is purely chemical; that of the glass is due to two causes, chemical and mechanical. Strange though it may seem, the windows serve as a substratum for lichens. These plants retain water between their tissues and the glass by capillarity; they also find favourable conditions for growth in proximity to the leadings, which check the drainage where they approach the horizontal plane, and when loose hold water. The amount of carbon dioxide normally dissolved in water is considerably increased by that evolved by the lichens during the process of respiration, and the chemical change of glass and lead is thus accelerated. Evidence of this augmentation of the chemical action is given by the opacity and squamosity of the glass closely following the track of the lichen.

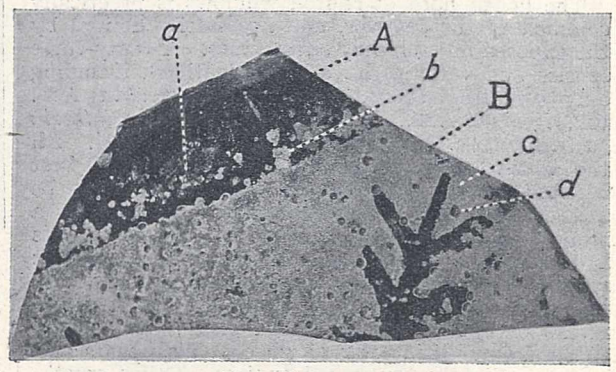

FIG. 2. (Natural size.)

A, Golden-yellow glass: (*a*) scaly glass; (*b*) opaque glass. B, Grey and colourless glass: (*c*) opaque surface; (*d*) pit.

The mechanical action of the lichens accounts for the disappearance of the opaque glass, and the consequent formation of pits and channels. The minute fissures in the opaque glass are penetrated by the lichen hyphæ, which by their varying states of

turgidity, and increase in length and number, loosen the particles and eventually incorporate them in their tissue. The inclusions, always microscopic, occur chiefly in crustaceous thalli below the apothecia and spermogonia, and in the rhizoids of the foliaceous thalli. Vertical sections of the thallus of a *Pertusaria leucosora* Nyl. contained numerous inclusions throughout the lower 0·4 mm. of their thickness.

The inner surface of the glass is the one most frequently squamose. The conditions here are most unfavourable for the development of lichens and usually there is no delimitation of the thallus. The

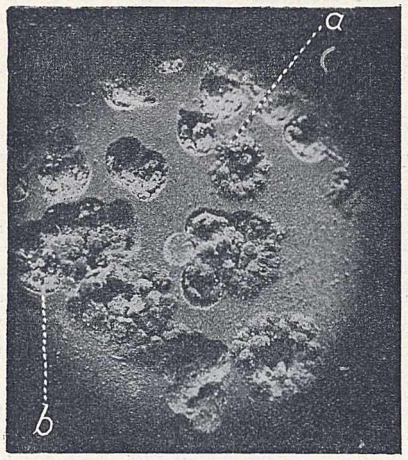

FIG. 3. (×36.)
(*a*) *Placodium murorum* DC. and circular pit; (*b*) corrosion showing outlines of original pits.

lichen constituents, hyphæ and gonidiæ, are not associated in a definite tissue but exist as a thin layer, resembling a cobweb, over more or less the whole surface, which shows a similar extensiveness in its alteration. Hyphæ and gonidiæ pass between the scales of glass, the former the more deeply, and incorporation follows.

The lichen flora of church windows is practically confined to the exterior, and necessarily limited by the exposed and slippery substratum. Twenty-three species and varieties have been identified, including only one fructaceous, *Ramalina polymorpha* Ach. var. *ligulata* Ach., and two foliaceous, *Xanthoria parietina* Ach. and its variety *tumida* Wed. All the others are crustaceous, these being the best adapted to the environment. There appears to be a succession in the flora analogous to that on a larger scale of the flora of dunes in so far as there is a preparation of the substratum for subsequent species of lichens. A crustaceous species, *Diploicia canescens* Ach., is the most abundant but it rarely occurs except on the unaltered glass; its thallus, of a maximum diameter of 4·6 cm., disappears and leaves a slightly roughened surface. Other crustaceous species follow, two varieties of *Placodium murorum* DC. being most interesting, showing as they do a conformity between their disc-shaped thalli and the circular pits of their substratum (Fig. 3). The crustaceous lichens apparently cease to thrive once the glass becomes deeply corroded, yet it is on this considerably altered surface that the fructaceous and foliaceous species exist (Fig. 4).

The lichens are not well developed. Some are not visible to the naked eye; the thallus is small, mal-formed, incomplete, or greatly soredified; apothecia are frequently absent or, conversely, persist longer than the thallus. Their determination is difficult, and is often only possible through a prolonged and concentrated study of the gradual change undergone by a species.

Lichens need plenty of air and a certain humidity, with little wind or sun, for their free growth; consequently, windows with a south aspect in the country and all windows in a crowded neighbourhood are unfavourable substrata; they have a scant flora or none at all, and show little deterioration. On windows with a west or north aspect, in humid, calm, but airy surroundings, lichens multiply abundantly and quickly, and the glass shows a correspondingly high degree of alteration. The colour or chemical composition of the glass probably influences the development of lichens, as it is not unusual to see glass of one colour bearing many of these small plants while adjacent glass of another colour is free.

Growth of lichens on windows can be prevented by the simple means of regularly brushing and washing the windows, or by the application of a liquid mastic to exclude air and lichen spores. The essential condition for the ultimate preservation of the windows is that the leadings should receive constant attention and periodic renewal.

The material examined has in the bulk been collected by M. Gaudin throughout Brittany, Normandy, Champagne, Ile-de-France, etc. A certain number of specimens from the Mayenne churches submitted by M. Alleaume, *peinte-verrier* of Laval, are now deposited in the museum of that town.

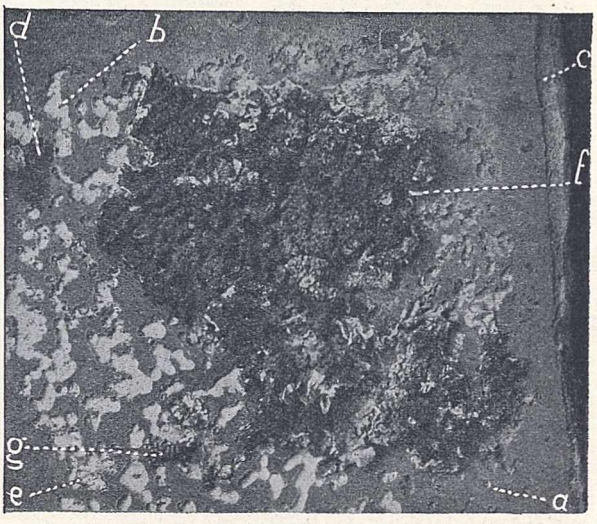

FIG. 4. (×2.)
(*a*) Circular pit; (*b*) irregular channel; (*c*) corroded border of glass originally inserted in leadings; (*d*) transparent surface; (*e*) lichen debris; (*f*) *Xanthoria parietina* Ach.; (*g*) *Placodium murorum* DC.

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The Liverpool Meeting of the British Association.

LOCAL ARRANGEMENTS.

AN elaborate programme of excursions to places of interest and visits to works has been arranged by the Local Committee. Dealing first with the general excursions, on Thursday, September 13, it is intended that a visit shall be paid to the biscuit works of Messrs. W. and R. Jacob and Co., Ltd., to the United Alkali Works at Widnes, the flour-mills of Messrs. W. Vernon and Sons, Ltd., and the Liverpool Corporation electric power-station, when some of the largest and most up-to-date plant will be inspected. The White Star Line is also inviting a party to view the s.s. *Adriatic*. On Friday, September 14, visits are arranged to Messrs. Bryant and May's match works, to the dyeing and cleaning works of Messrs. Johnson Bros., Ltd., and to the shipbuilding yards of Messrs. Cammell Laird and Co., Ltd. The Cunard Steamship Co. is inviting a party to inspect the s.s. *Franconia*.

On Saturday, September 15, there will be a whole-day excursion to Chester and the River Dee, including a visit to Eaton Hall, by kind permission of the Duke of Westminster. Another whole-day trip will be to the Dolgarrog works of the Aluminium Corporation, Ltd., the party, after inspecting the works, proceeding to Bettws-y-Coed and the Snowdon district. A visit, also occupying the whole day, has been arranged to the Liverpool Waterworks at Lake Vyrnwy.

