THURSDAY, MAY 14, 1914.

RECENT EXTENSIONS OF THE QUANTUM HYPOTHESIS.

Die Theorie der Strahlung und der Quanten. Mit einem Anhange über die Entwicklung der Quantentheorie vom Herbst 1911 *bis zum Sommer* 1913. Edited by A. Eucken. Pp. xii + 405. (Halle a. S.: Wilhelm Knapp, 1914.) Price 18.60 marks.

A SHORT account was given in NATURE in November, 1911, of a meeting of the principal authorities on radiation questions held in the autumn of that year in Brussels, under the auspices of M. Ernest Solvay. The present work is the German edition of the papers read at that congress, together with the discussions which took place on them. In the course of the last two years the subject has developed very considerably, and the opinions expressed at Brussels would only give a very incomplete view of the present state of the theory, but this defect has been corrected by the editor, Prof. Eucken, who provides at the end of the book a fairly detailed sketch of the chief advances up to the summer of 1913.

This section provides extraordinarily interesting reading. Though no solution has yet been found of the central problem, several new phenomena have been brought under the quantum *régime*, and the position of the theory of specific heats under that *régime* has been completely altered. The older theory of Einstein and Nernst (an account of which is given in the earlier part of the book), supposed that every atom in a solid vibrates with a certain definite frequency, and so by the quantum principle can only take up energy in certain definite amounts. The resulting value for the specific heat agrees only very roughly with experiment at low temperatures. The new theory, developed independently by Debye and by Born and Kármán, applies the quantum principle not to the separate atoms, but to the elastic waves which can be propagated through the body. The agreement with experiment is very greatly improved, and there can be little doubt that the work provides the right basis for a theory, though the mathematical difficulties have so far prevented its being worked out completely. Debye's application of the quantum principle directly to waves instead of merely to vibrating electrons is one of the most important changes of aspect which have come over the subject. Since energy in a wave is not localised in one spot, the new aspect makes the physical comprehension of the quantum even harder than it was before, but in spite of this there is a gain in generality, and it should probably be counted as a distinct advance towards the final elucidation of the problem.

Another question which has become very prominent is "Nullpunktsenergie"—residual energy at the absolute zero of temperature. This first arose in connection with Planck's second radiation hypothesis, according to which a vibrating electron absorbs energy following the ordinary laws, but can only emit it when its total energy has reached one of a definite series of values. Thus near the absolute zero a vibrator may have quite a finite amount of energy, since it cannot emit at all the energy which it is slowly absorbing. According to a very important paper by Poincaré—almost his last published work—there is grave difficulty in accounting for the observed radiation formula in this way; but in spite of this the question of residual energy has been the subject of a good deal of discussion, and it has been invoked with some success though in a very speculative way, to account for several phenomena. In considering the evidence on these points Prof. Eucken concludes that each separate one might be explained in another way, but that the sum of all gives some probability in favour of the existence of residual energy at the absolute zero. According to a suggestion of Debye the reflection of X-rays may be made to throw light on this, since it may be possible to discover in what way the atoms of the reflecting crystal vibrate. So perhaps this important question may be decided soon.

The most striking development, to which Prof. Eucken refers, is the application of the quantum to the rotation of gas-molecules. Hitherto it had only met with success when applied to vibrations. In a rotating gas-molecule we have a periodic, but not a vibrational motion, and it must be of fundamental importance that the quantum applies to this. The most remarkable result of all is the work of Eva von Bahr, who finds that the absorption of infra-red light by water-vapour may be taken to indicate that the molecules are rotating only with multiples of two definite angular velocities. By the use of the quantum it is possible to calculate two moments of inertia for the molecule, and the values deduced are of the size which would be expected from its known dimensions. When further developed this work may be expected to throw light not only on the meaning of the quantum, but also on the structure of the molecule.

It is unfortunate that the book came out just too early to include a mention of Bohr's theory of spectra. This theory is very speculative, but unlike any of the previous theories it does give a simple reason for the observed series in spectra. Perhaps his most striking result is the theoretical evaluation of Balmer's constant with extraordinary closeness from Planck's constant and the electron constants. Bohr's work may prove very valuable in the solution of the central problem of the quantum; for it has the merit of carrying the principle of Planck, already hard to understand physically, logically to a very extreme point, and it is by the accentuation of difficulties that their solution is usually brought about.

It would be impossible within the limits of this notice to discuss the rest of the book adequately. It is sufficient to say that it deals with all the more firmly established developments in this branch of physics, and that the names of the writers are a guarantee of its value. C. G. D.

BOOKS ON PLANT DISEASES.

(1) *The British Rust Fungi.* By W. B. Grove. Pp. xii+412. (Cambridge: University Press, 1913.) Price 4*s.* net.

(2) *Mildews, Rusts, and Smuts.* By George Massee, assisted by Ivy Massee. Pp. 229+iv plates. (London: Dulau and Co., Ltd., 1913.) Price 7*s.* 6*d.* net.

(3) *The Fungi which Cause Plant Disease.* By Prof. F. L. Stevens. Pp. viii+754. (New York: The Macmillan Co.; London: Macmillan and Co., Ltd., 1913.) Price 17*s.* net.

(1) THE twenty-four years which have elapsed since Dr. Plowright published his classic monograph of the British Uredineæ and Ustilagineæ have seen great progress in our knowledge of the biology and classification of the former group—the rusts. Their heterœcism was a recognised fact; the life-history of *Puccinia graminis* was familiar to most botanical students, but the subject has broadened considerably in the last quarter of a century; *P. graminis* itself has been shown to include several species easily separable by form and colour; and, further, biological differences have been demonstrated, embodying a close adaptation between fungus and host, and the recognition of "physiological races." In this connection Mr. Grove utters his protest against the excessive multiplication of "species" by "biological" nomenclators:—"Physiological unaccompanied by morphological distinctions should never be allowed to constitute a difference of species, unless it be as a temporary measure in cases which have not been investigated." The difficulty arising in the case of heterœcious species from the existence of distinct names for the various phases of the same species has been overcome by the rule agreed to at the Brussels Congress to give preference to the earliest name given to the perfect (in this case the teleutospore) stage.

The book consists of a general and a systematic part. The former comprises a useful account of the variously complicated life-history of the Uredinales, *Puccinia caricis,* the nettle and sedge rust, a species more accessible to students than *P. graminis,* the aecidum stage of which is now rarely found in this country, is taken as a general type, but full accounts of other species are also given. A chapter on the sexuality of the group supplies a review of the work done in recent years by Blackman and others, and its important bearing on the systematic relationships and phylogeny of the group. A chapter on specialisation gives some account of the "biological races" above mentioned, and also severely criticises the mycoplasma theory of Eriksson. There is also a discussion of the phylogeny of the group and of the reasons for deriving it from the red algæ.

The systematic portion contains working descriptions of about 250 species, representing twenty-two genera and five families. The species in the larger genera, Uromyces (38 species) and Puccinia (137 species) are arranged in the order of the families and genera of their host-plants. An adequate synonymy is given, and the spores of a large proportion of the species are figured. At the end of the text are a short glossary, a bibliography, an index of host-plants, and a general index.

(2) In the small volume, "Mildews, Rusts, and Smuts," the author supplies in handy form a synopsis of the families Peronosporaceæ, Erysiphaceæ, Uredinaceæ, and Ustilaginaceæ in so far as the species have been met with in Britain as parasites on native or cultivated plants, or are likely to occur, in so far as they are parasitic on host-plants, indigenous to this country. Some of the latter, by the way, have already arrived. The many years which Mr. Massee has devoted to the study of British fungi should be a guarantee of value and of accuracy, and students of our native fungus-flora from an economic or purely scientific point of view will find the book a useful companion. Keys are given to the genera and species, and under each species there is an ample description and a list of host-plants. The numerous species of Puccinia are arranged under the orders and genera of the host-plant or one of the host-plants, a method which is sometimes misleading. Thus the well-known hollyhock fungus, for instance, will not be found under Althæa, but under Malva, and in the heterœcious species one host only is cited, that bearing the teleutospores. A coloured illustration of the life-history of *Puccinia graminis* makes an attractive frontispiece, and there are also four black and

white plates, mainly illustrating spore-forms at the end of the book.

(3) Dr. Stevens's book is a systematic descriptive account of the fungi which cause diseases of economic plants in the United States, and to some extent a companion volume to his "Diseases of Economic Plants," in which the effect of the disease on the host-plant and methods of prevention and cure are described. The term "fungi" is used in a broad sense, and includes myxomycetes and bacteria, as well as true fungi. Under the myxomycetes the author includes the parasitic plasmodiophorales; otherwise this group is a saprophytic one, and innocuous apart from occasional injury owing to the plasmodium overgrowing other plants. The chapter on bacterial disease is also a short one, and the great bulk of the volume deals with parasitic fungi. The arrangement is under the three classes: phycomycetes, ascomycetes, and basidiomycetes, followed by the fungi imperfecti. Under each class keys are given to the orders and families, and class, order and family are concisely described. A key to the genera follows the description of each family. Individual species are described at varying length according to their importance, and many which are not yet known in the United States are briefly mentioned, especially the more important, or those which are likely to invade America. There are text-illustrations of most of the species, and each section is followed by an extensive bibliography; there is also a good glossary at the end of the volume.

MECHANICAL AND CHEMICAL ENGINEERING.

(1) *The Principles of the Application of Power to Road Transport.* By H. E. Wimperis. Pp. xiv+130. (London: Constable and Co., Ltd., 1913.) Price 4*s*. 6*d*. net.

(2) *Farm Gas Engines.* By Prof. C. F. Hirshfeld and T. C. Ulbricht. Pp. vii+239. (New York: John Wiley and Sons, Inc.; London: Chapman and Hall, Ltd., 1913.) Price 6*s*. 6*d*. net.

(3) *The Diesel or Slow-combustion Engine.* By Prof. G. James Wells and A. J. Wallis-Tayler. Pp. xvi+286. (London: Crosby Lockwood and Son, 1914.) Price 7*s*. 6*d*. net.

(4) *Cement, Concrete, and Bricks.* By Alfred B. Searle. Pp. xi+412. (London: Constable and Co., Ltd., 1913.) Price 10*s*. 6*d*. net.

(1) IN this work Mr. Wimperis has made available in an expanded form the substance of a series of lectures delivered in 1913 at the Finsbury Technical College on the application of power to road transport. In the chapter devoted to the measurement of power, the author describes fully the principles of construction, and the method of using the ingenious accelerometer, which he invented in 1909; by means of this instrument many measurements have now been made of the tractive effort exerted in moving motor-cars and wagons at various speeds, both on the level and on grades, and thus valuable experimental data have been accumulated as a basis for the design of motor vehicles. In a later chapter Mr. Wimperis shows by actual examples how the data obtained by such an instrument and from bench tests of engines may be utilised to design a motor vehicle from prescribed conditions; both motor wagons and touring cars are dealt with, and this chapter should prove of great assistance to designers of motor-cars.

In appendix ii. the author has reprinted the report on the brake horse-power tests carried out at Brooklands in July, 1912, and discusses the values obtained for the brake mean pressure, and the effects of air resistance. Mr. Wimperis has produced a notable little book, of interest to the amateur and of value to the expert.

(2) In this book the authors have attempted the somewhat difficult task of acting as a guide to the farmer who proposes to purchase an internal combustion engine for any power purpose. Though the book is entitled "Farm Gas Engines," it is really mainly concerned with engines using liquid fuel, such as gasoline and kerosene. Of necessity but little theory is given, and the main part of the book is wisely devoted to discussions of the essential points in the design of the working parts of these engines. When a non-expert is considering the suitability of any particular type of engine for his purposes, there are certain details of construction to which he should devote especial attention, and on this matter excellent advice is given in this little book. Though practically only American types of farm engines are discussed by the authors, nevertheless the information and advice given in the chapters devoted to details of engine construction will be found useful by any British farmer who has already obtained, or thinks of obtaining, an internal combustion engine of any type.

(3) It is just twenty years since Dr. Rudolph Diesel published a pamphlet in which he dealt fully with the principles which must govern engine design when the object aimed at is to secure the maximum possible thermal efficiency, and now the Diesel engine has become such a serious rival of the steam engine that it has even been utilised for locomotive work; it is only natural, therefore, that special text-books should be devoted to the theory and construction of the

Diesel or slow-combustion oil engine, as the authors term it.

The authors, in addition to much original matter, have brought together into convenient form for reference the results of experimental work and the information in regard to constructive details published in the columns of the technical Press of the past ten years, or embodied in the numerous papers read before the leading engineering societies of the world; for this reason alone the book will prove invaluable both to the many engineering firms which now build these engines, and to the engineers who have installed them in power stations, factories, and ships.

The first four chapters deal with the theory of the laws of perfect gases, the work which can be obtained from a given volume of gas when expanding under given conditions, and the application of the well-known entropy diagrams to the study of the internal combustion engine. The next chapter deals with oil fuels suitable for these engines, their physical properties and methods of transport, and storage; in this connection the authors refer to the vast shale deposits in Australia, and to their utilisation for the production of oils for power purposes in that continent. In connection with the question of the cost of power generated by Diesel engines, it may be mentioned that in a test of a 200 b.h.p. two-cylinder four-stroke cycle engine, Mr. Eberle obtained under full load a thermal efficiency of 34·2 per cent. reckoned on the b.h.p., a wonderfully good result. In connection with the testing of Diesel engines the authors give some useful advice as to the care and attention necessary in order to maintain a high state of efficiency.

In view of the importance to designers of Diesel engines of a thorough knowledge of the theory and practice of air compression, the authors have wisely devoted a whole chapter to this subject, and have done their work admirably. The ninth chapter deals with the data and calculations needed in the design of cylinders, crankshafts, valves, flywheels, and reversing gears, while the concluding chapter is devoted to an account, well illustrated, of a number of recently-constructed Diesel engines for all classes of land and marine work; it is in connection with marine work that the greatest advance has taken place in the last two or three years. In an appendix the authors give a most useful abridgment of the principal patents connected with this remarkable motor and its developments.

(4) In this volume, which forms one of a series of text-books on the chemistry of the national industries, Mr. Searle deals with the three important building materials—cements, concrete, and bricks. The importance of a knowledge of chemistry in the manufacture of cement has been long recognised, and to this fact is due the great advance this industry has made during the past twenty years, but it is only recently that the value of chemical research to the brickmaker has been fully realised. In the first five chapters the author deals with cement, most attention being given naturally to Portland cement; he discusses fully the necessary properties of the raw materials, and the various methods of manufacture; Mr. Searle is of opinion that with equal care and skill both the older wet process and the modern dry process produce good results. The chemical and physical changes which occur both in the manufacture and in the setting of cements are most fully and thoroughly discussed, especially the chemical relations between the lime, alumina, and silica. In chapter v. the question of the testing of cement is taken up, the various methods adopted are fully explained, and the importance of cement–sand tests is clearly brought out, the author expressing his opinion that tensile tests of neat cement are largely futile; in dealing with the tests for soundness it is shown that this is a test which it is difficult to carry out with accuracy, and that, as a matter of fact, the majority of the Portland cements now on the market will pass all the ordinary tests for soundness.

Two chapters are devoted to the components of concrete and its preparation, and much excellent practical advice is given; then follows a chapter on reinforced concrete; the author points out that many of the formulæ now used in calculation work contain constants, which in the hands of the experienced man are safely used, but when used by a beginner may lead to serious blunders. The remainder of the book is devoted to brickmaking; the chemical and physical properties of the raw materials are fully discussed, the various processes of manufacture described, and the properties of finished bricks of various classes explained. Mr. Searle has written a thoroughly sound, valuable text-book, which ought to prove of great service to manufacturers, builders, and architects.

T. H. B.

OUR BOOKSHELF.

Lehrbuch der Paläozoologie. Teil ii., Wirbeltiere. By Dr. E. F. Stromer v. Reichenbach. Pp. ix+32. (Leipzig and Berlin: B. G. Teubner, 1912.) Price 10 marks.

THE second part of Dr. Stromer's text-book of palæozoology deals with the fossil vertebrates in the same concise and philosophical manner as his previous account of the invertebrates. The descriptive sections comprise only just such conspicuous families and genera as are needed by a student who seeks a broad view of the subject; and at the end of the chapter on each class there is a brief summary of the leading features in the geological distribution and evolution of the class as a whole, with a table of diagnoses of its larger subdivisions. A useful list of the principal papers and books published during the last few years is also appended. The text throughout is well illustrated with drawings of more than usual artistic merit, and although the majority of them are taken, with acknowledgment, from various original works, Dr. Stromer himself has frequently amended them to bring them up-to-date. Some, indeed, are in advance of their formal publication, such as the drawing of the skeleton of the strange clawed ungulate mammal Moropus, contributed by Dr. W. J. Holland. So many are new to a text-book that their appearance is quite refreshing.

In a work designed for elementary teaching it is generally advisable to incline towards conservatism, and Dr. Stromer evidently holds this opinion. Among fishes, for instance, he still recognises the "orders" Ganoidei and Teleostei, though his so-called diagnoses do not define them; and his treatment of the early palæozoic Arthrodira and Ostracodermi is not altogether satisfactory from the modern point of view. His references to the literature, however, will enable the student to examine other views if he wishes to do so.

The last sixty pages of the book are devoted to the general principles of palæontology, and we can recommend this able summary to any zoologist who desires to understand the present position of those who study fossils. A. S. W.

A Treatise on Wooden Trestle Bridges and their Concrete Substitutes. By Wolcott C. Foster. Fourth revised and enlarged edition. Pp. xix + 440. (New York: John Wiley and Sons, Inc.; London: Chapman and Hall, Ltd., 1913.) Price 21*s.* net.