Of a more general type there will be a day excursion to the Isle of Man, and also by sea to Llandudno and Beaumaris. There will also be a two-day tour (Saturday and Sunday) to the Lake District. On Sunday, September 16, there will be a general excursion by sea to Llandudno and Beaumaris.

On Monday, September 17, visits will be paid to one of the works of the British Insulated and Helsby Cables Co., Ltd., Messrs. Lever Bros.' Soap Works at Port Sunlight, and to the works of Meccano, Ltd., and to the Union Cold Storage, Ltd. A party will also be shown the Liverpool housing scheme, and the Liverpool Salvage Association is inviting those interested to view their plant. The Booth Steamship Co., Ltd., is inviting a party to inspect the s.s. *Hildebrand*.

On Tuesday, September 18, a party will visit the Gladstone Dock and other works of the Mersey Docks and Harbour Board, the Llay Main Colliery near Wrexham, Planter's margarine works at Bromborough Pool, and the large bobbin works of Messrs. Wilson Bros. at Garston.

Of the sectional excursions at present arranged, Section A will visit the Automatic Telephone Manufacturing Co., Ltd., the British Oxygen Co. (Bootle works), and Stonyhurst College; Section B, the United Alkali Co.'s works at Widnes, the Highfield Tannery at Runcorn, Price's Patent Candle Co. at Bromborough, the lactose factory at Haslingden near Crewe, and Messrs. Joseph Crosfield and Co.'s works at Warrington.

Section C will go to Hall Road and Crosby on the north of Liverpool, Storeton Quarries, Burton Point and North Wirral, Lake Vyrnwy district, parts of Flintshire, the Lea Green Collieries and Brick Pits, and Scarth Hill and Skillaw Clough.

Section D is proposing to go a dredging expedition in Liverpool Bay, and to Delamere Forest. Section E is visiting the Liverpool Docks, Storeton, Burton Point and North Wirral, and a river trip to the Eastham Locks of the Manchester Ship Canal, and down the Mersey to the Crosby Channel.

Section F intends to visit the Liverpool Docks and the Cotton Exchange. Section G has arranged one excursion only, and that is to the Gladstone Dock. Section H will inspect the Roman remains at Chester, and will also visit Ince Blundell.

Section I has arranged no sectional excursions.

Section J has one excursion only, namely, to Rainhill, where the County Lunatic Asylum is situated.

Section K is planning to visit the Craven limestone district, Mr. Bulley's gardens at Neston, and the West Lancashire sand dunes near Freshfield. Section L has arranged no excursions. Section M will visit Wirral Farms and Messrs. Gartons, Ltd., at Warrington, and Haslington and the Nantwich district.

Large as this list of sectional excursions appears, if one is to judge from the experience of previous meetings it will be found to have increased by the date on which the meeting commences.

A list of all these excursions and visits will be sent, a short time before the meeting, to members who have intimated their intention of coming to Liverpool, and it will greatly facilitate the work of the Local Secretaries if members will intimate in advance which excursions they would wish to join.

At the close of the meeting in Liverpool there will be an excursion to the Isle of Man, leaving Liverpool on Wednesday, September 19, and returning on Monday, September 24. The party will have an opportunity of visiting all places of scientific interest in the island, but probably members of Sections E and H will find most to study. A special committee in the Isle of Man is making all arrangements, and details will, it is hoped, be completed by the opening day of the meeting in Liverpool.

Although perhaps it does not so much concern the actual members of the Association, yet a definite item in the programme of the meeting is the series of public lectures. The number of these it is proposed to give in Liverpool will be greater than in any town previously visited by the Association, and further, one will be given in Bootle, Wallasey, Birkenhead, Runcorn, Warrington, Wigan, and, St. Helens, while two lectures to young people will be given in Liverpool and one in Birkenhead and Warrington. It is the hope of the Local Committee that these lectures will prove a great success, and so develop one of the prime objects of the Association, namely, to promote interest in science and its applications.

ALFRED HOLT.

International Hydrography.

MANY abortive attempts were made before the War to found an international hydrographic organisation, but success was not achieved until after the War, when a conference was held in London, in 1919, at the invitation of the British Admiralty, with the cordial support of the French hydrographic office. Twenty-one states were represented at the conference, invitations having been sent to all countries likely to be interested, with the exception of the Central Powers, Russia, and Turkey. As a result an International Hydrographic Bureau was instituted in 1921, and all the States represented at the conference have now associated themselves with it. The Bureau has its official seat at Monaco. Soon after its institution it became affiliated to the League of Nations, and it uses the official languages of the League, namely,

English and French. Its three chief officials are Sir J. D. Parry (Great Britain), Admiral Phaff (Netherlands), and Captain Müller (Norway), the first-named being president. It confines itself to hydrography in the strictly nautical sense of the word, and one of its chief objects at present is the international standardisation of practice in relation to many maritime matters. For example, in relation to charts, among the questions which arise are those of the type of projection, the scale, the choice of units for depth and distance, the mode of delineation of soundings, the symbols and abbreviations, and the geographical names to be used. Lists of lights, sailing directions, and distance tables are other matters on which more uniformity and co-operation would be advantageous. It may be noted that most countries now use metric units for depth, Japan being one of the latest formally to adopt this system, though it has not yet actually introduced it. Great Britain and America are now the only States which exclusively use the fathom and foot, but the change to the metric system is one which they are as yet unwilling to make, because of the great difficulty and cost of altering the copper plates from which are printed the exceptionally large number of charts which these countries produce.

The Bureau has recently started a journal, the *Hydrographic Review*, of which the first number appeared in March last. It is bilingual, all its contents being duplicated in English and French, on opposite pages. A large part of the first issue is devoted to the history of the inception of the Bureau, and other official matters. The chief original articles consist of two reports on aerial photography as applied by the French and Netherlands services to hydrographic surveying and the discovery of shoals and covered rocks. There is also a discussion of the visibility of lights, considering the chances which a sailor has of sighting a given light in different circumstances at various distances, and a brief report on echo sounding as practised by the United States hydrographic department.

The Age of the Earth.[1]

SINCE the advent of our knowledge of radioactive processes, the old controversy over the age of the earth has been revived, and although there is now a marked change of opinion in favour of the longer estimates, it remains unfortunately true that there still appear to be tantalising discrepancies between the results from different methods. These discrepancies may be mitigated or exaggerated by special pleading, but they still stand in the way of an unequivocal settlement of the problem.

Twenty years ago various attempts were made to squeeze geological history into the narrow limits imposed by Kelvin and Tait. The discovery of radioactivity, and more recent advances in the study of stars and tidal friction, have destroyed the value of the older physical evidence, leaving various geologists committed to what are now seen to be absurdly low figures. In the last decade the geological methods have in turn been widely criticised, and the present tendency is greatly to extend the estimates formerly favoured. All the methods adopted depend on the rate of processes at present in operation. In order that the different lines of evidence should converge, it is necessary to suppose either that the rates of geological processes are at present too high, or that those of radioactive processes are too low, to justify integration over the whole duration of geological time.

In the symposium under consideration, held in Philadelphia on April 22 last year, the chief feature of interest is Chamberlin's spirited attempt to show how the geological estimates may be brought into harmony with the revised deductions from radioactivity and astronomy. The period required for the deposition of the whole of the sedimentary column or for the accumulation of salt in the oceans is easily arrived at from existing data on the assumption that present rates provide a characteristic average. There is now little doubt that this assumption is deceptive, and it certainly can no longer be admitted. De Geer's work on the yearly deposits from glacial waters in Sweden, though an exceptional case, suggests to Chamberlin a Glacial epoch fully twenty times as long as that assigned by the old methods. He further expresses the conviction that breaks in the continuity of more normal sediments, the time-values of which are best judged by comparison of the faunas above and below, must, when finally interpreted, greatly extend the simple arithmetical estimates. It has frequently been shown how denudation and deposition must be quickened up by human activities, and the effects of cultivation and excavation have been ably analysed by Dr. Sherlock in his recent "Man as a Geological Agent." Existing conditions also naturally favour a high rate of denudation, since continental elevation and breadth are both exceptional, and to these may be added the further consideration that broad areas are strewn with easily removable glacial deposits. So variable are the factors involved that there is no means of arriving at average rates which would properly include long periods of sea-transgression and base-levelling, periods when denudation was brought almost to a standstill.