IN the present edition of this work, which was first published in 1891, will be found a very full account of the construction, erection, maintenance, and preservation of timber trestle bridges. The book is profusely illustrated, and contains working drawings showing the details of the standard trestles used on the principal American railroads. Wooden trestles may be disappearing gradually from main lines of heavy traffic, but the increased growth of branch lines, or feeders, and of trestles at manufacturing plants and for electric railways, have probably more than kept pace with its abandonment on main lines. There is, on the average, about 100 ft. of bridges and trestles to each mile of railroad in the United States. The wearing out of wooden trestles and the increasing cost and scarcity of timber suitable for their replacement has taxed the ingenuity of railroad officials to find suitable structures to take their place. In some cases iron or steel structures have been employed, but there are numerous districts where local conditions make these methods so expensive as to be prohibitive.

In the past few years a number of roads have used concrete trestles in replacing those constructed of timber, and the author gives full particulars of reinforced concrete trestles and slabs which form a structure closely in line with the main features of the timber trestle. The book provides a great deal of valuable information regarding the strength, durability, and preservation of timber under all kinds of practical conditions, and therefore will be of service to British engineers, despite the fact that timber bridges do not occur often on British railways.

Durch König Tschulalongkorns Reich. Eine deutsche Siam-Expedition. By Dr. Carl C. Hosseus. Pp. xii + 219 + plates. (Stuttgart: Stecker and Schroder, n.d.) Price 15 marks.

DR. C. C. HOSSEUS, who visited Siam in 1904–06, gives us in the present volume an account of his journey and scientific observations. The route lay up the Mäping, and at various halting-places excursions were made to the neighbouring country. Chiengmai appears to have been his chief base, and from there Doi Intanon, Chieng Dao, Pahombuk, and Chiengrai, to mention only a few of the more important, were visited.

Zoologists, geologists, ethnologists, geographers, and other naturalists will all find much to interest them in the book; for quite a casual glance through its pages will suffice to show that the author was ever on the alert to note points of interest in any branch of science. But it is undoubtedly to the botanist that the author has in the first place appealed.

Previous to this work the author had published lists of his botanical collections, so that here we have no complete catalogue, but references are given to the new species found and to many others interesting for some morphological detail or for their associations. Here it may be noted that the index, copious though it may appear, is not a complete index to all the plants mentioned.

A word of praise is due for the numerous excellent illustrations included at the end of the book. All who are interested in Asiatic botany must feel indebted to Dr. Hosseus, to whom must be attributed the credit of being the first scientific traveller and collector on a large scale north of Bangkok, for supplementing his previous lists with such an interesting book.

Biology: General and Medical. By Prof. Joseph McFarland. Pp. 457, with 160 illustrations. Second edition. (Philadelphia and London: W. B. Saunders Co., 1913.) Price 7*s.* 6*d.* net.

THE first edition of Prof. McFarland's book appeared in 1910, and was reviewed at length in the issue of NATURE for March 23, 1911 (vol. lxxxvi., p. 106). In the present edition the author has endeavoured to eliminate defects discovered in the book, and without much increasing its size to introduce the new matter necessary to bring it up to date.

LETTERS TO THE EDITOR.

[The Editor does not hold himself responsible for opinions expressed by his correspondents. Neither can he undertake to return, or to correspond with the writers of, rejected manuscripts intended for this or any other part of NATURE. *No notice is taken of anonymous communications.]*

The Constitution of Atoms and Molecules.

DR. VAN DEN BROEK'S letter (NATURE, May 7, p. 241) contains one or two misapprehensions of the views put forward in my paper (*Phil. Mag.*, April, 1914), and I shall accordingly endeavour to make my meaning clearer. The paper does not purport to show that Dr. van den Broek's hypothesis is incorrect—in fact, in my own belief, it is fundamentally correct, though not necessarily in complete detail—but only to show that it is incompatible with the present form of Bohr's theory. Any atomic theory has two main things to explain in connection with optics—the X-ray spectra investigated by Moseley and the ordinary light spectra of atoms. The fact that coplanar rings are mathematically impossible is conclusive against them, whether on Bohr's theory or the present dynamical one. This must be admitted, in the face of any other evidence which appears to support them. There can be rings of electrons in an atom provided that they are not coplanar, but they must be of the same order of radius. There is only one case in which coplanar rings are possible—the case in which bound electrons *do not repel* each other, which is considered in detail in a paper to be published shortly, but such a supposition is in complete contrast to the present form of Bohr's theory.

As my letter to NATURE pointed out, we do not require an inner ring in order to explain X-rays having lengths of the order 10^{-8}. They can come from an ordinary ring of atomic size if the nucleus is of strength 10 or more, and the Balmer lines can be considered as an X-ray spectrum of hydrogen. X-rays can even come from the confines of a structural nucleus. Many physicists have not yet realised that the size of the wave-length given by a ring bears no fundamental relation to its radius alone. The *angular velocity* of the ring is the important deciding factor. If we suppose that the frequency of a line is the frequency of the vibration of the ring about its steady rotation, dynamics shows that it is of the same order as the frequency of rotation, w. If C is the velocity of light, the wave-length is of order C/w, and a ring of *any* radius can give any wave-length if it rotates with the proper angular velocity. So also can any portion of a structural nucleus, and, coplanar rings being impossible, the X-rays can come from the nucleus. The wave-lengths on Bohr's theory are also determined by the order C/w, and not in any fundamental way by the radius, as may be seen by an examination of Bohr's mathematics.

Although it is the only published attempt, Bohr's theory does not constitute the only one which can be suggested to deal with Moseley's results. The writer has obtained, for example, a simpler explanation of them by more ordinary dynamics, which will shortly be published, by attaching a definite structure to the nucleus—a structure which can explain a great deal more in connection with such phenomena as the velocity of emitted α particles. In this method, the meaning of N is essentially the same as in Dr. van den Broek's hypothesis. The difference is in detail only. It is not possible to dispute Moseley's contention that there is a fundamental number which changes by steps of 1 in passing from one element to another in the table, nor that it is an "atomic number" related to the charge on the nucleus. But there is an assumption—perhaps correct—made in identifying it with the *exact* place occupied by an element in the table as we now know it, and Bohr's theory is incompatible with this assumption. For the paper showed that if the atomic number of lithium, for example, is 3, it must (1) have no valency on Bohr's theory, and (2) it must have all its electrons in one ring, or moving in a manner prohibiting any two of them from forming a ring. The radii of the orbits of the two inner electrons cannot be more nearly equal than in the ratio 12 to 1.

Again, as in another paper (*Monthly Notices of R.A.S.*, April, 1914), no approach to the ordinary helium spectrum can be obtained from Bohr's theory if the atomic number of helium is 2. These are only illustrations of much more decisive results. They have related, in the work published already, to the supposition that the laws of force between bound electrons are those used by Bohr. But they are equally valid for other laws of force. The one case in which the coplanar rings can exist—when bound electrons experience no force from each other—is the only avenue towards the extension of the theory. But it has difficulties, and, in particular, it gives no place to Moseley's constant b, which is then zero in all atoms. The K radiation then leads to the conclusion that the atomic number usually differs by 1 from the place of the element in the table. Dr. van den Broek lays stress on the fact that $N-b$ changes from one element to another, and not N. But we must repeat, quite definitely, that b is zero in the only modification of Bohr's theory which can have more than one coplanar ring. By this statement, however, we do not imply that b has no existence in fact. Its different values for K and L radiation demonstrate that it is real. The theory would demand an identity of these radiations even if they came from different rings, when such rings can exist. A reconciliation with experiment can only be obtained by putting the electrons as a constituent part of the nucleus itself, or by supposing that X-radiation comes from the confines of the atom—the K type from a neutral atom, and the L type perhaps from an atom which has lost an electron. But this latter alternative is quite at variance with Dr. van den Broek's hypothesis, when calculations are performed, and the first has no relation to Bohr's theory.

The strongest argument in favour of Dr. van den Broek is the recent generalisation of the periodic table put forward by Soddy and Fajans, against which mathematical considerations cannot be raised; in fact, they tend to support it. This generalisation, however, in no case demands a strict identity between the nucleus charge, and the place in the table. The other phenomena depending on the atomic number could depend equally well, within the order of accuracy, on a number which differed from it by 1 or 2. In conclusion, so far as the table is concerned, Dr. van den Broek may be completely correct, but, if so, Bohr's theory cannot be modified to take account of X-ray spectra. The periodic table, however, is not a sufficient test. Astrophysical spectra demand, as proved in many papers in the *Monthly Notices*, the existence of simple "elements" the spectra of which can be calculated, which not only agree with actual spectra, but also have actually led to the discovery of several lines which the formulæ predicted. The atomic weight of one of these, with 6 electrons, is 2·94, as calculated theoretically. By an application of their interference method to a line in nebulæ, MM. Bourget, Buisson, and Fabry (*Comptes rendus*, April 6, 1914) have verified this value for the mass of the atom which emits the line. They have also made preliminary experiments on another element, and found results which support the theoretical value of the atomic weight, 1·31. Very simple elements can exist therefore in which the atomic number differs from the number of electrons, and Dr. van den Broek's hypothesis cannot be a complete principle, although perhaps satisfactory for the stable terrestrial elements. Nevertheless, if it is satisfactory in this range, Bohr's theory is not.

J. W. NICHOLSON.

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Temperature-Difference between the Up and Down Traces of Sounding-Balloon Diagrams.

IN his paper on the daily temperature change at great heights (January issue of the Quart. Journal of the Roy. Met. Soc.), Mr. Dines deals with the double traces shown by the diagrams of registering-balloons. He ascribes the difference for a great deal to the heating effect of the balloons, as the instruments swim in the wake of dead but heated air that follows the ascending balloon.

He rejects as a possible cause any thermal lagging of the instrument, because the double trace is most apparent in the isothermal layer, and also because it mostly occurs by day and not by night.

Receiving this number of the Quart. Journal, it just happened that I had made a synopsis of this kind of temperature-difference for the Batavian ascents, which throws another light on this question.

At Batavia the balloons are of a larger type than those used in England; also the string between balloon and instrument is much longer, measuring 30 m. and more. Moreover, it has been observed in numerous cases that up to the greatest heights the whole system of balloon-parachute-instrument often swings strongly. Accordingly any heating effect by the air in the wake of the balloon seems most improbable.

The instruments are of the pattern usual on the continent and made by Bosch (Strassburg); they are provided with clockwork. When possible the heights have been calculated separately for the ascent and the descent; thus, when the downward temperatures were found to be lower than the upward, the corresponding heights became lower, and accordingly the difference of temperature for the same calculated height in the ascent and the descent was increased. In half of the thirty ascents which up to the present have been made, the balloon was liberated 1–1½ hours before, and in the other half 1–1½ hours after sunrise. Thus, in the first cases only the latter part of the descent took place at an hour that solar radiation begins to be active.

The mean differences found are:—

Temperature Higher in the Ascent than in the Descent.

Height in km.	Before sunrise °C.	After sunrise °C.	Number of cases Before	Number of cases After
1	0·0	0·4	16	14
2	0·1	0·4	18	14
3	0·4	0·9	18	16
4	0·2	1·4	18	16
5	0·2	1·5	17	15
6	0·7	2·4	16	15
7	1·0	3·0	17	12
8	1·2	3·3	15	13
9	1·3	3·2	15	12
10	2·2	4·4	15	11
11	2·7	4·6	15	11
12	3·0	4·3	15	11
13	3·4	5·0	15	10
14	3·8	3·6	13	9
15	3·3	2·9	12	9
16	3·5	2·5	6	5

The prominent fact, demonstrated by this table, is that up to 13 km. the differences before sunrise are much smaller than those after sunrise.

The synopsis teaches, that before sunrise negative values occur in all heights, especially below 7 km. In one case up to the stratosphere the difference was negative in all heights.

On the contrary, in another ascent it went up to 9·2°. After sunrise no ascent, with negative values only, occurred, and in one case the differences amounted to 11·2°.

For the stratosphere, only in eight cases a set of these differences was obtained, its height being so great in these low latitudes that only part of the balloons reach its layers. Only in one of these cases (after sunrise) the descent-temperatures in the stratosphere exceeded those of the ascent, and in another case (before sunrise) higher temperatures alternated with lower.

In the five other cases (before sunrise) the sign of the differences in and below the stratosphere were contrary. It must be borne in mind that scarcely any isothermal state prevails in the tropical stratosphere, but that the temperature increases with the height (*cf.* my letter in NATURE of March 5, p. 5).

However, in the above-mentioned case of alternating positive and negative values, isothermal condition was met with up to 23 km.

The reversal in sign of the difference, which accompanies the reversal of the temperature gradient, strongly points to a thermal lagging of the instrument. Its heavy parts, and the basket also, will lag strongly and will influence the thermograph. In the ascent the lesser the ventilation the greater the heating. Thus the influence will increase with the height, as the ventilation decreases. In the descent the ventilation in most cases was greater than in the ascent, and accordingly the negative lagging less. After sunrise the thermal lagging of the basket will be enhanced in the ascent by sun-radiation, which easily explains the fact that the differences are larger after than before sunrise.

Perhaps the English instruments, being smaller than the German, have a smaller thermal lag than the latter. Thus Mr. Dines's explanation may be applicable to the facts observed in England, and mine to those met with in Java. From them I think the following lessons may be learnt, which applies to most Continental ascents made in a similar way and with the same pattern of instruments:—

(1) The temperatures of ascent and descent should be averaged.

(2) When descent or ascent is available only, a mean correction, to be derived from a large number of corresponding cases, should be applied.

(3) The temperatures and heights taken from the publication of the International Committee, in which, in most of the cases, ascents only are given, are affected by a systematic error.

W. VAN BEMMELEN.

Batavia, March, 1914.

Cellular Structure of Emulsions.

THE same arrangement that is shown by Fig. 2, in NATURE of May 7 (p. 240), may be seen in an emulsion of Oriental finely powdered coffee suspended in milk and water. I have supposed that it is connected with a strange phenomenon which I reported in NATURE about forty years ago. Sooty rain-water, after standing for some hours, will develop clear planes of water, as much as 10 cm. long and only 1 or 2 mm. wide. These planes are most readily seen by candle light when vertical, but may develop at any inclination, and change inclination. Such a straight segregation of clean water shows that no self-attraction of the suspended solids can be the cause. In a recent point of view it looks like a liquid crystal arrangement of water expelling the powder as foreign matter, especially when we remember the habit of ice crystals in very thin plates. The question then arises, Are all these emulsion figures due to the clear liquid segregating and expelling the suspended matter?

W. M. FLINDERS PETRIE.

MODERN FORMS OF RONTGEN-RAY TUBES.

IN spite of many obstacles, medical technique in the application of Röntgen rays has made steady progress during recent years. But there still remain certain primary difficulties which are often a source of hindrance and confusion. The demand for a more trustworthy method of working than exists to-day is the natural outcome of wider radio-therapeutic experience, but what is required above all is an accurate means of measuring the output of the tube.

The solution of this problem clearly requires that we shall have at our disposal an apparatus capable of emitting a specific type of ray in definite quantity; and were it not for some experiments by Dr. Lilienfeld, and more recently by Mr. Coolidge, of New York, there would be little prospect of actually realising this result in practice. I shall refer to their work more in detail later.

Meanwhile, it is worth noticing that the modern X-ray tube, with all its imperfections, is a triumph of craftsmanship. It is the result of numberless costly and difficult experiments carried out by manufacturers and others to meet a demand which grows more exacting every year. The collection of historical X-ray tubes brought together some time ago by the Röntgen Society, and now on view in the Science Museum at South Kensington, contains the first bulb which embodied the chief features adopted universally up to the present time in the construction of X-ray tubes. That bulb was made by Prof. Herbert Jackson in 1896, and measures only 3 in. across. The diameter of those in use to-day is, however, usually twice or three times as great, the electrodes being heavy and the vacuum carefully adjusted.

The successful working of the apparatus depends so largely upon this last factor that decrease in pressure of the residual gas, invariably accompanying prolonged use, has to be compensated for. The devices employed for regulating the vacuum may be divided into three main classes, viz., those:—

(1) In which a few discs of mica, a piece of carbon or asbestos, etc., fixed within the bulb, offer an alternative path for the discharge, so that gas is, when necessary, liberated by the heat generated, as the electric current follows the line of least resistance.

(2) In which a fine palladium tube stopped up at one end has a small tubular extension of platinum soldered to it for sealing into the X-ray bulb. A gas flame brought near so as to heat the palladium enables hydrogen to enter by osmosis, and so lower the vacuum. All the tubes used in the X-ray treatment cubicles at the London Hospital, for instance, have these "Osmo" regulators.

(3) In which air is allowed to enter through the pores of a piece of unglazed porcelain, which is usually sealed with mercury until by a pneumatic contrivance it is momentarily uncovered.

But none of these methods is free from objections. The regulation is generally too insensitive. The tube often outlives the supply of gas from the first sort, and the others are only trustworthy in skilled hands. The mica disc regulator is shown in the diagram (Fig. 1), which otherwise is self-explanatory.

Messrs. C. H. F. Muller describe some eighteen types of tubes of this character in their recently

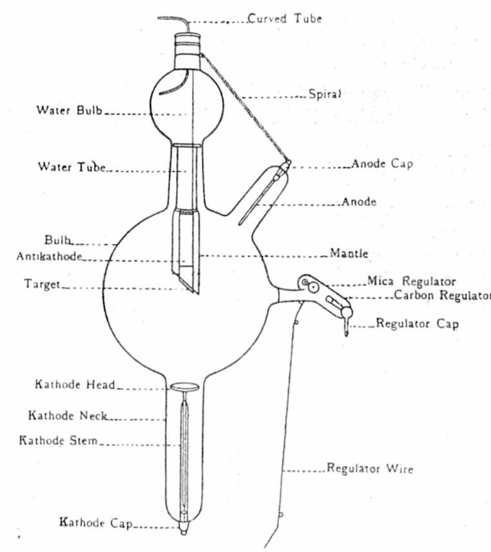


FIG. 1.—Showing the terms in common use to denote the different parts of the instrument.

published catalogue, and give precise instructions for the adjustment and use of each kind. There are in addition five coloured plates showing the appearance of X-ray bulbs in action, and a great amount of useful information besides. Fig. 2 (Muller) may be taken as representing a typical example of modern heavy discharge X-ray tube.

The cause of the disappearance of gas with prolonged use has given rise to much speculation. It has been suggested that the ions produced by the discharge are driven actually through the walls, and so escape; there is proof at least that the glass takes up a large part of the residual gas under these conditions, and that lead glass absorbs more than Jena.

Since the degree of vacuum controls the resistance of the tube, and this in turn determines the current that passes with a given potential difference between the electrodes, it is evident that the pressure of the residual gas is the chief factor which defines the type and quantity of rays to be obtained. Moreover, the kathode itself must carry a minute trace of gas to facilitate the transfer of electricity from the metal to the surrounding space. Further, the great heat often generated at the antikathode raises the temperature of the walls to such an extent that gas is set free there, and the balance of working conditions upset. A new tube, in fact, generally requires "maturing" until its vacuum when at work will keep practically constant, and yet be neither too high nor too low. This calls for much care and patience on the part of the operator. A bulb may in this way be coaxed to carry 5 milliamperes for hours at a stretch, and be of great service in "treatment." In most cases, however, the current does not exceed 2 milliamperes for that purpose. But in radiographic work the usual practice is to employ a heavy current—20 milliamperes—for a few seconds or even a fraction of a second. The length of exposure is, of course, determined by a number of considerations, but with such a large current it cannot exceed a few seconds on account of the enormous heat generated at the antikathode by the impact of electrons.

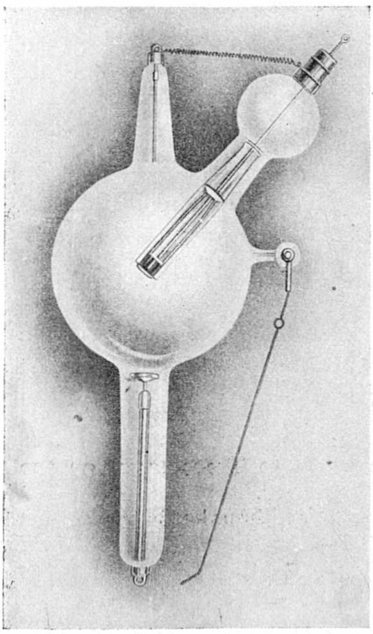


FIG. 2.—Heavy-discharge X-ray tube.

The same difficulty is met with in the treatment tubes, quite apart from the disengagement of gas,

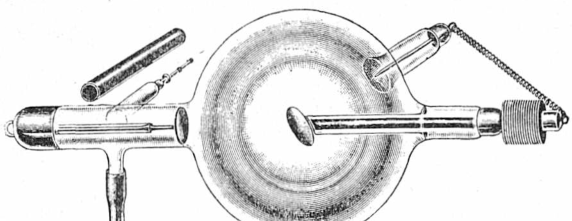


FIG. 3.—Heavy discharge radiator tube.

for a longer exposure has to be given now than would be necessary if more current could be carried with regularity and safety.

Under existing conditions the antikathode stem is usually made hollow, so as to enable water or air to flow in and carry off the heat, or an actual radiator may be fitted, as shown in Fig. 3 (Cossor). The osmosis regulator is also represented in the same illustration. Otherwise, even the hardest substance used as target would melt or become pitted by the impinging electrons. As an example of what occurs, the photomicrograph (Fig. 4; for which I am indebted to Dr. Rodman) of a plate of platinoid-nickel which has served as target may be of interest. In all cases except for very light work, the antikathode is made of stout copper faced with platinum-iridium or pure iridium, tantalum, etc., at the place where the kathode rays impinge upon it. The uncertain variation of vacuum, together with the development of excessive heat at the antikathode, constitute the most serious objections to the present system of working. The first difficulty especially hinders progress towards the attainment of an accurate method of measuring or describing the radiation dealt with, for it may change from day to day, or even during an exposure. But there are, in addition, many minor ailments which develop with the age of the tube. Thus a deposit comes gradually upon the inner surface of the walls. It is

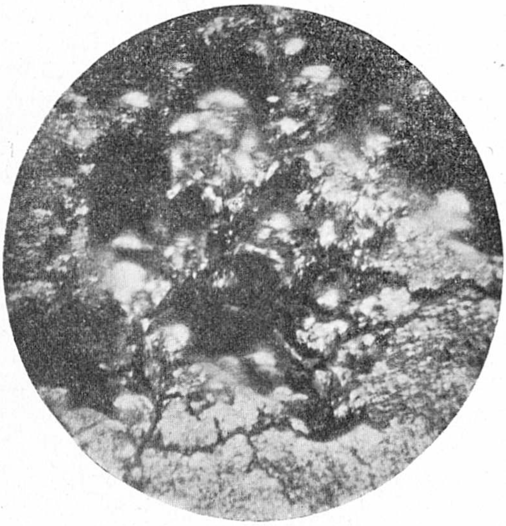


FIG. 4.—Photomicrograph of eroded target.

mainly metallic, and occludes gas; but it also provides electrified areas which disturb the normal streams of electrons. Occasionally, too, patches of bright fluorescence appear on the glass, due to specks of foreign matter sticking to the kathode. The direction of the discharge will sometimes reverse in the tube from no apparent cause. Indeed, the behaviour of a bulb is so erratic at times that a superstitious person might be excused for regarding it with distrust.

However, with care and experience, and in spite of many disadvantages, splendid work is being done with this super-sensitive apparatus. But it is none the less necessary to make every effort towards placing X-ray therapeutics upon an accurate quantitative basis, and to simplify the technique. With existing appliances the prospect of so doing is remote indeed.

But we are on the eve of great improvements! Dr. Lilienfeld, of Leipzig, has already constructed a Röntgen tube which is so highly exhausted that the residual gas plays no part in the working of the apparatus. The first description of this new departure was given in the *Fortschritte auf dem Gebiete der Röntgenstrahlen* for June, 1913, and more recently a further account has appeared in a later issue (Band xviii., p. 256).[1]

Dr. Lilienfeld creates an electric field in the neighbourhood of the antikathode between an aluminium tube and a white-hot wire. The working potential difference is then applied to the main electrodes and a discharge immediately passes. Since the current taken by the tube depends upon the temperature of the so-called priming device, the operation is under control.

But Mr. Coolidge[2] has simplified this design still further by placing a small spiral of tungsten at the centre of the kathode; heating this by an independent current he obtains a supply of electrons which are repelled and driven against the target with such speed as to produce copious X-rays where they strike. Thus, given a powerful induction coil and noting that the bulb is so well exhausted that 100,000 volts at its electrodes produce no discharge, the spiral is heated and the current that then passes is simply a function of the temperature. Variation of the potential difference would mean an alteration of the speed at which the electrons are driven against the target. The *quality* of the X-rays produced can therefore be varied, irrespective of their quantity. This is not possible with any other type of X-ray tube. Its importance cannot be over-rated. It places in the hands of X-ray operators an instrument of precision. Many questions are still outstanding; it is not even claimed yet that this apparatus is beyond the experimental stage. Meanwhile, however, it may be of interest to point out that the Coolidge tube has already given some remarkable results. The most successful bulb so far made measured 18 cm. in diameter, and was blown from German glass; it carried a current of from 1·7 to 36 milliamperes with the spiral heated to a temperature varying between 2010° and 2240° absolute. It was run for fifty minutes continuously on one occasion with 25 milliamperes passing. There was, of course, great heat developed in the antikathode, but the regularity of the action seems to have been unaffected. No fluorescence appeared upon the glass of this bulb, and the starting and running voltages were identical. The tube is also its own "rectifier," and may be run off an alternating circuit without any additional device to suppress one phase.

The prospect of being able to speed up the electron so much that it may give rise to a radiation with a wave-length equal to, or even shorter than, that of the Gamma ray from radium, offers great therapeutic possibilities.

It remains so far to improve the means of supplying electricity to the tube that a steady potential difference may be maintained at its electrodes. Then, since reversal seems impossible with the Coolidge system, it should be feasible to produce pencils of approximately *homogeneous* X-rays in definitely measurable *quantity* and of a *quality* expressed in terms of the coefficient of absorption in some agreed substance.

An attempt to construct a tube upon the new principle is at present being made in the physics laboratory of the Cancer Hospital, and experiments will be taken in hand there as soon as possible to test the types of ray obtainable by this means. CHARLES E. S. PHILLIPS.

[1] A good summary is published in the *Archives of the Röntgen Ray*, for February, p. 340

[2] *Physical Review*, December, 1913.

THE SICILIAN EARTHQUAKE OF MAY 8.

THE earthquake which visited the south-east flank of Etna on May 8 is evidently one of the strongest of the local shocks which occur so frequently within the bounds of the volcano. Unlike the Messina earthquake of 1908, the shock was heralded by many slight tremors in the surrounding district, several having been felt every day since April 25. But for these warnings, the loss of life might have been far greater than it was, though more than 150 persons are reported to have been killed and about 500 injured. The villages of Linera, Passapomo, Pennisi, and Zerbati are completely ruined; Cosentini, S. Caterina, and S. Maria Vergina are half-destroyed; while about a dozen other villages from Zafferana and S. Venerina on the north to Trecastagni on the south are seriously damaged.

The epicentre of the earthquake is clearly at and near Linera. The details at present known are insufficient to determine the boundary of the meizoseismal area, but its greatest dimension can scarcely exceed two or three miles. For the same reason, nothing more is known as to the extent of the disturbed area beyond the fact that it was small considering the violence of the shock near the epicentre. Probably the disturbed area is far less than that of some of the weakest of British shocks. This alone proves how rapid was the decline in intensity from the central region. At Acireale, only four miles south of Linera, the damage to property was slight. At Catania, seventeen miles to the south, the shock was felt, and excited some alarm. These two facts—the great intensity near the epicentre and the rapid decline in strength outwards—show that the focus must have been quite close to the surface.

It is, however, in its relations with previous earthquakes in the same region and with the eruptions of the neighbouring volcano, that the interest of the earthquake chiefly lies. Two and a-half years before, on October 15, 1911, a similar, though less destructive, earthquake occurred in the immediate vicinity. The meizoseismal area in this case was a narrow band, four miles long and about a-third of a mile wide, extending from Fondo Macchia to Guardia, and passing about a mile and a-half to the north-east of Linera. On this occasion twelve persons were killed and forty-eight injured. On July 19, 1865, the same district was ruined by an earthquake, by which seventy-four persons were killed and fifty-six injured. Other shocks visited the same or neighbouring villages on July 11, 1805, and January 26, 1859; while, from 1893 to 1900, twenty-seven strong shocks were felt, six of them being of ruinous strength.

Many of these earthquakes were closely connected as regards time with Etnean eruptions. The earthquake of 1805 occurred after, and that of 1859 during, a period of activity. The earthquake of 1865 took place eighty-eight days after the conclusion of a violent eruption; and that of 1911 twenty-two days after the close of the last eruption, which began on September 10 of that year and lasted for twenty-three days. The recent shock occurred about two years and eight months after the end of the same eruption.

The same phenomena seem to characterise all the earthquakes of this district. The disturbed area is small, the intensity of the shock great in its central portion, and the isoseismal lines extremely elongated in form. In some cases the axes of the isoseismal lines are directed towards the central crater; in others (as in the earthquake of 1911) in a perpendicular direction. The small depths of the foci, their situation within the Etnean boundary, the direction of the meizoseismal bands, and the close connection of many of the earthquakes with eruptions of Etna—all these phenomena point clearly to the volcanic origin of the earthquakes, their immediate cause being probably local slips along radial and peripheral fissures.[1]

C. DAVISON.

[1] M. Baratta, I terremoti d'Italia, 1901, pp. 829–33; A. Riccò, Boll. Soc. Sis. Ital., vol. xvi., 1912, pp. 9–38.

THE BACHELET LEVITATED RAILWAY.

THE daily Press, or rather a section of it, has been greatly excited during the past week by the exhibition of a model railway, the invention of M. Emile Bachelet, in which a metal carriage is levitated in the air above the rails in a model railway, and then flung forward with very great speed through a series of solenoids. The reporters for the daily Press have discovered new and tremendous possibilities in a scientific principle entirely new to them, but which has been perfectly well known to every electrician and physicist for the last twenty-five years.

The repulsion of a metal plate or ring by an electromagnet or coil carrying an alternating current was discovered independently by Dr. J. A. Fleming and by Prof. Elihu Thomson. In 1887 Dr. Fleming invented and described in the *Electrician* of March 25, 1887, an alternating current galvanometer, in which a copper disk suspended in the interior of a coil carrying an alternating current was repelled and deflected. On June 10, 1887, Prof. Elihu Thomson published in the *Electrician* a lecture on novel phenomena of alternating currents, in which he described the repulsion of copper disks and rings by an alternating electromagnet. Prof. Thomson's apparatus was exhibited at the Paris Exhibition in 1889, and the experiments shown by Prof. Fleming to the Royal Society of Arts in a lecture in May, 1890, and also at a Royal Society *soirée* in the same year, as well as at a Friday evening discourse at the Royal Institution in March, 1891.

Dr. Fleming expounded the whole matter with numerous striking illustrations. Heavy copper rings were made to float in the air, or were shot up into the air with great velocity. This repulsion is due to the repulsion between the currents in the magnet coil and the eddy curents set up by the alternating field in the plate or ring.

The principle was applied by Prof. Elihu Thomson in the invention of an alternating current electric motor, and it has been developed in the well-known compensated repulsion motor of Winter and Eichberg. It is also applied in several forms of rotating and recording electric meter. The phenomena known as "electromagnetic repulsion" are therefore perfectly familiar to electrical engineers, and except in the ingenious application to the support of a model railway carriage there is nothing new. Press reporters and others who have been astonished by the exhibition of this force are merely learning afresh facts which were publicly exhibited and described by Profs. Fleming and Elihu Thomson nearly a quarter of a century ago. Careful experiments and quantitative measurements will, however, be necessary before any valid opinion can be formed whether the principle admits of economical application in the propulsion of real railway trains. Nevertheless M. Bachelet deserves credit for his highly ingenious application of this well-known principle of electromagnetic repulsion.

NOTES.

LORD LAMINGTON, G.C.M.G., G.C.I.E., has consented to be president of the Research Defence Society, in succession to the late Sir David Gill, K.C.B., F.R.S.

ON the recommendation of the council and of the special committee on the Hayden award, the Academy of Natural Sciences of Philadelphia has this year conferred the memorial gold medal on Dr. Henry Fairfield Osborn, in recognition of his distinguished work in vertebrate palæontology.

AT the annual meeting of the Irish Forestry Society on April 23, it was stated by Prof. Campbell that the department hoped to secure 15,000 acres for State forestry in Ireland. A grant had been obtained from the Development Commissioners of 31,430*l.*, spread over fifty-two years, for a scheme of forestry in Cork, and the department is applying for a further grant of 45,000*l.* It is thus evident that State forestry in Ireland has broken ground in earnest, and this makes it all the more remarkable that State forestry in England and Scotland should still be waiting to start.

THE sixtieth general meeting of the Institution of Mining Engineers will be held in London, on Thursday, June 4, in the rooms of the Geological Society, under the presidency of Sir William E. Garforth. The following papers will be read, or taken as read:—Sinking and equipment of Blackhall Colliery for the Horden Collieries, Ltd., J. J. Prest and J. Leggat; development of the internal-combustion engine for power generation at collieries, J. Davidson; the geology of the Kent coalfield, Dr. E. A. Newell Arber. In addition, certain papers which have already appeared in the Transactions of the society will be open for discussion.

THE death is reported, in his seventy-fifth year, of Mr. Newton H. Winchell, State Geologist of Minnesota from 1872 to 1900, and professor of mineralogy at the University of Minnesota from 1873 to 1900. In 1888 he founded the *American Geologist,* which he continued to edit until 1905. He was the author of "Geology of Ohio and Minnesota," "The Iron Ores of Minnesota" (in collaboration with his son, Mr. Horace V. Winchell), "Elements of Optical Mineralogy," and "The Aborigines of Minnesota." Mr. Winchell was three times elected to the presidency of the Minnesota Academy of Sciences, of which he was the founder. Since 1906 he had been archæologist to the Minnesota Historical Society.

THE President of the Local Government Board has appointed a Departmental Committee "to consider the present state of the law with regard to the pollution of the air by smoke and other noxious vapours, and its administration, and to advise what steps are desirable and practicable with the view of diminishing the evils still arising from such pollution." The Committee will consist of:—The Right Hon. Russell Rea, M.P., Mr. H. Brevitt, Prof. J. B. Cohen, F.R.S., Colonel H. Hughes, C.B., Mr. J. F. MacCabe, the Right Hon. Lord Newton, Captain H. R. Sankey, Mr. B. Duncomb Sells, Mr. P. C. Simmons, Mr. E. D. Simon, Mr. W. B. Smith, Mr. H. O. Stutchbury, Mr. Christopher Turner, and Sir Aston Webb, C.B. Mr. E. A. Faunch, of the Local Government Board, will act as secretary of the Committee.