The validity of the method based on the accumulation of salt in the oceans depends partly on the rate at which the present streams are carrying sodium down to the sea—a rate which must be too high for reasons already mentioned—and partly on the irreversibility of the process. It has, of course, been generally recognised that sodium returns to the land in interstitial solutions held by sediments and as wind-borne salt, but other possibilities have been less emphasised. Actually it is found that the data used are inconsistent among themselves unless other cyclic processes are involved. The most serious discrepancy is found in the ratio of sodium to chlorine, which in igneous rocks is about 30 : 1 and in the oceans about 1 : 1·8. When volcanic exhalations are taken into consideration this enormous difference is reduced but by no means wiped out. Clarke and Washington have given figures which include the whole of the atmosphere and hydrosphere, and the discrepancy still remains as high as 20 : 1.

There can be only one explanation: that chloridised sodium plays a far greater part in cyclic action than has yet been detected. In the case of potassium such circulation is all-important and is effected by its greater retention by muds and soils. Dr. Milton Whitney writes, "Ocean shore deposits would undoubtedly absorb NaCl up to the point where the colloids were in equilibrium with sea water," but as to the relative efficiency of this and analogous processes there is still no exact knowledge. The sodium method is thus, as Chamberlin says, "not yet ready to render a verdict." As to the sedimentation method,

[1] From the Geological View-point. By T. C. Chamberlin. From the Paleontological View-point. By J. M. Clarke. From the Point of View of Astronomy. By E. W. Brown. The Radioactive Point of View. By W. Duane. (Proc. Amer. Phil. Soc., vol. lxi., No. 4, pp. 247-88, 1922. Philadelphia.)

he concludes that the cumulative effects of present-day conditions need not be strained to bring the older estimates up to the same order as those required by current deductions from radioactive minerals.

The remaining papers call for little comment. Palæontology presents faint hope of arriving at a trustworthy or even approximate conclusion as to the age of the earth, for no measure of the rate of vital processes has yet been devised. The endurance of an index species provides no firm basis for a definite calculation of the duration of a zone, or *phase*. Astronomical considerations have recently afforded support to the figures suggested by radio-activity for the age of the earth, but there is here no discussion of the work and views of Eddington, Jeffreys, or Shapley. Similarly the paper on the "Radioactive Point of View" omits to mention the interesting speculations of Joly, which are so ingenious that they will demand a thorough discussion in the future, even though in the present stage of knowledge they may be coldly regarded by physicists.

ARTHUR HOLMES.

University and Educational Intelligence.

CAMBRIDGE.—Dr. P. Kapitza, Trinity College, has been elected to the Clerk Maxwell Scholarship.

THE London County Council's programme for 1923–24 of lectures and classes for teachers comprises some 600 items grouped under the headings art, domestic subjects, economics and political science, languages and literature, geography, handicrafts, history, mathematics, music, pedagogy, phonetics, physical education, science, miscellaneous. The science group includes 52 items, namely, wireless, 5 (Prof. J. A. Fleming); history of science, 10 (Dr. C. Singer); psychology of vocational guidance, 5, and the neurotic child, 5 (Dr. Cyril Burt); bacteria, moulds, and yeasts, 5 (Dame Helen Gwynne-Vaughan); mental deficiency, 6; British weather, 6 (Sir Napier Shaw); animal parasites and pests, 5 (Dr. Philippa Esdaile); and Kew Gardens, 5 (Major Chipp). Moreover, the pedagogy group includes no lectures on the teaching of science. The lectures "are designed to bring London teachers in touch with the latest developments in educational technique and to give them opportunities, as well, for coming into touch with expert opinion on questions of national and civic importance. The lectures largely reflect therefore those questions which are the subject of topical discussion." The choice of subjects is limited by the fact that the scheme has to be self-supporting, and this may be the reason why no provision is made for lectures on civics, home-economics (except a course on domestic handicraft), nature-study, or general science. The lectures are open to all teachers actually employed in teaching within London at a fee of one shilling or less per lecture, and to teachers from outside at rates 50 per cent. higher. The attendance last year was 20,000. Several scientific societies place at the disposal of the London County Council a certain number of tickets of admission to their ordinary meetings for distribution to teachers of science in London schools.

BRITISH women students wishing to spend the coming academic year studying in Paris may like to know that three residence scholarships for British graduates studying at the Sorbonne or other institution of higher learning in Paris are offered by the American University Women's Club, 4 Rue de Chevreuse. The value of each scholarship is 350 francs per month for nine months, and the rates charged by the Club are such that each scholar would need to pay an additional 500 francs a month, *i.e.* about 60*l.* for the nine months. Applicants for these scholarships should send their names, stating their age, academic qualifications and proposed course of study, to the Secretary, International Federation of University Women, 92 Victoria Street, S.W.1, not later than September 15. Each application should be supported by at least two references permitted to persons well acquainted with the candidate's career.

THE use of the local environment of the school as a starting-point and source of material and interest in that school without exploiting it for vocational training is discussed in Rural School Leaflet No. 11 of the United States Bureau of Education, in which an attempt is made to show in detail how this principle should be applied in agricultural districts. It appears that in 17 states the teaching of "agriculture" in the elementary schools throughout the state has been prescribed by law somewhat precipitately, without regard to the fact that teachers with the requisite special training are not available and without any clear definition of objectives or methods. Such precipitation is, the writer points out, the more to be deprecated in view of the exceeding complexity of agriculture alike on the side of natural science, every branch of which it lays under contribution, and on the side of practice, wherein it involves not only a great variety of arts but a mode of living. At the same time this very complexity makes a naïve experience of agricultural happenings invaluable as a starting-point and source of material and interest. Dealing with the social and economic aspects of the subject, he contends that even in the elementary schools teachers should not fail (as they have failed in the past) to emphasise the necessity of the organisation of farmers as a means of economy in distribution and self-preservation in the struggle for existence in competition with other organised groups.

DEVELOPMENTS in medical education in the United States during the past 20 years, and especially during the years 1920–22, are summarised by Dr. N. P. Colwell in Bulletin 18 of 1923 of the U.S. Bureau of Education. Since 1904, when the American Medical Association started a campaign for raising educational standards, the developments in respect of medical school admission requirements, laboratory and library equipment, number and calibre of whole-time professors, and arrangements for clinical instruction, have been such that these standards, formerly lower than those of the principal European countries, can now challenge comparison with any in the world. Simultaneously the number of schools has been reduced by one-half—from 162 to 81—and the number of students from 28,000 to 13,000 in 1919, since when they have increased to 18,000. Of 81 schools, 66, rated as class A, require two years of college work as a condition precedent to entry on their four-years' course. Although students' fees, which formerly covered the cost of maintenance of the schools, have been largely increased, they amount now to little more than one-third of the cost. Along with improvement in medical schools has gone a corresponding advance in the standard of qualifications required by state medical licensing boards, but the laws on the subject have to some extent been stultified by the existence of sectarian "schools" with low educational standards, which have not been made subject to medical practice laws although their graduates assume the responsibility of undertaking to heal the sick.

Societies and Academies.

PARIS.

Academy of Sciences, July 23.—M. Albin Haller in the chair.—H. **Deslandres**: Mountain observatories. A description of the heights, position, and equipment of the existing mountain observatories. The four American observatories (Lick, Arequipa, Flagstaff, Mount Wilson) can be occupied all the year round, are equipped with large instruments, and have already produced important results: of the others, those on Mont Blanc, Pic du Midi, and Etna are insufficiently equipped and observations can be made only for a short period of the year. For a new French observatory Revard (near Aix-les-Bains) and Fort Romeu (Pyrenees), altitudes 1500 metres and 1800 metres respectively, have been examined. Fort-Romeu possesses the advantages of possible occupation all the year round and ease of access.—G. **Bigourdan**: The use of a completely free pendulum as a chronometer.—F. E. **Fournier**. The forms of hull most favourable to high speeds are only realised in racing automobiles.—**de Séguier**. Linear groups with bilinear or quadratic invariant in the real and complex field.—S. **Sanielevici**. An application of the tensorial calculus.—**Evans**. Poisson's integral.—F. H. **van den Durgen**: Some technical applications of integral equations.—Emile **Bélot**: An attempt at the representation of the period of continuous evolution, t, of the stars as a function of the effective temperature, θ. Application to the sun.—R. **Jarry-Desloges**: The influence of the various elements of an objective (aperture, focal distance, magnification) on the quality of telescopic images. Diaphragms smaller than two-thirds of the diameter of the objective cannot be usefully employed. As regards magnification there exists an optimum focal length of the refractors, between 6 and 6·75 metres: this result is new and difficult to explain.—E. **Selety**: The possibility of an infinite potential, and of a mean velocity of all stars equal to that of light.—Wladimir **de Bélaévsky**: A problem of elasticity in polar co-ordinates.—Th. **De Donder**: Synthesis of the gravific.—Camille **Gillet**: Aqueous solutions. The origin of osmotic effects. Starting with the assumption that water is a mixture in equilibrium of hydrol (H_2O), dihydrol $(H_2O)_2$ and of polyhydrol $(H_2O)_n$, of which the first is gaseous, a theory is developed affording an explanation of the existence of osmotic pressure, flocculation of solutions and of sols by electrolytes, the flocculation of sols by other sols, and the formation of emulsions.—A. **Boutiric** and M. **Vuillaume**: Study of the absorption spectrum of sols of arsenic sulphide.—Alfred **Gillet**: Researches on electrodiffusion (migration of the ions). Experiments on the migration of the ions in jellies (gelatine) containing sodium sulphate. A. **Lassieur**: The electrolytic estimation of antimony. If a thin coating of mercury is deposited on the cathode, and the potential not allowed to go over 1·3 volts, the antimony subsequently deposited electrolytically is coherent and accurately corresponds with the weight of metal present.—L. J. **Simon**: The sulphochromic oxidation of the aromatic hydrocarbons and the present conception of graphite. Comparison of the oxidation of aromatic hydrocarbons by sulphuric acid with chromic acid and silver bichromate, together with the results of the application of the silver bichromate reagent to various forms of carbon and coal.—L. S. **Glichitch**: The estimation of easily dehydrated alcohols in essential oils. The estimation of free alcohols in essential oils by acetylation fails in the case of certain alcohols, water being removed and hydrocarbons formed. By replacing acetic anhydride by a mixture of this substance with formic acid, this difficulty is overcome.—J. **Orcel**: The bavalite of Bas-Vallon.— — **Thiébaud**: Researches on the mineralogical composition of some chalk marls of the Tertiary of Alsace.—A. **Cholley**: Evolution of the karstic relief of the Parmelan (Préalpes de Savoie).—Henri **Coupin**: The supposed formation of chlorophyll in the dark. Experiments are described contradicting the view that etiolated plants can manufacture chlorophyll in the dark.—Jean **Politis**: The formation of a glucoside (saponarine) in the mitochondria.—A. **Demolon** and P. **Boischot**: The activity of the biological phenomena in peat. The relative passivity of peat from the biological point of view is due to the poverty of the medium in nutritive elements, and especially phosphoric acid, and the results of the partial sterilisation of peat by heat cannot be attributed to destruction of toxins or to an action on the protozoa.—A. **Quidor** and Marcel A. **Herubel**: The psycho-physiology of visual phenomena.—Paul **Benoît**: The polar globules of the egg of *Tubularia mesembryanthemum*.—Jean **Camus**, J. J. **Gournay**, and **Fiterre**: The mechanism of insipid diabetes.—E. **Lesné**, L. **de Gennes**, and **Guillaumin**: The action of light on the variations of calcemia in rickets.—A. **Juillet**: Remarks on the note by MM. Chevalier and Mercier on the pharmacodyamic action of the insecticidal principle of pyrethrum flowers.

SYDNEY.

Linnean Society of New South Wales, June 27.—Mr. A. F. Basset Hull, president, in the chair.—G. I. **Playfair**: Notes on freshwater algæ. A series of miscellaneous notes on algæ, in which twelve species and fourteen varieties are described as new; and remarks made on the development and life-history of many species.—Miss M. I. **Collins**: Studies in the vegetation of arid and semi-arid New South Wales. Part i. The plant ecology of the Barrier District. The paper consists of an introductory section in which the chief physiographic units of New South Wales are discussed in reference to the formation of the Great Western Plains. The geologic, physiographic, and climatic features of the Barrier Range are described, accompanied by an account of the chief plant associations, and lists of species for the different habitats. In a final discussion the developmental relationships of the associations are indicated.—Miss Marguerite **Henry**: A monograph of the freshwater Entomastraca of New South Wales. Part iii. Ostracoda. This paper gives brief descriptions of thirty-six species of Ostracods, with their synonymy and keys for their identification. Seven species are described as new, two are recorded for the first time in Australia and one for the first time in New South Wales. A freshwater member of the family Cytheridæ is recorded for the first time in Australia. Lists are also given of the species that are known to occur in other States.

Official Publications Received.

United States Department of Agriculture. Department Bulletin No. 1165: Report on Bird Censuses in the United States 1916 to 1920. By May Thacher Cooke. Pp. 36. (Washington: Government Printing Office.) 5 cents.

University of Liverpool: Tidal Institute. Fourth Annual Report, 1923. Pp. 7. (Liverpool.)

University of Colorado Bulletin. Vol. 23, No. 3, General Series No. 192: Catalogue, 1922–1923, with Announcements for 1923–24. Pp. 489. (Boulder, Colo.)

Supplement to NATURE

No. 2808 AUGUST 25, 1923

The Life History of an α-Particle.[1]

By Sir ERNEST RUTHERFORD, F.R.S.

IN this lecture I propose to discuss some of the properties of the high-speed α-particle which is spontaneously ejected from radioactive substances. This flying atomic nucleus is not only the most energetic projectile known to us, but it is also an agent of great power in probing the structure of atoms, so that an account of the effects produced by it is of wide scientific interest.

It is now well established that the α-particle expelled from radioactive bodies is in all cases a helium atom, or, to be more precise, the nucleus of a helium atom of mass 4 carrying two positive charges of electricity. It is only when the expelled nucleus is stopped by its passage through matter that it captures the two negative electrons required to convert it into the neutral helium atom. It is natural to suppose that the helium nucleus, which is shot out at great speed from the heavy nucleus of a radioactive atom, formed part of its structure. For some reason, which is not as yet understood, occasionally one of the radioactive nuclei breaks up with explosive violence, ejecting the component helium nucleus with high velocity. It is probable that the α-particle in escaping from the radioactive nucleus acquires part of its great energy of motion in passing through the repulsive electric field surrounding the latter, but at present we do not know the nature of the forces which hold the complex nucleus together, or whether the α-particle is at rest or in orbital motion in the nuclear structure before instability sets in. We know, however, that there is a very wide range of stability exhibited by different radioactive elements. In a substance like radium A, the average life of the radioactive atom before ejection of an α-particle is about 4·3 minutes, for radium itself 2250 years, while in the case of a very slowly changing element like uranium the average life is of the order of 7000 million years.

It is known that the α-particles from a given element are all shot out with the same speed but that this speed varies from element to element. There is apparently a close connexion between the velocity of ejection of the α-particle and the average life of the parent element. The shorter the average life of the element, the swifter is the speed of expulsion. This interesting relation between the violence of the explosion and the average life of the element holds in the majority of cases, but it is difficult at present to be at all clear of its underlying meaning. Sir William Bragg long ago showed that the α-particle travels through matter nearly in a straight line, and has a definite range of travel in a substance. This is well illustrated by the tracks of α-particles obtained by Wilson's expansion method. The majority of the tracks are seen to be quite straight, apart from an occasional deflexion near the end of the path. At the end of the range the photographic and ionising effects of the α-particle apparently cease with great suddenness. On account of its great energy of motion, the individual α-particle can be detected by the scintillation it produces in crystalline zinc sulphide, by the effect on a photographic plate, and by special electrical methods, while the beautiful expansion method of Wilson shows the trail of each individual α-particle through the gas.

We are enabled, particularly by the scintillation method, to count the individual particles, and thus we have at our command a method of great delicacy for studying the effects produced by the passage of α-particles through matter. In travelling through a gas the α-particle passes through the outer electronic structure of a large number of atoms and liberates electrons, thus giving rise to an intense ionisation along the track. The ionisation increases to a maximum near the end of the path of the α-particle and then falls rapidly to zero.

A careful study has been made of the law of decrease of velocity of the α-particle in passing through matter by studying the deflexion in a magnetic field of a pencil of α-particles before and after its passage through a known thickness of matter. In most of these experiments we employ the α-particles of radium C, which have a range of about 7 cm. in air under ordinary conditions. The initial velocity V_0 of these particles is known to be 19,200 kilometres per second, and the reduction of velocity can readily be followed down to about 0·4 V_0. At this stage the emergent range of the α-particles is less than one centimetre, and measurements are difficult, owing to the fact that a beam of α-particles becomes heterogeneous and contains particles moving with different velocities.