IN an article published in the *Times* of May 8 attention is directed to the great practical difficulties presented by the problem of the prevention of the spread of sleeping sickness in Uganda, and especially to that of obtaining the cooperation of the natives in carrying out preventive measures. Whatever the chiefs, wishing to stand well with the administration, may profess to believe, there can be no doubt that the native equivalent of "the man in the street" has no faith at all in the assertion of European science that the tsetse-fly is responsible for the spread of the disease; he points to the indisputable fact that the fly was there long before the disease, and he asks why, amongst the many hordes of biting flies, mosquitoes and other insects, should the tsetse alone be blamed? The further fact that the disease did not appear in the country until the Pax Britannica permitted natives to make long journeys in safety, and thus enabled persons infected elsewhere to enter the country, infect the fly, and so start the deadly epidemic, lends colour to the sinister suspicion that the Europeans introduced the disease into the country in order to establish effectually their dominion over its inhabitants. The writer in the *Times* refers to the comparative freedom from natural enemies enjoyed by the adult tsetse-fly, by reason of its alertness and swiftness of flight, but he seems to have forgotten that the insect passes a not inconsiderable period of its existence as a helpless pupa, buried close to the surface of the soil, and therefore much more easily destroyed.

AN account of some of the discoveries of expeditions to Peru in 1911–1912 was given by Prof. H. Bingham in NATURE of March 26. A new expedition has just started for the same region. As in 1912, the expedition is under the joint auspices of Yale University and the National Geographic Society. Unlike former expeditions, it will cover a period of two years, instead of being confined to one field season. The plan of work will include the making of a topographical map of the region north-west of Cuzco, between the Apurimac and Urubamba rivers; a detailed geographical reconnaissance of the more lofty portions of the mountains, including a study of the large undescribed glaciated region; the establishment of two meteorological stations at different elevations for the taking of systematic records for two years; a study of the distribution and history of food plants of this region; the collection of data respecting the forms and distribution of vertebrates, particularly mammals and reptiles; a survey of the present Indians inhabiting this region, including a study of their dialects, the collection of anthropometric data, and the collection and study of the skeletal remains; an archæological reconnaissance of the entire area, and a continuation of the studies begun by the first expedition, looking toward a geographical interpretation of the Spanish chronicles of the era of discovery and exploration, with particular reference to the identification of ancient place names, the story of Macchu Pichu, and its connection with the history of the Incas.

THE issue of the Journal of the Royal Anthropological Institute, July–December, 1913, is largely devoted to the ethnology of Africa. Sir H. H. Johnston contributes a masterly survey of the general question. One of his most important suggestions is that the cattle-keeping communities of the Central Sudan and of Bantu Africa owe much of the slight Caucasian element in their blood and almost all their culture to infiltration from ancient Egypt, rather than to influences from Galaland and Somaliland. In the same connection Prof. Seligmann's elaborate article on some aspects of the Hamitic problem in the Anglo-Egyptian Sudan deserves attention. He supports the suggestion made by Dr. J. G. Frazer in the recent edition of his "Attis, Adonis, Osiris," that the killing of the Shilluk rain-maker or divine king can best be understood in connection with the yearly renascence of vegetation.

THE Huxley Memorial Lecture, by Prof. W. J. Sollas, published in the July–December, 1913, issue of the Journal of the Royal Anthropological Institute, is devoted to an account of the exploration of the Paviland Cave at the base of the limestone cliffs of Gower, looking over the waters of the Bristol Channel. It belongs to the Aurignacian period, and the hunters who found shelter there were men of large stature, members of that Crô-Magnon race which occupied during that period the greater part of habitable Europe. They possessed highly developed brains, and had acquired such simple mechanical arts as are essential to primitive man. They had little artistic ability, and have left no recognisable drawings on ivory or bone, the red stripes discovered by Abbé Breuil and Prof. Sollas in the neighbouring cave of Bacon Hole being the only attempts at mural decoration which this race is known to have left behind in Wales. They wore rude ornaments, doubtless exercised some magical arts, and they respected their dead sufficiently to provide for them a ceremonial burial. Whether the Mousterians, their predecessors, occupied this cave is doubtful, nor is it certain that they were followed here by the Solutrians or Magdalenians. Prof. Sollas has thus opened up a new and interesting chapter in the prehistoric archæology of Great Britain.

DURING the last two months excavations have been carried on in a brickfield to the north of Ipswich with the object of discovering and collecting flint implements of probable Lower-Middle Aurignac-Palæolithic age, which are known to occur at a well-marked "occupation level" at varying depths round the sides of the small valley in which the brickfield is situated. Mr. J. Reid Moir informs us that on April 30 digging was commenced at a spot on the south side of this valley, and a section was exposed consisting of 2 ft. of sandy surface material with 2 ft. 3 in. of undisturbed sand below it. At the base of the section the solid London Clay was met with, and on the surface of this clay, under the compact, undisturbed sand many fragments of pottery, calcined flints, and the remains of a hearth were found. A large piece of pottery was found and photographed *in situ*. The pottery was carefully removed, and has been forwarded to the British Museum, Bloomsbury, where it is being examined. It was in an extremely soft and friable condition, contains many fragments of white quartz, and is of a primitive and rudimentary kind.

THE first memoir issued by the South African Institute for Medical Research is an inquiry, by Mr. G. D. Maynard, into the etiology, manifestations and prevention of pneumonia amongst natives on the Rand recruited from tropical areas (published by the institute, Johannesburg, price 5*s*.). Mr. Maynard has availed himself of modern statistical methods and finds, among other interesting results, that the attack and death-rates from pneumonia are influenced by the country of origin of the natives, that the highest attack-rates are found among the gangs which have the lowest physique, and that the prophylactic inoculations with a pneumococcus vaccine appear to reduce the incidence of pneumonia during a limited period. Mr. Maynard's results appear to show that the effect of such immunisation is transitory, the period during which some protection is afforded not exceeding four months, and that little reduction of the case mortality is attained. The paper should be read in conjunction with those of Sir Almroth Wright and his colleagues, who approach the subject from a somewhat different point of view.

WE have been favoured with a separate copy of an illustrated article, by Mr. A. Gallardo, from vol. xxvi. of the *An. Mus. Nac. Hist. Nat. Buenos Aires*, on the new museum of natural history it is proposed to erect in Buenos Aires, for which a considerable amount of money has been voted already. The building, which is to comprise all the essential features of an up-to-date museum, is to be in a modification of the Louis XVI. style, and will comprise a basement, a ground-floor, and a first-floor.

ALTHOUGH isolated mammalian remains of Sarmatian age have been known for some time from the Crimea, it was not till 1908 that a regular deposit of these was discovered, and this, too, in the very heart of Sebastopol itself during certain municipal works. The fauna, a part of which is described by Mr. A. Borissiak, with great wealth of illustration, in the *Mém. Com. Géol. St. Pétersbourg*, ser. 2, livr. lxxxvii., 1914, appears to show indications of affinity with the Pikermi fauna on one hand, and that of the Bugti Hill and Siwaliks on the other. An interesting item is a giraffe-like ruminant, regarded as representing a new genus and species, under the name of *Achtiaria expectans*.

THE fourth part of vol. viii. of Records of the Indian Museum contains seven articles, by as many writers, on the specimens of various groups of, for the most part invertebrate, animals collected during the Abor Expedition of 1911–12. Among these, it must suffice to refer to a preliminary note on certain groups of the Mollusca by Col. Godwin-Austen, who states that the collection as a whole "is one of the finest and most interesting from the eastern frontier I have ever looked over, containing as it does so many genera and new species, and so many that are quite distinct from land Mollusca at present known from the most western part of Assam." Descriptions of two new species appear in this part, and those of others are to follow.

MISSIONARIES and pioneer explorers of equatorial Africa long ago reported the finding of wild oranges and wild lemons; if the fruits were green, they resembled small limes and lemons, but if ripe their sweet flavour caused them to be classed as oranges. The plants yielding this fruit form the subject of an investigation by Mr. W. T. Swingle and Miss Maud Kellerman, of the United States Bureau of Plant Industry, which is published in No. 5 of vol. i. of the *Journal of Agricultural Research*. It is now clear that these plants have been wrongly classed in the Asiatic genus Limonia, and are more closely related to the Citrus; it is proposed to establish a new genus for these African oranges by raising to generic rank the section Citropsis of Engler. A detailed study is given of the different species of this genus. Interesting results have been obtained as regards the grafting and hybridisation of these plants, and an investigation is being made of their possible uses as a fruit. It is probable that Citropsis will show immunity to diseases and adaptations to soil and climate not possessed by the stocks upon which citrous fruits are usually grafted.

THE growing importance of the prickly pear pest in South Africa and Australia has given rise to a search for remedial measures, two of which, the one biological and the other chemical, are described in the March number of the Agricultural Journal of the

Union of South Africa. The first paper, by Dr. Ernest Warren, describes infection experiments with a species of cochineal insect (Green's *Coccus cacti*, var. *ceylonicus*) which showed that, of the two species of prickly pear common in South Africa, the long-spined *Opuntia monocantha* and the small-spined *O. tuna*, only the former succumbed to the attack of the insect, some substance probably being present in the sap of the latter which is injurious to the cochineal insect, since even a wounded surface is not attacked. The second paper, derived from the *Queenslander*, describes a method introduced by Mr. O. C. Roberts, in which treatment consists in the action of arsenious trichloride vapour, at the rate of three quarts of the compound per acre of bush. Up to the present this has only been tested on several hundred acres of land, but the results are said to be sufficiently promising to warrant much more extensive operations in the near future.

STUDENTS of palæobotany will note with pleasure a folio memoir in German on certain fossil calcareous algæ from Japan and China, by Dr. H. Yabe (Sci. Rep. Tôhoku Imp. University, Sendai, Japan, vol. i., No. 1). Only three species are described, but two represent new genera, Metasolenopora and Petrophyton, and the author's well-known care in microscopic details leads to their adequate illustration.

UNDER the title of "Les plus jeunes volcans de la France," Prof. Glangeaud, of Clermont-Ferrand, contributes a well-illustrated account of the chain of the Puys to the *Revue générale des Sciences*, 25e Année (1914), p. 50. The trachytic domes, which are more common in the Mont-d'Or region, are compared with those of the Montagne Pelée and Guadeloupe. Reyer's descriptions of those in Bohemia may provide, however, examples nearer home. A remarkable amount of modern information, including an explanation of the puzzling Puy Chopine, is compressed into this single article.

IN vol. xx. of the *Berichte der naturforschenden Gesellschaft zu Freiburg-im-Breisgau* (1913), W. Deecke discusses the frequent variation in type to be found in European sedimentary rocks of all ages, and concludes that deep marine basins and shallow waters lay side by side, and that the European area always showed, as now, an interlocking of sea and land. Continuous oceanic deposits seem wanting, and the acceptance of this view helps to account for the near association of different sedimentary facies, which other writers have ascribed to the importation of one type over another during lateral thrusting. It may be noted that the author regards the fucoids of the Alpine Flysch, not as algæ or worm-tubes (see NATURE, vol. lxxxv., p. 284), but as sponge-bodies indicative of deep water. In a later paper on "Die Bedeutung salzführender Schichten für tektonische Vorgänge," Deecke ascribes the anomalous position of some of the Alpine masses to gravitational slipping over Triassic strata, from which solution has removed sulphates and chlorides. Such solution takes place easily when the beds are lifted above the usual water-table and are exposed to free percolation, and the author asks for caution before the faulted relation of any overlying mass to its support is ascribed to overthrusting from a distant source. It will be seen that these two papers have a common philosophic aim.

THE Rev. H. V. Gill has sent us a reprint of his paper read at the last meeting of the British Association on the distribution of large earthquakes in time and space. Mr. Gill's theory is that a great mass-displacement of the crust, such as occurs during a violent earthquake, gives rise to a "wobble" or unevenness in the rotation of the earth, which is neutralised by other mass-displacements occurring either in a distant region or regions symmetrically placed along the great circle through the origin, or of displacements in the opposite direction in the neighbourhood of the origin. To test this view, he has examined the distribution of the 889 world-shaking earthquakes recorded by the seismological committee of the British Association. He finds that 674 (or three out of every four) great earthquakes occurred in groups, successive members of which were separated by a week or less, while the remaining 215 were isolated disturbances. Of the former, 163 (or 18·6 per cent. of the whole) belonged to groups of two or more earthquakes occurring at different places symmetrically situated with reference to the origin of the first earthquake of a group; 511 (or 57·1 per cent.) were members of groups occurring at or near the same place. No attempt, however, is made to show that the displacements of individual groups of the latter class occurred in opposite directions.

THE annual report of the Hampstead Scientific Society for 1913 naturally refers with gratification to the favourable reception which was accorded to the publication, "Hampstead Heath: its Geology and Natural History." The membership of the society has attained a "record figure" of 374, with a net increase of thirty for the year. The report contains brief notices of the many valuable papers which have been read to the society, and a summary of the meteorological statistics for the Hampstead Observatory for 1913. "The combination of meteorological circumstances in July was most unusual; coupled with a remarkable cloudiness of eighty-two and an extremely deficient sunshine of only 109 hours were a mean pressure of 30·087 in.—a figure some way in excess of the average—and a rainfall an eighth of an inch below the normal, falling on only eleven days." For the first time, average meteorological data are included in the report; this action marks the fact that the station has been at work for five years. From these preliminary averages it would appear that Hampstead is the coldest, rainiest, snowiest, and frostiest, as well as almost the sunniest and foggiest of the stations in the neighbourhood of London.

THE report of the Royal Prussian Meteorological Institute for the year 1913 (director, Prof. G. Hellmann) exhibits great activity in useful work, relating chiefly to land meteorology and special researches. Arrangements have been made for the preparation of an important work on the climate of Germany, and a special department has been created for the purpose. Among the researches made at the Potsdam Observatory may be mentioned the comparison of different sunshine recorders, and the investigation of unexplained differences which occasionally exist in the indications of ordinary and self-registering rain gauges. The report is accompanied, as in previous years, by several interesting scientific papers. One of these, by Dr. Hellmann, "On the determination of air temperature," bears particularly on the recent discussion on that subject in this country (NATURE, April 9, p. 143). Comparisons of readings in a "Stevenson" screen with those of an aspiration thermometer showed that on a sunny day the temperature by the latter might change more than 1° C. within a minute, while the readings in the screen are not so quickly affected by sudden changes. The results seem to indicate, as was also inferred by Dr. J. Aitken, that the screen readings give trustworthy mean values for short intervals (say two to three minutes); a closer agreement than this in the *time* of observing, as Dr. Hellmann remarks, can scarcely be expected.

A NEW form of Gauss's principle of least constraint forms the subject of a short note by Dr. H. Brell, of Graz, in the Vienna *Sitzungsberichte*, vol. cxxii., p. 7, in which the author obtains a single formula for Appell's equations.

AN addition to the numerous tables of logarithms and anti-logarithms that have been published by various writers for special purposes is the "Table auxiliaire d'Intérêts composés" of M. A. Trignart (Paris: Gauthier-Villars, 1914, price 2 francs). This table gives the various powers of the base, 1·0001, for all integral indices from 1 to 1000, for indices in "thousands" from 1000 to 100,000, and for the ten indices completing the range from 100,000 to 1,000,000. In the first two tables the anti-logarithms to this base are calculated to fifteen decimal places. Those in the third table are given to twenty significant figures. It will be observed that to all intents and purposes these anti-logarithms differ from those of the natural system of logarithms in that the fundamental base differs from unity by 1 in 10,000 instead of by an infinitesimal quantity; at the same time it would appear that a similar difference existed in the case of the original logarithms of Napier. The present table is obviously adapted to meet requirements of a special character, such as might perhaps occur in actuarial computations.

AMONG the reports of recent investigations at the Imperial Institute the first quarterly issue of vol. xii. (1914) of the Bulletin includes papers on the little-known economic products of Somaliland, and on the composition of monazite, which is used extensively in the manufacture of incandescent gas mantles. An illustrated article describes an important plant of rubber-testing machinery set up at the Institute for the purpose of carrying out a systematic investigation of samples of plantation Para rubber specially prepared in Ceylon in different ways, in order to secure accurate data for comparison. A note of agriculture in the Gold Coast states that the cultivation of cocoa is still being extended, and that the crop in 1913 was valued at nearly two and a half millions sterling. The interesting fact, probably not commonly known, is stated that more than one-third of the world's production of cocoa is produced under the British flag.

IN part vi. of the *Verhandlungen* of the German Physical Society Dr. F. A. Lindemann shows how the simple method of dimensions may be applied to the construction of atomic models which shall have many of the properties of the actual atoms. Taking the frequency of the electronic oscillations in such an atom to depend only on the distances between the negative and positive charges, the mass of the carriers of the charges, the force between the charges at unit distance apart, and on Planck's constant h, he shows that if the frequency is proportional to the nth power of the force, it must also be proportional to the $(n-1)$th power of the mass, the $(n-2)$th power of the distance and to the $(1-2n)$th power of h. Taking n in succession equal to 0, 1, and 2, he shows how far the model will represent the behaviour of an actual atom without further hypothesis, and what additional hypotheses must be brought in to reproduce given atomic properties. In this way he arrives at the relations previously given by Balmer, Moseley, Bohr, Gehrcke, and others, as holding for the actual atoms.