[1] Discourse delivered at the Royal Institution on Friday, June 15.

For this reason the velocity of the α-particle cannot be followed with certainty below $0{\cdot}38\ V_0$. We must bear in mind that even at the lowest velocity at which it is possible to detect the α-particle by the scintillation or photographic method, it is still moving at a high speed compared with the positively charged particles generated in an ordinary discharge tube.

It is clear that ultimately the α-particle must be slowed down to such an extent that it captures electrons and becomes a neutral atom, but until recently no evidence of this process of capture of electrons had been obtained. G. H. Henderson (Proc. Roy. Soc. A, 102, p. 496, 1922) has recently added much to our knowledge of this subject by examining the deflexion of α-rays in a magnetic field in a very good vacuum. For the success of these experiments it is essential that the apparatus in which the deflexion is observed should be exhausted to a very low pressure, corresponding to that required for a good X-ray tube. The reason of this will be seen later. When a narrow pencil of α-rays was deflected in a magnetic field two bands were observed on the photographic plate, one the main band, due to ordinary α-particles carrying two positive charges, and another midway band which he supposed to consist of particles which had captured one electron, *i.e.* to singly charged helium atoms. At low velocities he also obtained evidence of the existence of neutral α-particles resulting from the capture of two electrons by the helium nucleus. In these experiments Henderson employed Schumann plates, where the film is so thin that low velocity particles produce as much or more photographic effect than the swifter particles.

I have repeated these experiments, by the scintillation method, and confirmed the deduction of Henderson. By observing the deflexion of the midway band in an electric as well as in a magnetic field I find there is no doubt the particles composing the midway band consist of particles of mass 4 and charge 1, *i.e.* to singly charged helium atoms which have the same speed as the doubly charged particles comprising the main band.

Some recent experiments have been made by me to throw light on the conditions under which the flying α-particles may gain or lose an electron. The general arrangement of the experiment is shown in Fig. 1. A fine platinum wire coated with radium B+C, by exposure to the emanation (radon) serves as a nearly homogeneous source of α-rays, since the α-particles are emitted only from the atoms of radium C, which are too few in number to form a film on the platinum of even one molecule thick. The α-rays from this source pass through a narrow slit about 0·3 mm. wide and fall on a screen of zinc sulphide. The distribution of α-particles on the screen is determined by the scintillation method in a dark room, using a microscope outside the box. The vessel containing the source and screen is completely exhausted by means of a Gaede and mercury diffusion pump, and if necessary the residual pressure can be measured by a Macleod gauge. The box is placed between the plane pole pieces of a large electromagnet so that the pencil of α-rays is bent in the direction shown in the figure. Usually the distance between the source and screen was 16 cm., with the slit midway. The whole path of the rays was exposed to a nearly uniform magnetic field and the deflexion of the pencil of rays was proportional to the strength of the magnetic field. Under normal experimental conditions the pencil of α-rays from the

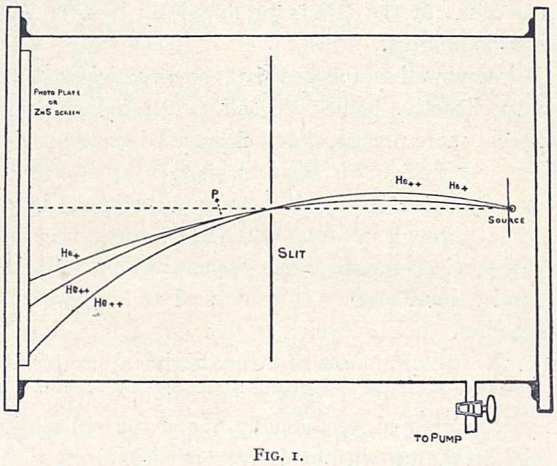

FIG. 1.

bare radium C wire was bent a distance on the screen of about 15 mm. from the zero position without field. The field of view of the microscope was sufficient to take in the depth of the whole pencil of α-rays without the field.

Special precautions were taken to prevent contamination of the screen by the escape of active matter from the wire in a low vacuum. It must be borne in mind that the type of wire source employed always introduces some heterogeneity in the beam of α-rays even from the uncovered source. This is due to the escape from the back of the wire of α-particles which are reduced in velocity in passing through the material. This effect is clearly manifest when the pencil of α-rays is deflected by a magnetic field; for in addition to the main band of α-rays there is always a distribution of particles extending beyond the main beam. The intensity of this heterogeneous beam at any point is generally less than one per cent. of the main beam and does not seriously interfere with the accuracy of the deductions discussed in this lecture.

In Figs. 2 and 3 are given illustrations of the distribution of singly and doubly charged α-particles

along the zinc sulphide screen. Fig. 2 shows the result when a thickness of mica corresponding in stopping power to 3·5 cm. of air is placed over the source. The main band, due to He_{++} particles, is sharply defined on the high velocity side, but there is evidence of some heterogeneity produced in the beam by its passage through the mica. As we should expect, the midway

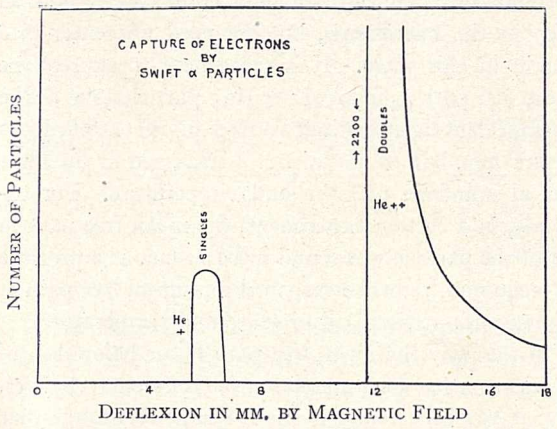

FIG. 2.

band (He_+ particles) lies exactly between the zero position and the main band and contains only about 1/55 of the particles in the main beam. Fig. 3 shows the distribution when the thickness of mica is increased to correspond to a stopping power of about 6 cm. of air. Both the main and midway bands are no longer sharply defined as in the first case, but each

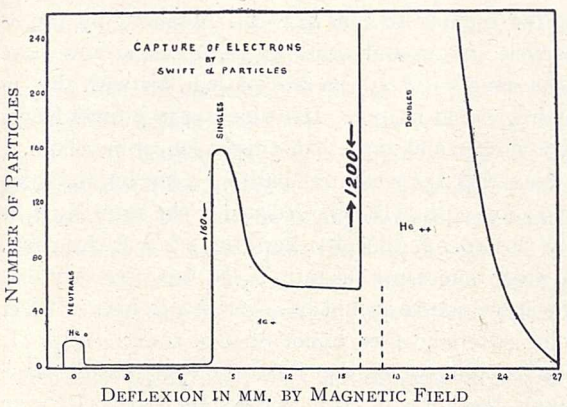

FIG. 3.

consists of particles with a considerable range of velocities. The relative number of He_+ and He_{++} particles is about 1/8 for the swifter particles, but this ratio increases with decreasing velocity. The midway band extends and joins the main band where it can no longer be followed. The brightness of the scintillations due to He_+ particles falls off obviously and continuously from A to B. At this stage, too, some neutral particles make their appearance. This is shown by the He_0 band, which is not deflected by a magnetic field, but its intensity is small compared with that of the midway band. There is also a sparse distribution of faint particles between the neutral and midway band, probably due in part to scattering of the α-particles by the edges of the slit and possibly in part due to recoil atoms of oxygen and other elements constituting the mica. The distribution of the charged and uncharged helium particles for a still lower velocity will be seen in curves A, B, Fig. 4, which will be referred to later. It is seen that the relative number of He_+ to He_{++} particles has increased; similarly, the relative number of neutral particles is much greater.