THE flow of sand and other fine materials through openings of various shapes and in different circumstances is not a subject which has received much attention from experimentalists, although it is of considerable practical importance. We welcome therefore the recent work of Prof. E. A. Hersam, of the University of California, on sands of various degrees of coarseness, on crushed slate, crushed shale, mustard seed, and lead shot. From Prof. Hersam's paper in the April number of the Journal of the Franklin Institute we gather that the following are his principal results. The velocity of flow is determined mainly by the size of the particles and of the opening, but is slightly diminished by angularity of the particles or by moisture on them. The specific gravity of the particles, the height of the material above the opening, and the shape of the upper contour of the material have little effect. If D is the diameter of the opening, d that of the particles, both in inches, the mean velocity of flow V in feet per second is given with sufficient accuracy for most practical purposes by the equation, $V=(D-2d)/\sqrt{D}$.

WE have received a report by Prof. Ph. A. Guye on the unification of the bibliographic abbreviations in chemical memoirs which was presented at the third session of the council of the "Association internationale des Sociétés chimiques," held at the Institut Solvay at Brussels in September, 1913. The author points out the inconvenience which arises from the same periodical being represented by several different abbreviations, and suggests that a uniform system should be adopted by scientific societies and by authors of chemical works. It appears there are only two systematic methods at present in use, namely, those of the International Catalogue of Scientific Literature and of the Concilium Bibliographicum de Zürich. Neither of these lists is complete, but the author is in favour of adopting the system of the International Catalogue, which is under the control of the Regional

Bureaus of twenty-six States and of five societies, and is therefore truly international. The International Catalogue has four regulations for the abbreviation of titles: (*a*) the abbreviated title must be intelligible without a key; (*b*) in the abbreviated title the words, whether entire or abbreviated, must follow each other in the same order as in the original title; (*c*) titles of proceedings, reports, or scientific periodicals in general which are edited or published by learned societies, academies, etc., must, however, begin with the name of the place where the society resides; (*d*) in the case of other periodicals the name of the town where they are edited follows the abbreviated title. The regulations of the Consilium Bibliographicum contain the first two rules of the International Catalogue, but the names of towns are used only when necessary to avoid confusion. It would be a great convenience to readers of chemical works if a uniform system could be adopted, and it is to be hoped that Guye's suggestions will be carried out.

Engineering for May 8 gives particulars of the arrangements made at the Royal Air-craft Factory, Farnborough, for the aeroplane engine competition instituted by the British Government, and now proceeding. The engines are to be of British manufacture throughout (magneto excepted), and in view of the successful performances of British aeroplanes fitted with foreign engines, it is satisfactory to note that there has been a good entry, and that a large number of engines has actually been delivered for test. The test-house has been arranged with six test-beds and friction brakes, each contained in a separate cubicle, and supplied with a wind current of sixty miles an hour. The brakes are the latest pattern of Heenan and Froude's water dynamometer. The War Office proposes to publish a report at the conclusion of the trials.

THE new Cunard liner *Aquitania* was towed successfully from the Clydebank yard of Messrs. John Brown and Co., Ltd., to Greenock on Sunday, May 10. After her trial trips this week, she will proceed to Liverpool to be prepared for her maiden voyage to New York on May 30. *Engineering* for May 8 contains an illustrated article dealing with the propelling machinery of this ship. There are twenty-one cylindrical double-ended boilers, each having eight furnaces. The turbine machinery driving the four propeller shafts has been arranged to work on the triple system. The high-pressure ahead turbine, which, along with a high-pressure astern turbine, occupies a separate compartment on the port-wing turbine-room, receives boiler steam direct, which is passed in turn to the intermediate-pressure turbine, occupying, along with a high-pressure astern turbine, a similar compartment on the starboard wing. Two low-pressure ahead turbines on the two inner shafts receive their steam from the intermediate-pressure turbine. Some idea of the enormous size of these turbines may be obtained from the diameter of 15 ft. 4 in. over the tips of the blades of the low-pressure turbine. The combined weight of the low-pressure ahead and astern turbines on one shaft is 445 tons.

OUR ASTRONOMICAL COLUMN.

A REGISTERING MICROPHOTOMETER.—In 1912 Dr P. Paul Koch described a registering microphotometer designed by himself; the apparatus records photographically the varying intensities of a series of objects such as the lines in a spectrum or a set of interference rings and show their distance apart. The principle involved is to move the negative to be measured slowly in front of an opening through which a beam of light from a constant source is passed, and the resulting changes in the intensity of this light are recorded on a moving photographic plate. Dr. Koch now describes (Contributions from the Mount Wilson Solar Observatory, No. 77) an application of this instrument to the study of certain types of laboratory spectra, and displays in diagrams the resulting curves obtained. Thus, there are types of curves for furnace lines for different temperatures, for lines displaced by pressure, reversed lines, tube-arc lines, etc. While the observations described are stated to be only preliminary and very limited in scope, they are sufficient to indicate the usefulness of the instrument in those branches of spectroscopy in which it is desired to investigate quantitatively measures of line-intensity and structure.

VARIABLE STAR OBSERVATIONS.—No. iii. of the Publications of the Vassar College Observatory contains a most useful series of variable star observations made during the period 1901 to 1912, totalling in all 4797 observations. In the publication two points in particular have been aimed at, namely, first to reduce all magnitudes to a uniform standard, that of the Harvard photometry; and secondly, to give the original observations with the exact identification of the companion stars, in order that they may be reduced to any other desired photometric scale. In the introductory remarks, written by the present director, Caroline E. Furness, a detailed account is given of the instruments used, methods of observation employed, etc. Table I., which occupies the greater portion of the publication, gives the details of the observation of each variable; Table II. deals with some photometric observations; Table III. gives the magnitude on the Harvard photometric scale for every tenth grade of the Hagen, while the observed maxima and minima are compared with the ephemeris in Table IV.

ENHANCED MANGANESE LINES AND α ANDROMEDÆ.—The spectrum of α Andromedæ displays peculiarities which have rendered it difficult to couple it up with other stars in stellar classifications. Both the Harvard and the South Kensington classifications have indicated this star as an anomaly. The lines which are responsible for this peculiarity have now been run to earth by Mr. F. E. Baxandall, and he finds that in the main they are due to a form of manganese known as proto-manganese (Monthly Notices R.A.S., vol. 74, No. iii., p. 250). In his paper, Mr. Baxandall publishes three independent sets of measures of the stellar lines, and he states that while there is no proto manganese line which does not agree in position—within the limits of error in measurement—with an α Andromedæ line, this long succession of close agreements leaves little or no doubt that the two sets are identical. Attention is directed to the interesting fact that while in α Cygni and α Canis Majoris the enhanced lines of iron, chromium, and titanium are strongly shown, and the proto-manganese lines are comparatively weak or lacking, on the other hand, in α Andromedæ the case is the opposite. It will thus be seen that important criteria are being accumulated to help in the task of stellar classification, a former prominent case of another proto-substance being that of chromium in the spectrum of ϵ Ursæ Majoris shown at South Kensington.

THE CARNEGIE TRUST.[1]

THE Carnegie Trust for the Universities of Scotland has been in operation for twelve years, and it is now possible to draw some general conclusions as to the success which has attended its working. No other scheme for the endowment of higher education and research in this country has been planned on such a large scale as that indicated in the present report and its predecessors, and the progress of an experiment of such magnitude has been followed with interest by all who have to do with University affairs.

The financial statement for the year 1912–13 shows that the annual income of the trust amounts to rather more than 100,000*l*., and after defraying the expenses of administration there is left about 99,000*l*. as the net revenue available for distribution under the two main heads of the scheme. Half of this sum is earmarked annually for the payment of students' fees, while the other moiety is devoted (*a*) to the better equipment of the Scottish universities and colleges by the foundation of additional chairs and lectureships, and by the provision of new laboratories and permanent equipment, and (*b*) to the endowment of research. Of course, the equipment section of the expenditure also plays its part in the advancement of research work, as it furnishes places in which investigations can be carried on and also helps to provide posts for men who become directors of research in their various departments. It will be seen that the operations of the trustees are financially on a grand scale; for the funds at their disposal annually represent a sum equivalent to about 60 per cent. of the total Government grant in support of the higher educational institutions in England and Wales.

In the allocation of the funds, the trustees have been guided by two main considerations. First, they decided that their assistance to the four universities and their kindred colleges should be given under a quinquennial scheme, so that each step forward has been based upon the allocation of approximately half a million sterling. Secondly, a general rule was laid down that the trust would not hamper its income by paying salaries for new posts year by year out of the annual revenue, but instead, any new chair or lectureship is endowed fully at the start, so that its subsequent career entails no further draft upon the funds of the trustees. In this way, each chair on its foundation disappears from the books of the trust, and the next quinquennial distribution can be devoted to entirely fresh needs.

Any visitor to the Scottish universities in recent years must have been struck by the progress which has been made in the provision of new laboratories and departments of all kinds; buildings have sprung up until the older part of the fabric appears to be lost in the new. But buildings alone are of little value, and the influence of the trust is equally marked in the large increases of staff which have been rendered possible.

These, however, though they represent the major part of the trust's expenditure, are by no means the most striking monument which the trustees have raised, for their endowment of research and post-graduate study has been on an equally far-reaching scale. A system of scholarships and fellowships has been founded, which is supplemented by a series of grants in aid of research to Scottish graduates resident in Scotland; and this part of the trust's work has been of equal, if not greater, importance to the Scottish university system. Thus from the time a student enters the University to the day he leaves Scotland he finds a helping hand extended to him should he wish to grasp it.

[1] Twelfth Annual Report of the Carnegie Trust for the Universities of Scotland, 1912–13.

During his undergraduate career, he may obtain payment of his university fees; later, he may aspire to carry out researches, in which case he may apply for a scholarship or a fellowship. The research scholarships are conferred upon students on the recommendation of experts—usually the persons under whom the beginner in research will have to take his first steps in original work. Research fellowships are meant for men who have already accomplished something, and they are allocated on the merits of the work which the candidate has already published. In neither case is there any competitive examination, nor do the trustees bind themselves to furnish a fixed number of scholarships or fellowships in a given year. This is one of the most desirable features of their policy; for, as any teacher knows, an institution may turn out, say twenty first-class men in a given year, whilst in the following year only one or two may appear, so that the granting of a fixed number of scholarships per annum simply means that in some years a first-class man may not secure an appointment to a scholarship which in the following year will fall to the lot of a much inferior man owing to there being a dearth of candidates. It should be pointed out that the trustees retain all these appointments in their own hands, so that graduates of all the four universities are dealt with on equal terms. The scholarships are of the value of 100*l*. per annum, and are tenable for one year with a possibility of extension or of the holder's promotion to a fellowship; the fellowships are of the value of 150*l*. per annum, and are normally tenable for two years, though further renewals are possible.

The facts given in the report with regard to the subsequent careers of scholars and fellows go to prove that the research training they have undergone has fitted these men for the most varied appointments; and it must be remembered that the actual output of research work during the tenure of a scholarship or fellowship is not by any means the full index of the success of the scheme. Most of the men continue their investigations after they have severed their actual connection with the trust, and their later work must to some extent be placed to the credit of the trustees.

The impetus to research which has been produced by the work of the trust can be gauged from an example chosen from one science, chemistry. In the eight years 1903–11, the trust appointed in this department forty-five scholars, twenty-five fellows, and thirty-one grantees. The work of these has resulted in the publication of more than 130 original communications to scientific journals. Now, in 1912, the contributions of the whole British chemical world to the Transactions of the Chemical Society amounted to only double this number, 266, so that it is evident that the Carnegie Trust, by its encouragement of research, has indirectly in the course of eight years produced a series of results equal to half the annual output of the whole Empire at the present time. This, it must be remembered, represents only a single department of the trust's activities; for, in addition to chemistry, work is being carried out in physics, biology, medicine, economics, history, and languages.

One final point deserves note. In dealing with a machine of this magnitude, it is, of course, impossible to proceed without laying down some general rules; but the Carnegie Trustees have hitherto avoided the pitfall of too great rigidity, and the flexibility of their system is one of its most valuable features. There can be no doubt that Dr. Andrew Carnegie's experiment has resulted in brilliant success in the development of the research talent of his native country.

A. W. S.

LAWS OF ATMOSPHERIC MOVEMENTS.[1]

THE motion of the upper layers of the atmosphere is discussed in these two papers by Dr. W. N. Shaw, recently published. It is difficult in a short space to give a clear idea of the conclusions reached, but some of the main points may be here summarised.

In the paper published by the Scottish Meteorological Society it is shown that if p denote the pressure in millibars, and θ the absolute temperature (C.), and Δp and $\Delta\theta$ the changes that occur in passing horizontally from one place to another, then the rate of increase of pressure difference in millibars per metre of height is $0{\cdot}0342\ p/\theta\ (\Delta\theta/\theta - \Delta p/p)$. It is then shown that from about 1 km. to 9 km. the values of $\Delta\theta$ and Δp have in general the same sign, so that the term in brackets is small, and hence pressure differences, *i.e.* the barometric gradient, are maintained without much alteration up to 9 km. Above 10 or 11 km. $\Delta\theta$ and Δp have in general a different sign and the magnitude of the gradient rapidly falls off. The effect upon the wind at various altitudes is then considered, and special cases where simultaneous observations over England, Scotland, and Ireland are available are taken.

In the paper published by the Royal Society of Edinburgh, Dr. Shaw gives five axioms or laws of atmospheric motion, two lemmas or postulates, and six propositions. His first law reads thus:—

"In the upper layers of the atmosphere the steady horizontal motion of the air at any level is along the horizontal section of the isobaric surfaces at that level, and the velocity is inversely proportional to the separation of the isobaric lines in the level of the section."

The whole discussion turns upon the truth of this law, and Dr. Shaw confesses that observation is at present incapable of proving or of disproving it. There can be very little doubt that it is approximately true, for except near the equator pressure differences come into existence and persist for days or even weeks. These differences could not continue even for an hour if there were not some compensating horizontal acceleration acting on the air from the low towards the high pressure, for otherwise the inevitable rule which makes the surface of a liquid horizontal would come into play, and a depression would be filled up almost as soon as it was formed. Some opposing acceleration must therefore act whenever and wherever there is a barometric gradient, and we can conceive of no other possible source of this acceleration save that given in law I. But in the upper strata there must be a certain small amount of flow outward across the isobars from low to high pressure to compensate for the inverse flow that occurs close to the earth, where frictional resistances prevent the requisite velocity along the isobars from being attained. The other laws and the two lemmas will probably be accepted with the small reservations given by the author without demur.

The propositions follow from the laws and postulates. They are of great interest, but are too long to be quoted here. It will suffice to say that Dr. Shaw finds that a current flowing east or west will be stable, but a current flowing north or south is more or less unstable, and must lose or gain air as it goes. Also his suggestion about the flow of air up or down the land slopes from the interior of the continents to the sea is very pertinent, and, to my mind, affords a better explanation of the winter anticyclone over Asia and North America than that commonly given.

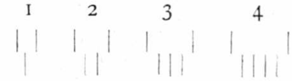
W. H. DINES.

[1] (1) "Upper Air Calculus and the British Soundings during the International Week (May 5–10), 1913." From the Journal of the Scottish Meteorological Society. Third series. Vol. xvi. No. xxx.
(2) "Principia Atmospherica: a Study of the Circulation of the Atmosphere." (Proc. Roy. Soc. Edin., vol. xxxiv., 1914, pp. 77–112).

AN ELECTRICAL ANALOGY OF THE ZEEMAN EFFECT.

THE discovery, announced by J. Stark in NATURE of December 4, 1913, that when hydrogen in a state of luminescence is placed in an electric field of suitable strength and direction, the spectral lines are resolved into three or more components, is evidently a fact of prime physical importance. It will place in the hands of physicists another method of investigating the internal structure of the atom, and, in conjunction with the Zeeman effect, will no doubt be of immense service in the discovery of further regularities in spectral series, and in the attempts now being made by Bohr, Nicholson, and others to explain the origin of spectra on a dynamical basis. In this connection a series of papers in the *Rendiconti della R. Accad. dei Lincei* by Garbasso, Lo Surdo, and Puccianti will be of great interest to readers of NATURE.

The effect appears to have been observed independently by Lo Surdo whilst working on the retrograde positive rays in the neighbourhood of the kathode. An account of his first observations is given in a paper read on December 21, 1913. A cylindrical tube 20 cm. long and 4 mm. in diameter was used. It carried disc electrodes which completely filled the section, and it was excited by means of an accumulator battery. In these circumstances it was found that the electric field in the Crookes dark space was of itself sufficient to produce resolution of the lines. The observations were made with a four-prism quartz spectrograph. By suitable modifications the tube was varied so that the line of sight was either along or perpendicular to the field. The two outer components are polarised with the electric vector parallel to the field, the remainder in a perpendicular plane. When observations are made along the lines of force the outer components are missing. In a later paper, using a tube 1·5 mm. in diameter, Puccianti finds that the effect can readily be seen in the well-known Hilger wave-length spectroscope with constant deviation prism. The lines of the hydrogen spectrum show an interesting series of regularities; these are displayed in the following table (after Lo Surdo). Writing the Balmer formula in the form, $1/\lambda = a - 4a/n^2$, n has the values 3, 4, etc., for the different lines.

	H	H_β	H_γ	H_δ
n	3	4	5	6
Total no. of components	3	4	5	6
Order of line in the series	1st	2nd	3rd	4th
Component with electric vector ⊥ to the field...	1	2	3	4
Appearance of resolved lines[1]				

It is seen that the number of components in a given line is the same as the corresponding value of n in the Balmer formula, and that the number of internal components is the same as the order of the given line in the spectral series. According to the measurements of Puccianti the separation of the outer components for H_β and H_α are in the ratio 1·49, or, expressed as fractions of the corresponding wave-lengths,

$$\frac{\delta_\beta}{\lambda_\beta} \Big/ \frac{\delta_\alpha}{\lambda_\alpha} = 2{\cdot}01$$

In a paper of December 21, 1913, Garbasso discusses the matter theoretically, to arrive at the conclusion that the Thomson model atom is incapable of explaining the (earlier) observations, except by the introduction of improbable hypotheses.