We may now consider the interpretation to be placed on these observations. It is clear that the particles emerging from the mica consist of doubly charged, singly charged, and neutral particles, but the relative number of these three types varies markedly with the stopping power of the mica plate. We may suppose that the α-particle in passing through the outer electron

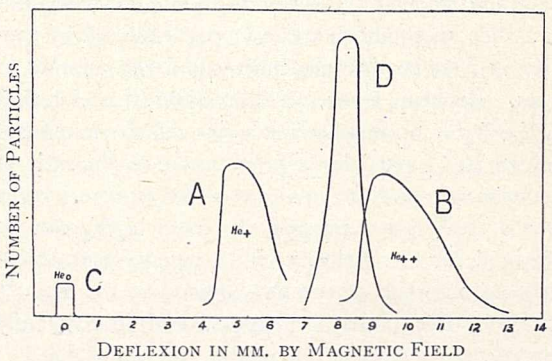

FIG. 4.

structure of the atoms in its path occasionally removes and captures an electron. This electron falls into a stable orbit round the doubly charged helium nucleus and moves with it.

This singly charged atom will, however, have only a limited life, for in passing through other atoms the electron is knocked off and the singly charged α-particle reverts back to the doubly charged type. This process of removal is analogous to the ordinary process of ionisation where an electron is ejected from an atom by a collision with an α-particle; for as a singly charged particle can remove electrons from another atom, so there is a chance that the He_+ particle should lose its attendant electron. We may thus consider that two opposing processes are at work, one resulting in the capture of an electron and the other leading to its removal. From the data given later it will be seen that this process of capture and loss may repeat itself more than a thousand times in the flight of an α-particle, so that the average path travelled by an α-particle before capture of an electron or before loss of the captured electron is small compared with the total

distance of travel of the α-particle before it comes to rest. It is clear from this, for a given velocity of α-particle, that there must be a momentary equilibrium between the number of He_+ and He_{++} particles such that, on the average, the number of captures in a given small distance is equal to the number of losses.

It is very convenient to suppose that for a given velocity each He_{++} particle has a mean free path λ_1 cm. in the material before it captures an electron, and the He_+ particle a mean free path λ_2 cm. before it loses its attendant electron. No doubt some of the individual particles travel distances much shorter or longer than this mean distance before either capture or loss, but in considering a large number of particles we may suppose there is an average distance traversed before capture or loss, to be called the mean free path.

When N_1 He_{++} particles traverse a small distance dx of a material the number which capture electrons is $N_1 dx/\lambda_1$. If N_2 He_+ particles are present the number which lose an electron is $N_2 dx/\lambda_2$. But we have seen that when an equilibrium is set up, the number of captures in a given distance must equal the number of losses. Equating these two expressions, it is seen that $N_2/N_1 = \lambda_2/\lambda_1$, or, in other words, the relative number of He_+ to He_{++} particles is proportional to the ratio of the mean free path for loss to that for capture. Since by the scintillation method the ratio N_2/N_1 can be measured for any velocity, by using different thicknesses of absorber we can thus determine the ratio of the mean free paths for capture and loss for any velocity.

The actual value of the mean free path λ_2 of the He_+ particle before it loses its electron can be directly determined by experiment. Suppose the microscope is focussed on the midway band of Fig. 2 and the number of scintillations per minute observed in a good vacuum. If the pumps are shut off and a small quantity of air or other gas is introduced into the apparatus, the number of scintillations is found to diminish with increasing pressure of the air until the band has completely disappeared. This takes place at quite a low pressure of air, for example, for a pressure of about 1/4 mm. in the box.

The explanation of this result is obvious. The He_+ particles which escape from the mica occasionally collide with an atom of the gas in its path, and the electron which it captured in passing through the mica is removed. In such a case the He_+ becomes again an He_{++} particle, and the latter is twice as easily deflected in a magnetic field as the former. Suppose the collision occurs for the first time at the point P (Fig. 1). The particle after losing its electron travels along a new path shown in the figure, and the particle no longer strikes the part of the screen viewed by the microscope. It is found that the number of scintillations seen in the microscope falls off according to an exponential law as the pressure of the gas is raised. Such a result is to be expected, and from this data the average distance which the He_+ particle traverses before it loses its electron can be simply deduced. Certain small corrections are necessary to take into account the finite width of the band of scintillations as seen in the microscope, but we need not enter into details at this stage. It is convenient to express the mean free path λ_2 in air of the He_+ particles, not as the average length of path traversed in the rarefied gas before loss, but as the distance traversed in the same gas at standard pressure and temperature. For example, in a certain experiment, the mean free path in air of the particle was found to be 12 cm. at a pressure of 0·040 mm.; this corresponds to a mean free path of 0·0063 mm. at standard pressure and temperature.

In this way the mean free path in air before loss of an electron has been measured for different velocities, and it has been found over a considerable range that the mean free path varies directly as the velocity of the α-particle, so that the mean free path becomes shorter as the velocity of the α-particle diminishes. Since we may regard the loss of an electron from the singly charged particle as the result of a process of ionisation, such a relation is to be expected, and indeed, if we take into account the strong binding of a single electron by the He_{++} nucleus, the mean free path for loss is of the same order as that calculated from considerations of the number of ions per cm. produced by the α-particle in air and other gases. Comparisons have been made of the mean free path in air with that in hydrogen and helium. Its value is 4 to 5 times longer in hydrogen and more than 5 times longer in helium.

Now that the mean free path λ_2 is known, the value of λ_1 for capture can be deduced if the ratio N_2/N_1 is also known. A difficulty, however, arises at this point. In order to measure the ratio N_2/N_1 it is necessary that the active source should be covered with mica or other solid material. Gas cannot be used conveniently. It was found, however, that the ratio N_2/N_1 was the same within the limits of error whether the α-particles were reduced in velocity by passage through celluloid, mica, aluminium, or silver. For this purpose the mica was kept the same and a very thin sheet of the substance under examination spread over it. The thickness of the sheet was sufficient to set up a new equilibrium between the singly and doubly charged particles, but not sufficient to alter materially the velocity of the ionising rays.

Since the value of the ratio N_2/N_1 suffers no appreciable change for absorbers of such different atomic weights, we may safely conclude that the ratio for a

hypothetical sheet of solid air would be the same as for mica.

We have now all the data required to determine the values of λ_1 and λ_2 corresponding to α-particles of different velocities. The results are given in the following table for three different velocities. The mean free paths are expressed in terms of millimetres of air at standard pressure and temperature. V_0, the maximum velocity of the α-particles from radium C, is $1{\cdot}9 \times 10^9$ cm. per second.

Velocity V in terms of V_0.	$\lambda_2/\lambda_1 = N_2/N_1$ for Mica.	Mean Free Path λ_2 for Loss in Air.	Mean Free Path λ_1 for Capture in Air.
0·94	1/209	0·011 mm.	2·2 mm.
0·76	1/67	0·0078 mm.	0·52 mm.
0·47	1/7·5	0·0050 mm.	0·037 mm.

It has been seen that the mean free path for loss varies directly as the velocity, and thus only alters in a ratio of about 1 to 2 over the range of velocities given in the table. On the other hand, the ratio λ_2/λ_1 increases very rapidly with diminution of velocity varying approximately as V^{-5}. From this it follows that λ_1 varies as V^6, thus decreasing by a factor of 60 or more when the velocity is halved.

From these data and relations it can easily be calculated that the mean free path for capture should be equal to that for loss for a velocity about $0{\cdot}3\ V_0$, and for this speed the numbers of He_+ and He_{++} particles should be equal.

The actual value of the velocity for equality of the two types in a special experiment was found to be $0{\cdot}29\ V_0$, in good agreement with the calculated value. It is a difficult matter to determine the values of λ_1 and λ_2 for velocities less than $0{\cdot}3\ V_0$, for not only are the scintillations weak in intensity and difficult to count with accuracy, but also the issuing rays are very heterogeneous and no longer show well-defined edges on the high velocity side. It was, however, noted that the ratio N_2/N_1 rapidly increased below the velocity $0{\cdot}3\ V_0$.

We have so far dealt with the equilibrium between He_+ and He_{++} particles. It is clear, however, that similar considerations apply to the equilibrium between singly charged and neutral helium particles at low velocities of the α-particle. It was noted that the neutral particles appear prominently after the rays have passed through mica of 6 cm. stopping power, but no doubt they could be detected for still lower stopping power. These neutral particles, of course, produce scintillations, but of an intensity corresponding to an α-particle of low velocity. These neutral particles probably lose and regain an electron many times before they are stopped in the zinc sulphide or other absorbing material. This effect was shown by introducing gas at low pressure into the apparatus, when the scintillations due to the neutral particles diminished in number and ultimately vanished. The explanation of this is similar to that given for the disappearance of the He_+ band, for the neutral particles occasionally lose an electron in passing through the gas and are then deflected away from the zero position by the magnetic field.