R. S. W.

[1] The components placed above have the vector parallel to the field.

*RELATIONS BETWEEN THE SPECTRA AND OTHER CHARACTERISTICS OF THE STARS.**

III.

TO proceed farther we must have recourse to the study of eclipsing variable stars. Methods for computing their orbits have been developed at Princeton during the last few years,[20] the main motive for the investigation being the astrophysical importance of the results. Dr. Shapley, using the methods devised by the speaker, has obtained elements for eighty-seven such systems,[21] for each one of which the density of the components may be calculated. The values here employed are those which result from the assumption that the stars present discs darkened toward the edge, like the sun, but to a still higher degree, and the principal uncertainty of the results (which in any case cannot be very serious) arises from our present ignorance of the actual degree of this darkening. For our present purpose, they may be best utilised by computing the absolute magnitudes which the brighter component of each system would have if its mass and surface brightness were equal to those of the sun, leaving outstanding the differences due to density alone.

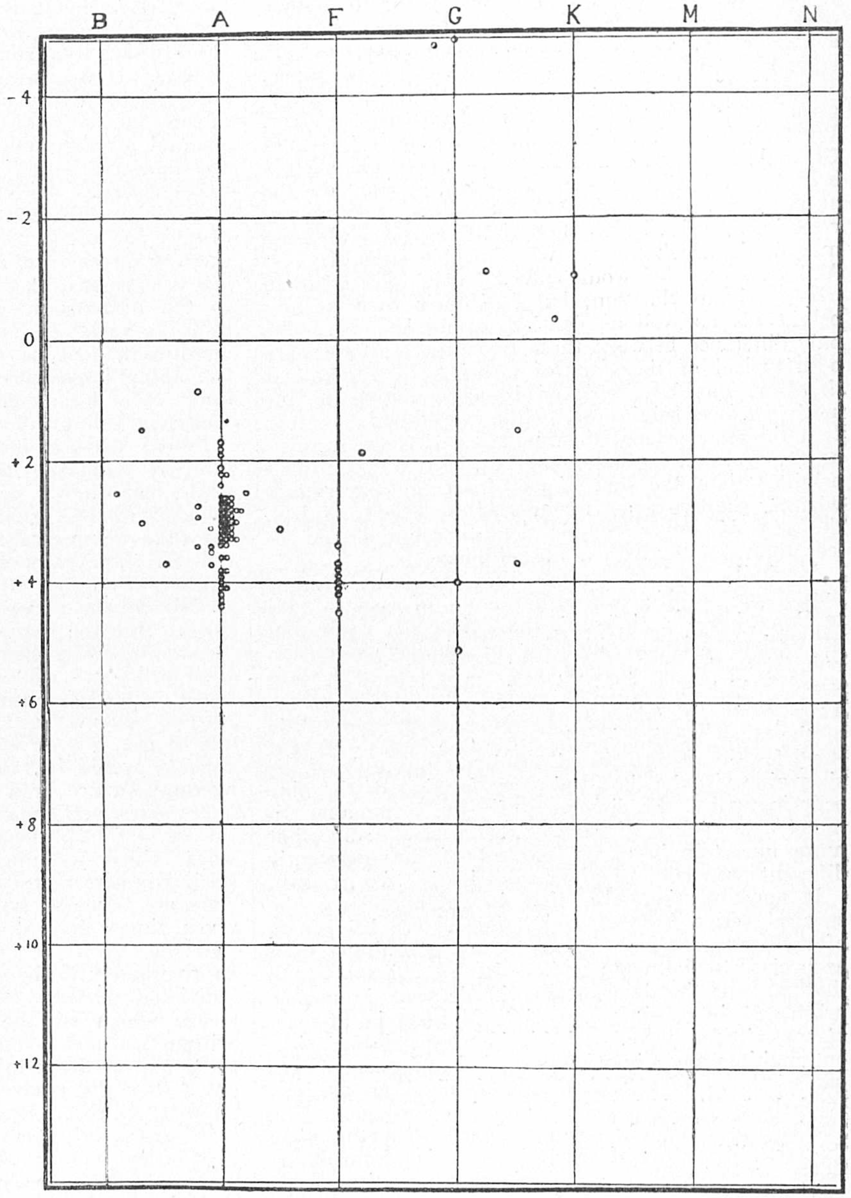


FIG. 4.

The results for the eighty eclipsing variable the elements and spectra of which are known are plotted in Fig. 4, on the same system as in the preceding figures. The black dots represent those stars for which the photometric data are most trustworthy, the open circles those of less precision. We are once more greatly indebted to Prof. Pickering and Miss Cannon for information regarding the spectra of these stars. To the absolute magnitude 4·0 on this diagram corresponds a density 1/3 that of the sun; to 3·0, 1/11; to 2·0, 1/45; to 1·0, 1/180 of the sun's density, and so on.

This diagram bears at first sight but small resemblance to the previous ones, but a little study brings out several important things. First, though the majority of these eclipsing variables are of Class A, every class from B to K is represented, and there are eight stars of Class G or redder. Secondly, all but one of these eighty stars are less dense than the sun, though but few of them are of less than 1/100 the sun's density. Thirdly, the stars of Classes A and B are fairly similar to one another in density, the great majority having densities between 1/3 and 1/45 of the sun's; those of Class F show a compact group of high density, and an isolated star of low density; but in Classes G and K the range of density is enormously great—from nearly twice that of the sun (W Ursæ Majoris) to one-millionth of the sun's density (W Crucis, at the top of the diagram). Fourthly, among the stars of density less than 1/200 that of the sun (corresponding to about +1·0m. on the diagram), only one of the seventy-one stars of Classes B to F appears, while four of the eight stars

* An address delivered before a joint meeting of the Astronomical and Astrophysical Society of America and Section A of the American Association for the Advancement of Science, at Atlanta, Georgia, December 30, 1913, with a few additions, by Prof. H. N. Russell. Continued from p. 258.

[20] *Astrophys Jour.*, vol. xxxv., p. 315, and vol. xxxvi., pp. 54, 239, 385, 1912.

[21] *Astrophys. Jour.*, vol. xxxviii., pp. 159–73, 1913.

of Classes G and K are included. We may now answer decisively, and in the affirmative, the first two questions which were put a few moments ago. Some stars actually have densities quite as low as any that might be required to explain the great brightness of the reddest giant stars; and these stars of low density show a very marked preference for the "later" spectral classes, while practically all the stars of "earlier" type are far denser.

We can answer the third question as well, and in a quantitative fashion, if we are willing to assume that the eclipsing binaries, and also the telescopic double stars, of the various spectral classes are typical of the stars of these classes as a whole. Though this may not be rigorously true, there is good reason to believe that it is not seriously in error. We find, from Fig. 4, that the fifty eclipsing stars of Class A, if they all had the sun's mass and surface brightness, but their own densities, would, on the average, be of the absolute magnitude 3·06. Now, referring to Fig. 3, we find that the mean absolute magnitude which the 115 visual double stars of Class AO there recorded would have, if they were equal in mass only to the sun, but had their own surface brightness as well as density, would be 1·07. The only difference between these two groups (if they are both typical of the stars of Class A in general) is that one has been reduced by computation to the sun's surface brightness, while the other has not. It is therefore evident that the stars of Class A must, on the average, for equal surfaces, be two magnitudes brighter than the sun. Apart from the uncertainty whether the two groups compared are exactly typical, the probable error of this determination should be less than one-tenth of a magnitude.

In similar fashion, we find that the mean absolute magnitude of fifty-two visual pairs of spectra Oe5 to B9, reduced to the sun's mass, is −0·4, while that of twelve eclipsing binaries of similar spectrum, reduced to the sun's mass, and surface brightness, is +2·8, which makes the surface brightness of an average star of Class B greater by 3·2m. than that of the sun. Again, for the stars of Class F, we get +2·6 for the mean reduced absolute magnitude of the sixty-nine visual pairs, and +3·7 for that of the nine eclipsing pairs, the difference of 1·1m. being approximately the effect of surface brightness (somewhat more uncertain here, on account of the apparently different proportion of giant stars in the two groups).

It appears, therefore, that in passing down the spectral series from B to G, the surface brightness of the stars decreases by about one magnitude from each class to the next; and we have previously found that, among the dwarf stars, the decrease in surface brightness in passing from G to M must be at least 2½ magnitudes more. All this has been shown without making any use whatever of the physical meaning of the spectra, which have simply been used as symbols in classifying the stars into groups. The results are obviously in accordance with the view that the differences of spectral type arise from differences of temperature. Indeed, they constitute new and important evidence in its favour. How well they agree with other independent lines of evidence is shown by comparing the relative surface brightness just computed with the colour-index for the various classes. Taking A as a standard, we have:—

Spectrum	B	A	F	G	K	M
Surface brightness	−1·2	0·0	+0·9	+2·0	—	+4·5 (at least)
Colour-index ...	−0·3	0·0	+0·3	+0·7	+1·2	+1·6

The computed differences in surface brightness are in all cases about three times the colour-indices, in good agreement with the theoretical ratio.

We may now estimate the density of the redder giant stars. It appears from Fig. 3 that the mean absolute magnitude of the giant stars, if reduced to the sun's mass, is +0·6 for Class G, +0·5 for Class K, and 0·0 for Classes K5 and M. The differences between these values are small, and we may well take the general mean, +0·44, as typical of the whole. This corresponds to about fifty times the sun's luminosity. Such a giant star of Class G, if of the sun's surface brightness, would have to be of about seven times the sun's radius, and of 1/350 of its density. If we assume, on the basis of the foregoing study of the dwarf stars, that the surface intensities of the giant stars of Classes K and M are respectively 1·5 and 3 magnitudes fainter than that of the sun, we find that their densities must be 1/2800 and 1/25,000 of the sun's density. The observed densities of several eclipsing variables of Classes G and K are of just the order of magnitude here found, so that there is direct observational evidence in favour of all our conclusions, except the very low density assigned to the giant stars of Class M (among which no eclipsing variables have yet been found, so that their densities cannot be directly determined). But there is nothing improbable about so low a density, for we know of at least one star—W Crucis—the density of which is still smaller.

Before leaving these diagrams we should notice that, by comparing the data of Fig. 3 with those of Figs. 1 and 2, we may obtain the average masses of the stars of the various types. Consider, for example, the stars of spectra B to B5. From Fig. 3 we see that, if these stars were reduced to the sun's mass without changing either their surface brightness or density, their mean absolute magnitude would be −0·6. But the actual mean absolute magnitude of the stars of this spectral class is −2·0 according to Campbell, or −0·8 according to Boss. Taking the mean of these determinations, we find that these stars are, on the average, 2·1 times as bright as stars of unit mass, but of the same surface brightness and density, would be, from which it follows that their average surface area must be 2·1 times that of the latter stars, and their average mass 3·0 times that of the sun. The uncertainty whether the groups of stars which we are comparing are really exactly similar is here more serious than usual; if Campbell's stars are taken as typical, the mean mass comes out seven times that of the sun. It should be noticed that the "average" mass here obtained corresponds approximately to the average of the logarithms of the individual masses, and hence to their geometrical mean, which will be somewhat smaller than their arithmetical mean, and that we are here dealing with the mass of the brighter component of each system only. For the twelve spectroscopic binaries of spectrum B, which are available for comparison, the mean mass of the brighter components is about 9, and the geometrical mean probably about 7·5, times the sun's mass. As the observational selection in this case undoubtedly favours the larger masses, there is no serious discrepancy between the two results.

Proceeding similarly for the stars of the other spectral classes, we obtain the results collected in Table VII. The observed absolute magnitudes of the stars in clusters have been taken in preference to those of the stars of directly measured parallax, for the reasons already stated, and for the giant stars the mean of the results of Boss and Campbell has been used (except for Class G, for which Boss's value alone really represents them).

TABLE VII.

Mean Masses of Bright Components of Double Stars.

Spectrum	Observed absolute mag.	Abs. mag. reduced to sun's mass	Resulting average mass
B2	−1·4	−0·6	3·0
Ao	+0·5	+1·1	2·3
A5, dwarf	+1·5	+1·6	1·2
Fo ,, ...	+2·4	+2·8	1·7
F3 ,, ...	+3·3	+3·1	0·8
F8 and Go ...	+4·8	+4·0	0·5
G5, dwarf	+5·1	+4·2	0·3
Ko ,, ...	+6·4	+5·5	0·3
K5 and M, dwarf	+8·9	+7·7	0·2
G and G5, giant	−0·2	+0·6	3·0
Ko, giant ...	+0·2	+0·5	1·5
K5 and M, giant	−0·3	0·0	1·5

The general similarity in mass among the stars of such widely different characteristics is very striking. In view of the small numbers of stars in some of the groups, the differences between the individual values should not be greatly stressed, but the gradual decrease of average mass among the dwarf stars is in accordance with the results of direct measurement. The geometrical mean of the computed masses of the bright components of the eight visual binaries of spectra A to F5, the parallaxes of which have been determined with tolerable accuracy, is 1·8 times the sun's mass; for the ten similar stars of spectra F8 to K it is 0·8. The greater mass of the stars of Class B is scarcely shown by these figures, but on this matter the testimony of the spectroscopic binaries deserves much the greater weight. The important conclusion which may be drawn from Table VII. is that, although the range in mean luminosity among the various groups of stars exceeds ten-thousandfold, the range in the mean masses probably does not exceed twenty-, or at most thirty-fold.

We may now summarise the facts which have been brought to light, as follows:—

(1) The differences in brightness between the stars of different spectral classes, and between the giant and dwarf stars of the same class, do not arise (directly at least) from differences in mass. Indeed, the mean masses of the various groups of stars are extraordinarily similar.

(2) The surface brightness of the stars diminishes rapidly with increasing redness, changing by about three times the difference in colour-index, or rather more than one magnitude, from each class to the next.

(3) The mean density of the stars of Classes B and A is a little more than one-tenth that of the sun. The densities of the dwarf stars increase with increasing redness from this value through that of the sun to a limit which cannot at present be exactly defined. This increase in density, together with the diminution in surface brightness, accounts for the rapid fall in luminosity with increasing redness among these stars.

(4) The mean densities of the giant stars diminish rapidly with increasing redness, from one-tenth that of the sun for Class A to less than one twenty-thousandth that of the sun for Class M. This counteracts the change in surface brightness, and explains the approximate equality in luminosity of all these stars.

(5) The actual existence of stars of spectra G and K, the densities of which are of the order here derived, is proved by several examples among the eclipsing variables, all of which are far less dense than any one of the more numerous eclipsing stars of "early" spectral type, with the sole exception of β Lyræ.

Evolution.

These facts have evidently a decided bearing on the problem of stellar evolution, and I will ask your indulgence during the few minutes which remain for an outline of the theory of development to which it appears to me that they must inevitably lead.

Of all the propositions, more or less debatable, which may be made regarding stellar evolution, there is probably none that would command more general acceptance than this—that as a star grows older it contracts. Indeed, since contraction converts potential energy of gravitation into heat, which is transferred by radiation to cooler bodies, it appears from thermodynamic principles that the general trend of change must, in the long run, be in this direction. It is conceivable that at some particular epoch in a star's history there might be so rapid an evolution of energy—for example, of a radio-active nature—that it temporarily surpassed the loss by radiation and led to an expansion against gravity; but this would be, at most, a passing stage in its career, and it would still be true in the long run that the order of increasing density is the order of advancing evolution.

If, now, we arrange the stars which we have been studying in such an order, we must begin with the giant stars of Class M, follow the series of giant stars, in the reverse order from that in which the spectra are usually placed, up to A and B, and then, still with increasing density, though at a slower rate, proceed down the series of dwarf stars, in the usual order of the spectral classes, past the sun, to those red stars (again of Class M), which are the faintest at present known. There can be no doubt at all that this is the order of increasing density; if it is also the order of advancing age, we are led at once back to Lockyer's hypothesis that a star is hottest near the middle of its history, and that the redder stars fall into two groups, one of rising and the other of falling temperature.[22] The giant stars then represent successive stages in the heating up of a body, and must be more primitive the redder they are; the dwarf stars represent successive stages in its later cooling, and the reddest of these are the farthest advanced. We have no longer two separate series to deal with, but a single one, beginning and ending with Class M, and with Class B in the middle, all the intervening classes being represented, in inverse order, in each half of the sequence.

The great majority of the stars visible to the naked eye, except perhaps in Class F, are giants; hence for most of these stars the order of evolution is the reverse of that now generally assumed, and the terms "early" and "late" applied to the corresponding spectral types are actually misleading.

This is a revolutionary conclusion; but, so far as I can see, we are simply shut up to it, with no reasonable escape. If stars of the type of Capella, γ Andromedæ, and Antares represent later stages of development of bodies such as δ Orionis, α Virginis and Algol, we must admit that, as they grew older and lost energy, they have expanded, in the teeth of gravitation, to many times their original diameters, and have diminished many hundred-, or even thousand-fold in density. For the same reason we cannot regard the giant stars of Class K as later stages of those of Class G, or those of Class M as later stages of either of the others, unless we are ready to admit that they have expanded against gravity in a similar fashion. We may, of course, take refuge in the belief that the giant stars of the

22 Phil. Trans., vol. clxxxiv., p. 688, 1902; Proc. Roy. Soc., vol. lxv., p. 186, 1899.

various spectral classes have no genetic relations with one another—that no one class among them represents any stage in the evolution of stars like any of the others—but this is to deny the possibility of forming any general scheme of evolution at all.

We might be driven to some such counsel of despair if the scheme suggested by the observed facts should prove physically impossible; but, as a matter of fact, it is in conspicuous agreement with the conclusions which may be reached directly from elementary and very probable physical considerations.

There can be very little doubt that the stars, in general, are masses of gas, and that the great majority of them, at least, are at any given moment very approximately in stable internal equilibrium under the influence of their own gravitation, and very nearly in a steady state as regards the production and radiation of heat, but are slowly contracting on account of their loss of energy. Much has been written upon the behaviour of such a mass of gas by Lane, Ritter, and several later investigators,[23] and many of their conclusions are well established and well known. So long as the density of the gaseous mass remains so low that the ordinary "gas laws" represent its behaviour with tolerable accuracy, and so long as it remains built upon the same model (*i.e.*, so long as the density and temperature at geometrically homologous points vary proportionally to the central density or temperature), the central temperature (and hence that at any series of homologous points) will vary inversely as the radius. This is often called Lane's law. If, after the contraction, the star is built only approximately on the same model as before, this law will be approximately, but not exactly, true.

The temperature of the layers from which the bulk of the emitted radiation comes will also rise as the star contracts, but more slowly, since the increase in density will make the gas effectively opaque in a layer the thickness of which is an ever-decreasing fraction of the radius. The temperature of the outer, nearly transparent gases, in which the line absorption takes place, will be determined almost entirely by the energy density of the flux of radiation through them from the layers below—that is, by the "black-body" temperature corresponding to this radiation as observed at a distance.

As the gaseous mass slowly loses energy and contracts, its effective temperature will rise, its light will grow whiter, and its surface brightness increase, while corresponding modifications will occur in the line absorption in its spectrum. Meanwhile, its diameter and surface will diminish, and this will at least partially counteract the influence of the increased surface brightness, and may even overbalance it. It cannot therefore be stated, without further knowledge, in which direction the whole amount of light emitted by the body will change.

This process will go on until the gas reaches such a density that the departures of its behaviour from the simple laws which hold true for a perfect gas become important. Such a density will be first reached at the centre of the mass. At the high temperatures with which we are dealing, the principal departure from the simple gas laws will be that the gas becomes more difficultly compressible, so that a smaller rise in temperature than that demanded by the elementary theory will suffice to preserve equilibrium after further contraction. The rise in temperature will therefore slacken, and finally cease, first at the centre, and later in the outer layers. Further contraction will only be possible if accompanied by a fall of temperature, and the heat expended in warming the mass during the earlier stages will now be gradually transmitted to the surface and liberated by radiation, along with that generated by the contraction. During this stage, the behaviour of the mass will resemble, roughly, that of a cooling solid body, though the rate of decrease of temperature will be far slower. The diameter and surface brightness will now both diminish, and the luminosity of the mass will fall off very rapidly as its light grows redder. It will always be much less than the luminosity of the body when it reached the same temperature while growing hotter, on account of the contraction which has taken place in the interval, and this difference of luminosity will be greater the lower the temperature selected for the comparison. Sooner or later, the mass must liquefy, and then solidify (if of composition similar to the stellar atmospheres), and at the end it will be cold and dark; but these changes will not begin, except perhaps for a few minor constituents of very high boiling point, until the surface temperature has fallen far below that of the stars of Class M (about 3000° C.).

The "critical density" at which the rise of temperature will cease can only be roughly estimated. It must certainly be much greater than that of ordinary air, and (at least for substances of moderate molecular weight), considerably less than that of water. Lord Kelvin,[24] a few years ago, expressed his agreement with a statement of Prof. Perry's that "speculation on this basis of perfectly gaseous stuff ought to cease when the density of the gas at the centre of the star approaches one-tenth of the density of ordinary water in the laboratory."

It is clear from the context that this refers rather to the beginning of sensible departures from Lane's law than to the actual attainment of the maximum temperature, which would come later; and it seems probable, from the considerations already mentioned, that the maximum temperature of the surface would be attained at a somewhat higher density than the maximum central temperature.

The resemblance between the characteristics that might thus be theoretically anticipated in a mass of gas of stellar dimensions, during the course of its contraction, and the actual characteristics of the series of giant and dwarf stars of the various spectral classes is so close that it might fairly be described as identical. The compensating influences of variations in density and surface brightness, which keep all the giant stars nearly equal in luminosity, the rapid fall of brightness among the dwarf stars, and the ever-increasing difference between the two classes, with increasing redness, are all just what might be expected. More striking still is the entire agreement between the actual densities of the stars of the various sorts and those estimated for bodies in the different stages of development, on the basis of the general properties of gaseous matter. The densities found observationally for the giant stars of Classes G to M are such that Lane's law must apply to them, and they must grow hotter if they contract; that of the sun (a typical dwarf star) is so high that the reverse must almost certainly be true; and the mean density of the stars of Classes B and A (about one-ninth that of the sun, or one-sixth that of water) is just of the order of magnitude at which a contracting mass of gas might be expected to reach its highest surface temperature.

We may carry our reasoning farther. Another deduction from the elementary theory (as easily proved as Lane's law, but less generally known) is that, in two masses of perfect gas, similarly constituted and of equal radius, the temperatures at homologous points are directly proportional to their masses. As in the previous case, the effective surface temperature of the

23 An excellent summary may be found in Emden's *Gaskugeln*.

24 NATURE, vol. lxxv., p. 368, 1907.

more massive body will be the greater, though to a less degree than the central temperature. A large mass of gas will therefore arrive at a higher maximum temperature, upon reaching its critical density, than a small one. The highest temperatures will be attained only by the most massive bodies, and all through their career these will reach any given temperature at a lower density, on the ascent, and return to it at a higher density, on the descending scale, than a less massive body. They will therefore be of much greater luminosity, for the same temperature, than bodies of small mass if both are rising toward their maximum temperatures. On the descending side the difference will be less conspicuous. Bodies of very small mass will reach only a low temperature at maximum, which may not be sufficient to enable them to shine at all.

All this, again, is in excellent agreement with the observed facts. The hottest stars—those of Class B—are, on the average, decidedly more massive than those of any other spectral type. On the present theory, this is no mere chance, but the large masses are the necessary condition—one might almost say the cause—of the attainment of unusually high temperature. Only these stars would pass through the whole series of the spectral classes, from M to B and back again, in the course of their evolution. Less massive bodies would not reach a higher temperature than that corresponding to a spectrum of Class A; those still less massive would not get above Class F, and so on. This steady addition of stars of smaller and smaller mass, as we proceed down the spectral series, would lower the average mass of all the stars of a given spectral class with "advancing" type, in the case of the giants as well as that of the dwarfs. This change is conspicuously shown among the dwarf stars in Table VII., and faintly indicated among the giant stars. The average masses of the giant and dwarf stars appear, however, to be conspicuously different, which at first sight seems inconsistent with the theory that they represent different stages in the evolution of the same masses. But the giant stars which appear in these lists have been picked out in a way that greatly favours those of high luminosity, and hence, as we have seen, those of large mass, while this is not the case among the dwarf stars. The observed differences between them are therefore in agreement with our theory, and form an additional confirmation of it.

It is now easy, too, to understand why there is no evidence of the existence of luminous stars of mass less than one-tenth that of the sun. Smaller bodies presumably do not rise, even at maximum, to a temperature high enough to enable them to shine perceptibly (from the stellar point of view), and hence we do not see them. The fact that Jupiter and Saturn are dark, though of a density comparable with that of many of the dwarf stars, confirms this view.[25]

We may once more follow the lead of our hypothesis into a region which, so far as I know, has been previously practically untrodden by theory. It is well known that the great majority of the stars in any given region of space are fainter than the sun, and that there is a steady and rapid decrease in the number of stars per unit volume, with increasing luminosity. The dwarf stars, especially the fainter and redder ones, really greatly outnumber the giants, the preponderance of which in our catalogues arises entirely from the egregious preference given them by the inevitable method of selection by apparent brightness.

What should we expect to find theoretically? To get an answer, we must make one reasonable assumption, namely, that the number of stars, in any sufficiently large region of space, which is, at the present time, in any given stage of evolution, will be (roughly at least) proportional to the lengths of time which it takes a star to pass through the respective stages.[26] While a star is growing hotter it is large and bright, is radiating energy rapidly, and is also storing up heat in its interior; while, on account of its low density, contraction by a given percentage of its radius liberates a relatively small amount of gravitational energy. It will therefore pass through these stages with relative rapidity. Its passage through its maximum temperature will obviously be somewhat slower. During the cooling stages its surface is relatively small and its rate of radiation slow; it is dense, and a given percentage of contraction liberates a large amount of energy, and the great store of heat earlier accumulated in its interior is coming out again. It must therefore remain in these stages for very much longer intervals of time, especially in the later ones, when the rate of radiation is very small.

This reproduces, in its general outlines, just what is observed—the relative rarity of giant stars, the somewhat greater abundance of those of Class A near the maximum of temperature, and the rapidly increasing numbers of dwarf stars of smaller and smaller brightness. The well-known scarcity of stars of Class B, per unit of volume, is further accounted for if we believe, as has been already explained, that only the most massive stars reach this stage.

In this connection we will very probably be asked, What precedes or follows Class M in the proposed evolutionary series, and why do we not see stars in still earlier or later stages? With regard to the latter, it is obvious that dwarf stars still fainter than the faintest so far observed (which are of Class M) would, even if among our very nearest neighbours, be apparently fainter than the tenth magnitude. We cannot hope to find such stars until a systematic search has been made for very large proper-motions among very faint stars. The extreme redness of such stars would, unfortunately, render such a search by photographic methods less profitable than in most cases.

But a giant star of Class M, a hundred times as bright as the sun, certainly cannot spring into existence out of darkness. In its earlier stages it must have radiated a large amount of energy, though perhaps less than at present. But as the temperature of a radiating body falls below 3000° C., the energy-maximum in its spectrum moves far into the infra-red, leaving but a beggarly fraction of the whole radiation in the visible region. Stars in such stages

[25] In the foregoing presentation of the theory, to avoid interference with the progress of the main argument, no mention has been made of certain considerations which should be discussed here.

(1) It is probable that at stellar temperatures the gaseous matter is very considerably dissociated and ionised. But this will not affect its gaseous nature. For our present purpose it amounts to little more than a diminution of the mean molecular weight. This will lower the temperature corresponding to a given density and pressure, and so tend to lower the maximum attainable temperature; but as the degree of dissociation is likely to vary gradually with the temperature, it should not affect the orderly sequence of changes which form the basis of the previous arguments.

(2) It is also probable that the available potential energy of a star is not entirely gravitational, but partly, if not mainly, of radio-active or similar atomic origin. If, as in the relatively very small range accessible to experimental investigation, the rate of liberation of this energy is independent of the temperature and pressure, it would simply supply a constant annual addition to the energy derived from gravitational contraction, and the only difference in the course of events would be that a star, on cooling, would approach, not complete extinction, but a steady state, of very long duration, in which as much energy was annually radiated away as was supplied by atomic disintegration. If the rate of disintegration is increased under the extremely violent molecular collisions which must occur in the interior of a star, a great liberation of energy may occur when the interior has got hot enough, thus increasing the maxima temperature and prolonging its duration. But, even on this hypothesis, the number of the violent collisions which liberate the atomic energy would increase gradually as the temperature of the interior rose, and the general character of the evolutionary changes, including the relation of the mass and density of the body to the time of their occurrence, would not be radically altered.

It seems, therefore, probable that the previous reasoning would require no essential modification on account of either of these factors in the problem.

[26] Hertzsprung, *Zeitschrift für Wissenschaftliche Photographie*, vol. iii, p. 442, 1905.

would therefore emit much less light than they would do later, and stand a poor chance of being seen.[27] We know, as yet, very little about the colour-index and temperature of stars of those varieties of Class M (Mb and Mc) which are evidently furthest along in the spectral series, and it may well be that a star usually reaches the temperature corresponding to these stages by the time that it begins to shine at all brightly. In any case, stars in these very early stages should be of small or moderate luminosity, and rare per unit of volume, and hence very few of them would be included in our catalogues.

The great luminosity and extreme redness of the stars of Class N suggest that they belong at the beginning of the series of giant stars; but the relations of this very distinct spectral type to the others are not yet quite clear, and it would be premature to give it a definitive place in the sequence. It seems clear, however, that these stars must be in a very primitive condition, rather than in a very late one, as believed by Lockyer. The stars of Class O (Wolf-Rayet stars) are of very great average luminosity, and probably lie beyond those of Class B at the apex of the temperature scale, as Lockyer supposes. But in the absence of data concerning their masses, densities, and the like, we cannot place them definitively, except that Oe5 and Oe come almost certainly just above Bo.

One further application of the theory may be very briefly mentioned. If we have a large number of contracting masses of gas endowed with various moments of momentum, more and more of them will split up into pairs as they grow denser, and the pairs latest formed will have the shortest periods. A large percentage of spectroscopic binaries, especially of short period, is therefore direct evidence of a fairly advanced state of evolution, and the occurrence of this condition among the stars of Classes B and A supports—indeed, almost by itself compels—the view that they are far removed from a primitive condition. Most of the stars which have been investigated for radial velocity are giants, and the absence of spectroscopic binaries of short period among the redder stars is in agreement with the view that they are in earlier stages of evolution.

The distribution of the visual binaries and physical pairs among the various spectral classes depends mainly upon a quite different factor, namely, the resolving power of our telescopes, which allows us to separate the closer pairs of short period only among the nearer stars, so that the systems for which orbits have been determined are nearly all dwarf stars.

I have endeavoured in the past hour to set before you the present state of knowledge concerning the real brightness, masses, densities, temperatures, and surface brightness of the stars, and to sketch the theory of stellar evolution to which the study of these things has led me. This theory is inconsistent with the generally accepted view. Its fundamental principle is identical with that of Lockyer's classification, but it differs radically from the latter in the principles according to which it assigns individual stars, and even whole classes of stars, to the series of ascending or descending temperature. (For example, Lockyer puts such conspicuously giant stars as Canopus, Capella, Arcturus, and β Cygni, and all the stars of Class N, into the descending series, and places β Hydri and δ Pavonis (which are clearly dwarf stars) in the ascending series.)

Two things have gone farthest to convince me that it may be a good approximation to the truth—the way in which it explains and coordinates characteristics of the different spectral types which previously appeared to be without connection or reason, and the way in which a number of apparent exceptions to its indications have disappeared, one by one, as more accurate information concerning spectra, orbits of double stars, and the like, became available, until only one doubtful case remains.

I have purposely made no attempt at this time to touch upon certain other interesting matters, such as the difference of the mean peculiar velocities of stars of the various spectral classes, although, with the aid of simple and very reasonable assumptions, they may be added to the list of things explainable by the new theory. My reason for this has been less for lack of time than because there is at present no definite reason, assignable from general considerations in advance, why we should expect an old star to be moving faster or slower than a younger one, while there is such a reason why we should suppose that a dense star is in a later stage of evolution than one of low density. It seems better to find out what we can about the order of evolution from data of the latter kind, and then apply our results to the study of problems of the former sort, than to attack them without such aid or by means of unproved assumptions. The assumptions that are necessary on the new theory are simple and probable enough, but they do not form an integral part of the theory, and cannot be established directly from general considerations, and so I will not discuss them now.

The new theory will not explain everything about the stars—I should be rather afraid of it if it did; for example, it leaves the phenomena of preferential motion, or "star-streaming," as puzzling as ever. I have only tried to interpret some of the facts most obviously capable of evolutionary explanation, on the fundamental assumption that the properties of matter, and the forces in operation, among the stars, are the same as those with which we are familiar in the laboratory. He would be a bold man indeed who would assert that this assumption is entirely true, but it seems clear that it should be thoroughly tried out before the existence of new forces can legitimately be postulated.

If the ideas to which you have so kindly listened to-day shall prove of any help toward removing the need for belief in unknown forces, and extending the domain of those already known, my labour will be far more than repaid; but it should not be forgotten that the real labourers have been those who, through long and weary nights, accumulated bit by bit, and, through monotonous days, prepared for the use of others the treasures of observational knowledge with which it has been my pleasurable lot to play in the comfort of my study.

I need scarcely add that, if what I have said proves of interest to any of you, your frank and unsparing criticism will be the greatest service which you can render me.

27 Russell, *Science*, N.S. Vol. xxxvii, p. 646, 1913.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

BIRMINGHAM.—At its last meeting the University council passed the following resolution:—"That the council desires to record its deep sorrow at the death of Prof. Poynting, who so faithfully served the Mason College and the University for thirty-four years. During his distinguished career as professor of physics he was not only an inspiring teacher and investigator, but bore a considerable part in the development of the college and of the University. His keen interest in all that concerned the University, its staff, and its students, his genial and attractive personality, will be long and affectionately remembered; his death leaves a gap which it will be most difficult to fill."

Mr. Frank E. Huxley has resigned his lectureship in dental surgery.

Dr. L. G. Parsons has been appointed assistant to the chair of forensic medicine and toxicology.

A full-time lectureship in classics, ancient history, and archæology is being established.

Miss M. Le Bour has been appointed to undertake a special investigation in helminthology in the department of agricultural zoology.

CAMBRIDGE.—Mr. E. R. Burdon has been appointed University lecturer in forestry.

The Anthony Wilkin studentship in ethnology and archæology will be available at the end of the Easter term. Applicants should send their names, qualifications, and a statement of the research which they wish to undertake, to the Vice-Chancellor before June 1.

Mr. H. C. Haslam, of Gonville and Caius College, has been approved by the General Board of Studies for the degree of Doctor of Science.