It was estimated that the mean free path in air for conversion of neutral helium particles to singly charged particles was about 1/600 mm. No doubt this is an average for particles of very different velocities which may be present in the neutral band.

For the higher velocities we have to deal mainly with the interchange $He_{++} \rightleftarrows He_+$. For velocities less than $0{\cdot}5\ V_0$ the interchange $He_+ \rightleftarrows He_0$ also comes in and becomes all-important for velocities less than $0{\cdot}3\ V_0$. No doubt, as Henderson has shown, at still lower velocities most of the He_{++} particles disappear and the He_0 and He_+ particles predominate.

At these low velocities, counting scintillations becomes very difficult and uncertain, and the photographic method, as used by Henderson, is preferable. It will be a matter of very great interest to examine whether the relative numbers of the three types of particles alter when the α-particles are slowed down by passage through different materials. This side of the work is being attacked by Mr. Henderson in the University of Saskatchewan.

There is one very interesting point that may be considered here. It has been shown that these singly and doubly charged α-particles are always present after the α-rays have passed through mica or other absorber, but are there any singly charged particles present when α-particles escape from a wire coated with an infinitely thin deposit of active matter? This was first tested for a platinum wire coated with a deposit of radium B + C, by exposure to the radium emanation, when it was found that singly charged helium atoms were present in about the equilibrium ratio for this velocity. This was a rather surprising observation, but it was thought it might result from the fact that by the recoil from radium A the radium B particles penetrate some distance into the material of the wire. Under these conditions many of the α-particles expelled from radium C have to pass through a small but appreciable thickness of matter before escape from the wire and might thus capture electrons. This explanation seemed unlikely because the average distance penetrated by the recoil atom is only a minute fraction of the mean free path for capture at such high velocities of the α-particle. The experiment was tried with a nickel wire on which radium C had been deposited on

the surface by the well-known method of dipping the wire in a hot solution of radium C. In this case the difficulty due to recoil is absent, but the number of singly charged particles was the same as before.

It is very significant that the relative number of singly and doubly charged particles is about the equilibrium ratio to be expected when the wire, after being activated, is coated with an appreciable thickness of copper or other material. We can scarcely suppose that singly as well as doubly charged particles are actually liberated from the radioactive nucleus itself, for even if it be supposed that an α-particle with an attendant electron is expelled, the electron must be removed in escaping through the very powerful electric field close to the nucleus. It is much more probable that the doubly charged α-particle in passing through the dense distribution of electrons surrounding the radioactive nucleus occasionally captures an electron, and that the process of capture and loss goes on to some extent in escaping from the radioactive atom. This seems at first sight rather unlikely when we consider the relatively large number of atoms an α-particle ordinarily passes through before equilibrium between capture and loss is established, but it is well known that the chance of effective electronic collisions appears in general to be greater for a charged particle expelled from the central nucleus than for a similar particle passing from outside through the electronic distribution of an atom. It may be that those electrons, the orbital motion of which round the nucleus is comparable with the speed of the α-particle, are particularly effective in causing capture or loss.

So far we have dealt mainly with the distribution in a magnetic field of the particles in a vacuum after their escape from a mica surface. Some very interesting points arise when the distribution is examined in the presence of sufficient gas to cause a rapid interchange of capture and loss along the path of the α-particle in the gas. This is best illustrated by a diagram, Fig. 4, in which the results are given for α-particles escaping through mica with a maximum emergent range of about 4 or 5 millimetres in air. Curves A and B give approximately to scale the distribution of He_+ and He_{++} particles in a vacuum, while C gives the relative number of neutral particles under the experimental conditions. Suppose now sufficient air is introduced into the vessel to cause many captures along the gas but yet not enough to reduce seriously the velocity of the α-particles. The first salient fact to notice is that the distributions A, B, C vanish and there remains a distribution of particles (curve D) about midway between A and B. This band is narrower than either A or C, and its height at the maximum much greater than either. It is evident that the particles have been compressed into a band of much narrower width than the normal distribution in curve B.

This is exactly what we should expect to happen. The swifter particles present suffer less capture than the slow; consequently the average charge of the swifter α-particles along the gas is less than $2e$, and their deflexion is less than the swiftest particles shown in curve B. On the other hand, the slower α-particles have an average charge nearer $1e$ than $2e$ and are relatively still less deflected than the swifter particles. It is thus clear that the resulting distribution of particles with air inside the vessel will be concentrated over a much narrower width than the main band of He_{++} particles. From calculation based on the laws of capture and loss, the width of the band under the experimental conditions can be deduced and is found to be in good accord with experiment. It will be seen to be significant that similar results have been observed for hydrogen under corresponding conditions.

General Discussion of Results.

Attention may now be devoted to a consideration of the results so far obtained and the possibility of their explanation on present views. In the first place, it is important to emphasise the large number of capture and losses that occur during the flight of an α-particle from radium C. While the mean free path of the α-particle from radium C of 7 cm. range is about 3 mm. in air, its value rapidly decreases with lowering of the velocity of the α-particle and is probably about 0·0015 mm. for a velocity of $0{\cdot}3\ V_0$. It is not difficult to calculate that not far short of a thousand interchanges of charge occur during the path in air of a single particle between velocities V_0 and $0{\cdot}3\ V_0$. While the data so far obtained do not allow us to calculate the number of interchanges of charge that occur between velocities $0{\cdot}3\ V_0$ and 0, it seems probable that the number is considerably greater than a thousand. We have already pointed out that for low velocities the interchange $He_+ \rightleftarrows He_0$ predominates. When we consider the rapidity of interchange of charges of the α-particle at average velocities, it seems clear that we cannot expect to observe any appreciable difference in power of penetration between a beam of rays of the same velocity, whether consisting initially of singly or doubly charged particles. It is clear that a singly charged particle after penetrating a short distance is converted into a doubly charged particle and *vice versa*, and that the effects due to the two beams should be indistinguishable. Henderson tried such absorption experiments, using the photographic method, but with indefinite results.

When an α-particle captures an electron, the latter presumably falls into the same orbit round the helium nucleus as that which characterises an ionised helium atom, *i.e.* an atom which has lost one electron. When the α-particle with its attendant electron passes swiftly through the atoms of the gas in its path, it will not only ionise the gas but will also occasionally be itself ionised, *i.e.* will lose its attendant electron. When we take into account the strong binding of the first electron to the helium nucleus—ionisation potential about 54 volts—the mean free path for loss of the captured electrons in air is of the right order of magnitude to be expected from considerations based on the ionisation by the α-particle per unit path in air. While we can thus offer a quantitative explanation of the mean free path for loss observed experimentally, the inverse problem of the capture of an electron by the flying α-particle presents very great difficulties.

In the actual case, the α-particle is shot at high speed through gas molecules which for all practical purposes may be supposed to be at rest. For convenience of discussion, however, it is preferable to make an equivalent assumption, namely, that the α-particle is at rest and

the gas molecules stream by it with a velocity equal and opposite to that of the α-particle. Now the maximum velocity of an α-particle from radium C is equivalent to that gained by an electron in falling freely between a difference of potential of about 1000 volts; so that the electrons comprising the molecules of air or other gas have a velocity of translation numerically equal to this. For brevity, it is very convenient to speak of this velocity or energy as that due to a "1000-volt" electron.

When the electrons in an atom pass close to the α-particle, one of them may be removed from the parent atom by the collision, energy being required for this process. The ionisation potential for oxygen or nitrogen is about 17 volts, which is a very small quantity compared with the energy of translation of a 1000-volt electron.

If we consider the forces involved between an α-particle and moving electron as of the ordinary electrostatic type, the electron will describe a hyperbolic orbit round the nucleus, the angle of deflexion of the path of the electron resulting from the collision depending on the nearness of approach of the electron to the nucleus. On ordinary dynamics, the electron will never be captured in such a collision if there is no loss of energy by radiation. If capture for some reason results from the collision, it means that an amount of energy corresponding to at least a 1000-volt electron has in some way been got rid of. This loss of energy may be supposed to be due to some interaction between the α-particle and colliding nucleus with its attendant electrons, or to the loss of energy by radiation during the collision. The first supposition seems at first sight plausible, for we know that the innermost electrons of oxygen or nitrogen are strongly bound and require energy of the order of 500 volts to remove them from the atom. But there is one very strong and, it seems to me, insuperable objection to this view.

I have found that the deflexion in a magnetic field of a pencil of α-particles passing through a suitable pressure of hydrogen is similar to that shown in curve Fig. 4 for air. This shows that the α-particle passing through hydrogen captures electrons of energy about 120 volts to about the same degree as in air. Now we know that the electrons in the hydrogen atom or molecule are lightly bound, and an energy of not more than a 30-volt electron, suitably applied, would entirely separate the component nuclei and electrons in the hydrogen molecule. In the case of hydrogen, therefore, we cannot hope to account for the requisite loss of energy, which for the experiment considered is about 100 volts. If these experiments with hydrogen are correct, and are valid for all velocities of the α-particle, we are driven to conclude either, that some unknown factors are involved in the capture, or that the loss of energy of the electron must be ascribed to radiation. In such a case, capture of an electron may be regarded as the converse of the photo-electric effect, where radiation falls on matter and swift electrons are ejected from the matter. In the case under consideration, swift electrons are shot towards a charged nucleus and an occasional electron is captured with the emission of energy in the form of radiation. On such an hypothesis the radiation of energy from an α-particle passing through a gas due to the frequency of capture is very great, amounting to about 3 per cent. of the total energy of the α-particle. This seems to be an unexpectedly large amount, but cannot be ruled out as impossible in the present state of our knowledge.

In the discussion of this very thorny question, I have confined myself mainly to the case of capture by the swift α-particle, where the difficulties of explanation are much greater than for capture at slower velocities. Our information is at present too incomplete to give a decisive answer, but there seems to be no doubt that the unexpected frequency of capture of electrons by swift α-particles raises many new and interesting questions of the nature of the processes that can occur in collisions between electrons and matter.

I need scarcely say that the phenomena of capture and loss are not confined to the α-particle, but are shown by all charged atoms in swift motion through a gas, and were long ago observed in the case of positive rays. On account, however, of the high velocity of the α-particles and the ease of their individual detection, the process of capture and loss can be studied quantitatively under simpler and more definite conditions than in the case of the electric discharge through a gas at low pressure.

On this occasion I have devoted my attention to the most recent additions to our knowledge of the life history of the α-particle. This knowledge has been obtained from the study of the rapid interchange of charges when an α-particle passes through matter. I have only incidentally referred to the numerous collisions with electrons along the track of the α-particle which result in dense ionisation. I have omitted any consideration of those rare but interesting encounters in which an α-particle is deflected through a large angle by a close collision with a nucleus. I have omitted, too, the still rarer encounters which may result in a disintegration of an atomic nucleus like that of nitrogen or of aluminium. We have seen that an α-particle has an interesting history. Usually it is retained as an integral and orderly part of a radioactive nucleus for an interval of more than a thousand million years. Then follows a cataclysm in the radioactive nucleus; the α-particle gains its freedom and lives an independent life of about one hundred millionth of a second, during which all the incidents referred to in this lecture occur.

If we are dealing with a dense and compact uranium or thorium mineral, the α-particle after acquiring two electrons and becoming a neutral helium atom may be imprisoned in the mineral as long as the mineral exists. The occluded helium can be released from the mineral by the action of high temperature, and after removal of all other gases can be made to show its presence by the characteristic brilliant luminosity under the stimulus of the electric discharge. In the circumstances of such an experiment, only small quantities of helium are liberated. Large quantities of helium, sufficient to fill a large airship, have, however, been isolated from the natural gases which escape so freely from the earth in various parts of Canada and the United States. It is a striking fact that every single atom of this material has in all probability had the life history here described.

Addendum.[1]

It may be of interest to give here a brief review of some additional facts in connexion with the α-particle, brought to light in recent years. It has long been known that α-particles, although projected from the source at the same speed, travel unequal distances through a gas. For example, the maximum distance travelled by the α-particles from radium C in air is 7·04 cm. at 760 mm. and 15° C., the minimum distance is about 6·4 cm., and the mean distance about 6·8 cm. Some "straggling" of the α-particles is to be anticipated on general grounds, since the α-particle loses its energy mainly in liberating electrons from the atoms of matter in its path. On the laws of probability, one α-particle may meet more atoms and liberate more electrons than another, and thus lose energy at a faster rate. The amount of straggling observed is, however, much greater than can be accounted for in this way, and the occasional large deflexions of the α-particles due to nuclear collisions are so rare, except near the end of the range, that they do not seriously influence the final distribution.

Henderson has suggested that the property of an α-particle of capturing and losing electrons will introduce a new factor in causing straggling. No doubt this is the case, but the rates of capture and loss observed appear to be too rapid to account entirely for the discrepancy between theory and experiment. Another interesting suggestion has been made by Kapitza to account for the magnitude of this straggling. From the experiments of Chadwick and Bieler on the collision between α-particles and hydrogen nuclei, it has been deduced that the α-particle or helium nucleus has an asymmetrical field of force around it. This asymmetry of the electric field must become small at the distance of the orbits of the electrons in the neutral helium atom, but may be sufficient to fix the plane of the orbit of an electron relative to the axis of the helium nucleus.

Suppose that the α-particles liberated from a radioactive source have their axis orientated at random, and that the direction of the axis of each individual particle remains unchanged during its motion. In some cases, for example, the captured electron will describe an orbit of which the plane is nearly in the direction of motion of the α-particle; in other cases nearly perpendicular to it. It is to be expected, however, that the chance of losing the captured electron by collision will be greater in one case than the other; or, in other words, the mean free path of the singly charged α-particle before loss of its electron will be different in the two cases.

On this view, it is to be anticipated that one group of α-particles will lose energy faster than the other, and the ranges will be different. In order to test whether α-particles show the individual differences to be expected on this theory, Kapitza has photographed in the Cavendish Laboratory the tracks of a number of α-particles by the Wilson expansion method, using a strong magnetic field of about 70,000 Gauss, produced by a momentary current of great intensity. The magnetic field was sufficiently strong to cause a marked bending of the track of the α-particle. It was found that the curvature of the tracks at equal distances from the ends showed marked variations. Before any definite decision can be reached, a large number of tracks obtained in this way must be carefully measured up and allowance made for the sudden bends which occur due to a nuclear collision with the atoms of nitrogen or oxygen. The frequency of these bends near the end of the range complicates the interpretation of the apparent curvature which is measured. The experiments, which are still in progress, are difficult and require great technical skill, and it will be a matter of much interest if any definite asymmetry in the orbits of the singly charged α-particles can be established by this or other methods. If such an asymmetry exists, it must influence to a small extent the arrangement of the two electrons round the helium nucleus and possibly their spectrum.

During the past two years, Blackett, in the Cavendish Laboratory, has made a careful examination of the frequency of occurrence of sharp bends or forks in the tracks of α-particles near the end of their range in air and other gases. For this purpose, a simple form of Wilson expansion chamber, of the type designed by Shimizu, has been used, and each track has been photographed in two directions at right angles to each other to fix the angle of the forks in space. A large number of photographs have been taken, and the frequency of the forks has been examined in different gases, particularly in the last centimetre of the range of the α-particle. Assuming that these forks arise from nuclear collisions, it is possible to deduce from the experimental data the variation of velocity of the α-particle near the end of its range. It is known from the work of Geiger and Marsden that the maximum velocity v of the α-particles of emergent range R is given by $v^3 \propto R$, when R is not less than one centimetre. Blackett finds that this relation between velocity and range no longer holds near the end of the track but is replaced by a relation of the form $v^{1\cdot5} \propto R$.

In the course of these experiments a number of well-defined forks have been photographed in hydrogen, helium, air, and argon by Blackett, and also by Auger and Perrin in Paris. By measuring the angles between the original direction of the α-particle and the direction of the colliding particles after collision, the accuracy of the laws of impact can be directly tested. The results are found, within experimental error, to be in agreement with the view that the impacts are perfectly elastic and that the conservation of energy and of momentum hold in these nuclear collisions. Conversely, by assuming that the impacts are perfectly elastic, it is possible to deduce the mass of the recoil atom in terms of the α-particle of mass 4·00. For example, a fork in helium gave the mass of the recoil atom 4·03, and a fork in hydrogen gave the mass of the recoil atom 1·024. In a collision between the α-particle and a helium nucleus the angle between the forks should be exactly a right angle; the value measured was 89° 45′.

[1] This did not form part of the Royal Institution discourse, but it may usefully supplement one or two of the points surveyed in that lecture.

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