THE governors of the South Wales and Monmouthshire University College at Cardiff have accepted the generous offer of an anonymous donor to provide funds for the erection of a great school of preventive medicine. The money value of this gift, together with that of Sir William James Thomas to erect a school for other branches of medicine in connection with the college, is estimated at 180,000*l.*

Two lectures entitled "La Catalyse et mes divers Travaux sur la Catalyse," will be given by Prof. Paul Sabatier, of the University of Toulouse, at King's College, W.C., on May 14 and 15, at 5 p.m. Special interest is attached to these lectures as the subject-matter is one with which Prof. Sabatier is particularly associated, and one from which he has obtained important results in the synthetical preparation of organic substances.

IT is announced in the issue of *Science* for May 1 that the Catholic University of America, Washington, will receive the greater part of the estate of 200,000*l.* left by the late Mr. Theodore B. Basselin, of Croghan. From the same source we learn that Mr. James Deering, in a letter addressed to the trustees of North-western University and of Wesley Hospital, announces a gift of 200,000*l.* to the hospital. It is provided that Wesley Hospital shall be a teaching hospital under Northwestern University. The gift is made in honour of the donor's father and of his sister.

PROF. SIMS WOODHEAD, in his presidential address to the Royal Microscopical Society (Jour. Roy. Microscop. Soc., 1914, part 2, p. 109), suggests that too little attention is paid in our medical schools to the education of the students in the *technical* use of the microscope. He urges that there should be sound teaching on the optical and mechanical principles on which are based the construction and use of the microscope, and that the best students, at any rate, should have some opportunity of acquiring facility in the use of the various types of substage condenser, dark-ground illumination, monochromatic illumination, methods of measurement, ultra-microscopic work, micro-spectroscopy, polarisation, and the like.

FREE vacation courses in scientific instrument-making and glass-blowing will again be held this year at the University of Leyden. The course in instrument-making will include practice with modern machine tools, such as lathes, milling machines, etc., and will extend from August 20 to August 29; it will involve the cutting of screw threads, turning spheres, copying divided discs, and grinding various hardened objects. The course on elementary and advanced glass-blowing, from August 20 to September 2, will include the manufacture of vacuum tubes, vacuum flasks, and various other forms of apparatus used in physical and chemical investigation, and the manipulation of high-vacua pumps. The director of the course is Prof. Kamerlingh Onnes, and the secretary Dr. C. A. Crommelin, to whom all communications should be addressed at the Physical Laboratory, Leyden, Holland.

THE Medical Officers of Schools Association from time to time issues pamphlets on problems connected with conditions of health in schools. The latest of these useful publications deals with "School Lighting," and is a reprint of a paper read before the association by Dr. E. H. T. Nash. The author puts the difficulties of the problem of daylight illumination, and rightly asks that the Government should either subsidise further research or conduct a thorough inquiry through the Board of Education. In the present regulations of the Board we read: "The light so far as possible should be admitted from the left side of the scholars. This rule will be found greatly to influence the planning." So far all authorities agree, but there is great diversity of opinion and practice as regards bilateral and overhead lighting, the shape of class-rooms, the relative areas to be assigned to windows. These matters have an important influence on the health of the children, the class-room efficiency, and the expenditure of public money on school buildings. As regards artificial lighting, the problem is vastly more simple, and Dr. Nash gives an instance of efficient and economic lighting by incandescent gas, the cost for a class-room being rather more than $\frac{3}{4}$*d.* an hour. In this case the illumination at the desks ranged from 3·5 foot-candles to 5 foot-candles, as compared with the usually recommended minimum of 2 foot-candles. The pamphlet is illustrated with diagrams, includes an account of the discussion which followed the reading of the paper, and is published by Messrs. Churchill at 1*s.*

SOCIETIES AND ACADEMIES.

LONDON.

Royal Society, May 7.—Sir William Crookes, president, in the chair.—Lord **Rayleigh**: (1) Some calculations in illustration of Fourier's theorem. (2) The theory of long waves and bores.—Sir Joseph **Larmor** and J. S. B. **Larmor**: Protection from lightning and the range of protection afforded by lightning rods. On modern ionic views discharge in the atmosphere should originate at a place of maximum intensity of electric field and spread both ways from it along a line which should be roughly the line of force. The explanation of branching, zigzag, and multiple lightning discharges is to be sought on these lines. The introduction of a narrow linear conductor cannot sensibly disturb a steady field of force, and not at all if it is transverse to the field. Thus it would seem to be the top of the building itself, not of the lightning conductor, that attracts the discharge, and the function of a single rod can only be to lead it more safely away. But a number of rods distributed over the area of the roof, and effectively connected to earth by a conductor, can, by their joint action, lift the intensest part of the field from the top of the building to the region around their summits, and so obviate or much mitigate the danger of discharge from above to the building which they cover. In illustration, diagrams are given of a vertical field of force as disturbed by vertical pillars of semi-ellipsoidal form and of various breadths, or by an earthed conducting region overhead, such as might be originated by gradual discharge from a pointed rod.—Prof. A. **Schuster**: Newcomb's method of investigating periodicities and its application to Brückner's weather cycle.—E. N. Da C. **Andrade**: The flow in metals subjected to large constant stresses. The law connecting the extension with time for wires of various metals subjected to large stresses has been examined at different temperatures. The stress was kept constant throughout the flow by the device of a hyperbolic weight employed in former experiments. The different types of flow observed for different metals at room temperature are only particular cases of one general law governing the flow of all single metals, and can all be found for one metal by choosing an appropriate temperature; thus, soft iron at 450° C. behaves similarly to lead at 15° C.—G. I. **Taylor**: Eddy motion in the atmosphere. The paper contains a theoretical discussion of the function of eddies in conveying heat and momentum through a fluid. It is shown also that measurements of the temperature of the air over the Great Bank of Newfoundland made by the author last year, lead to the conclusion that eddies extend upwards over the sea to a height of at least 800 metres; and that there is no appreciable diminution in their size or intensity at this height. On the assumption of a uniform amount of eddy motion, the velocity of the wind at various heights above the ground is calculated, and shown to agree with the most recent observations carried out over Salisbury Plain.—Prof. Ernest **Wilson**: The properties of magnetically-shielded iron as affected by temperature. In a paper recently read before the Royal Society, it is shown that if stalloy in ring form is shielded from the earth's magnetism and subjected to a considerable magnetising force at atmospheric temperature, the permeability can be increased. The present experiments deal with the effect of allowing stalloy to cool down through the temperature at which it regains magnetic quality when in a shield and when under the influence of a magnetising force due to a continuous current. Two specimens have been subjected to this treatment, and in each case the maximum permeability has a value of above 10,000 when the specimen is at atmospheric temperature.

Geological Society, April 29.—Dr. A. Smith Woodward, president; and afterwards, Mr. W. Hill, vice-president, in the chair.—A. S. **Woodward**: The lower jaw of an anthropoid ape (Dryopithecus) from the Upper Miocene of Lérida (Spain). The greater part of a mandibular ramus and symphysis of *Dryopithecus fontani* is described. The specimen is the latest jaw of an anthropoid ape hitherto discovered in Europe. The relatively small size of the first molar is to be regarded as a primitive character, lost in all modern anthropoids except some Gibbons. The shape of the mandibular symphysis is remarkably primitive, with the surface of insertion for the digastric muscle nearly as large as that of the ancestral Macaques. The anterior face of the symphysis slopes directly upwards from the front edge of this insertion, as in the Macaques, some Gibbons, and very young individuals of the chimpanzee, gorilla, and orang. It thus differs from the mandibular symphysis in adult individuals of these existing apes, in which the lower portion of the slope curves backwards into a flange or shelf of bone, while the digastric insertion is reduced in extent. So far as its lower jaw is concerned, Dryopithecus is a generalised form from which modern anthropoid apes and man have diverged in two different directions.—Prof. J. W. **Gregory**: The structure of the Carlisle-Solway Basin, and the sequence of its Permian and Triassic rocks. The Carlisle-Solway basin has been generally represented as a syncline, with the Solway resting on a great thickness of Triassic rocks. A boring made near Gretna in 1794 shows, on the contrary, that Lower Carboniferous rocks crop out there at the surface. This boring shows that the basin is not a simple syncline. The evidence derived from the boring necessitates reconsideration of the Permo-Triassic sequence in north Cumberland, as to which the Geological Survey maps and memoirs are not in agreement. Arguments are given to show that the evidence for the existence of the St. Bees Sandstone at the bottom of the Abbeytown and Bowness borings is quite inconclusive, and the fact is improbable. The view adopted by the Geological Survey map that the area west and north-west of Carlisle consists of Keuper deposits, is also improbable.

MANCHESTER.

Literary and Philosophical, April 7.—Mr. F. Nicholson, president, followed by Prof. F. E. Weiss, vice-president, in the chair.—W. C. **Grummitt** and Dr. H. G. A. **Hickling**: A preliminary note on the structure of coal. It was suggested that the essential constituent of coal is a homogeneous substance, red or orange in colour when thin enough to be transparent. This material under the microscope frequently shows evidence of "flow," and was doubtless a liquid vegetable decomposition product. This, in its purest form, constitutes the "bright" layers of coal; with strongly developed "cleat" or cleavage. Vegetable structures are preserved in coal in two forms: (1) in a "carbonised" condition, as is found pure in "mother-of-coal," and is quite opaque even when less than 1 μ thick; (2) impregnated with the transparent material described above, spores being the most readily distinguishable parts preserved in this manner. The ash from the various coals consists largely of fibrous material which is clearly an incombustible residue of vegetable structure and closely resembles the ash obtained by burning wood. The spores from certain coals can be isolated by maceration with Schultz solution.

April 28.—Mr. F. Nicholson, president, in the chair.—R. F. **Gwyther**: Specification of stress. Part v., An outline of the theory of hyper-elastic stress. The author dealt with the mathematical conditions of a body from the time of exceeding the elastic limit and when approaching to the conditions of rupture.—H. P. **Walmsley** and Dr. Walter **Makower**: The photographic action of α rays. Each α particle on striking a grain of silver in a photographic film affects that grain in such a manner as to be capable of photographic development. The path of the ray is thus apparent under the microscope.

PARIS.

Academy of Sciences, May 4.—M. P. Appell in the chair.—The **President** announced the death of M. van Tieghem, perpetual secretary.—Maurice **Hamy**: The position to be given to the astronomical observatory on Mont Blanc. Various possible sites have been examined from the points of view of uninterrupted horizon, accessibility and stability, and the advantages and disadvantages of each site discussed. The best position would appear to be the Petit Flambeau (3435 metres).—Emile **Picard**: Some reflections on certain results of Henri Poincaré concerning analytical mechanics.—Pierre **Termier**: Eduard Suess, the man and his work.—C. **Guichard**: Certain special congruences of circles and spheres.—René **Baillaud**: A photographic astrolabe.—N. E. **Nörlund**: Series of faculties.—Ernest **Esclangon**: The quasi-periodic integrals of linear differential equations.—Michel **Fekete**: A lower limit of the changes of sign of a function in an interval.—N. **Lusin**: a problem of M. Baire.—Lucien **Godeaux**: Double algebraic surfaces having a finite number of points of ramification.—Louis **Roy**: Quasi-waves in three dimensions.—L. **Dunoyer** and R. W. **Wood**: Correction to our note entitled photometry of the superficial resonance of sodium vapour under the stimulation of the D lines. A correction of an error of calculation in the determination of the width of the resonance lines.—F. **Charron**: A hydrodynamical arrangement for the magnification and registration of radio-telegraphic signals. The telephonic receiver is modified so that the vibrations are concentrated on the orifice of a vertical capillary tube. A stream of gas is flowing out of the capillary tube with a velocity just below that of turbulent flow. Sounds in the telephone produce disturbances in the flow of the gas through the jet, and these can be utilised to form a record without using a Morse receiver.—H. **Bourget**, H. **Buisson**, and Ch. **Fabry**: Interferential measurements of the radial velocities and wave-lengths in the nebula of Orion. The mean radial velocity of the nebula is +15·8 kilometres a second with respect to the sun, that is, the distance between the sun and the nebula is increasing at that rate. The wave-lengths of the characteristic double ultra-violet line had been determined and found to be 3726.100 and 3728.838. These lines are not emitted by any known element.—B. **Fessenkoff**: The law of reflection of light by matt surfaces.—J. **Minguin** and R. **Bloc**: The influence of solvents on the optical activity of the camphoric esters. The optical activity of the *allo*-acids is the same in alcoholic, benzene, or toluene solutions: the *ortho*-acids give higher rotations in benzene or toluene than in alcohol.—Marcel **Delépine**: Lithium chloro-iridate and chloro-iridite.—Jacques **Bardet**: The extraction of germanium from Vichy water. Germanium had been previously detected spectroscopically in Vichy water, and an attempt was made to isolate germanium compounds from this source. The starting point was the mixture of insoluble carbonates deposited on heating the water, and 0·06 gram of germanium oxide was prepared from 100 kilograms of deposit, representing about 250,000 litres of mineral water. The method of separation is given in detail.—M. **Vasticar**: The apparatus of support of the internal acoustic region.—Michel **Cohendy** and Eugène **Wollman**: Experiments on life without micro-organisms. Aseptic growth of guinea-pigs. These experiments prove that it is possible to raise guinea-pigs under strictly aseptic conditions, development and utilisation of food being in no way prejudiced by the absence of micro-organisms.—Louis **Cruveilhier**: Treatment of blennorrhagia by the method of sensitised virus vaccines.—Auguste **Lumière** and Jean **Chevrotier**: Some new considerations concerning the culture of gonococci.—P. **Macquaire**: The amylolytic diastase of the pancreas.—L. **Cayeux**: Eastern prolongation of the ferruginous formation of the May (Calvados) synclinal.

CAPE TOWN.

Royal Society of South Africa, April 15.—Mr. S. S. Hough in the chair.—T. **Muir**: (1) Note on a theorem of Ph. Gilbert, regarding the differentiation of a special Jacobian. (2) Note on Rosanes's functions, resembling Jacobians.—R. T. A. **Innes**: The triple stellar system ζ Virginis and Σ 1757. These two stars, although a considerable distance apart, constitute a system as they are moving through space with almost identical velocities and directions.—G. A. H. **Bedford**: A curious mosquito.—A. L. du **Toit**: The porosity of the rocks of the Karroo system. Determinations are given of the porosity of more than ninety rocks, the majority being from borehole cores. It was found with the three-fold division of the Beaufort beds the mean porosity of the Sandstone was 2·9 per cent. for the lower, 5·2 per cent. for the middle, and 5·5 per cent. for the upper division. The figures for the Transvaal phase of the Karroo were much higher. The effects of weathering in increasing the porosity are discussed and analysed.—J. R. **Sutton**: A note on the temperatures of the air observed at Mochudi. The note gives a brief account of some points of interest in the results of temperature observations by Harbor at Mochudi in the Bechuanaland Protectorate. The extremes of temperature are considerable, the greatest range so far observed being from 108° F. to 28° F. The mean maximum temperatures depend upon the sun's meridian altitude in much the same way as they do at Kimberley. The annual cold wave of the middle of July is felt at Mochudi like it is elsewhere further south.

BOOKS RECEIVED.

The Simpler Natural Bases. By Prof. G. Barger. Pp. viii+215. (London: Longmans and Co.) 6*s.* net.

Department of Marine and Fisheries. Report of the Meteorological Service of Canada, Central Office, Toronto, for the Year ended December 31, 1910. Vol. i. Introduction and Parts i.–iii. Pp. xxiii+341. Vol. ii. Parts iv.–vi. and Appendix. Pp. 342–604. (Ottawa: C. H. Parmelee.)

The Therapeutic Value of the Potato. By H. C. Howard. Pp. 31. (London: Baillière and Co.) 1*s.* net.

Ernährungsphysiologisches Praktikum der höheren Pflanzen. By Prof. V. Grafe. Pp. x+494. (Berlin: P. Parey.) 17 marks.

American Mathematical Society. Colloquium Lectures. Vol. iv. The Madison Colloquium, 1913. i., On Invariants and the Theory of Numbers. By L. E. Dickson. ii., Topics in the Theory of Functions of Several Complex Variables. By W. F. Osgood. Pp. vi+230. (New York: American Mathematical Society.)

Smithsonian Institution. Bureau of American Ethnology. Bulletin 56. Ethnozoology of the Tewa Indians. By J. Henderson and J. P. Harrington. Pp. x+76. (Washington: Government Printing Office.)

Lehrbuch der vergleichenden mikroskopischen Anatomie der Wirbeltiere. Edited by Prof. A. Oppel. Achter Teil. Pp. x+168. (Jena: G. Fischer). 8 marks.

The British Academy. Palissy, Bacon, and the Revival of Natural Science. By Sir T. Clifford Allbutt. Pp. 15. (London: Oxford University Press.) 1*s.* net.

Bulletin of the Illinois State Laboratory of Natural History, Urbana, Ill., U.S.A. Vol. x., Article 3: Studies on the Enchytrœidœ of North America. By Dr. P. S. Welch. Pp. 212+Plates viii–xii. (Urbana, Ill.)

British Museum (Natural History). A Monograph of the Genus Sabicea. By H. F. Wernham. Pp. v+82+xii Plates. (London: British Museum.) 6*s.*

A Revision of the Ichneumonidæ. Based on the Collection in the British Museum (Natural History). Part iii. By C. Morley. Pp. xi+148. (London: British Museum.) 5*s.* 6*d.*

British Museum (Natural History). Report on Cetacea stranded on the British Coasts during 1913. By Dr. S. F. Harmer. Pp. 12. (London: British Museum.) 1*s.* 6*d.*

Elements of Algebra. By G. St. L. Carson and Prof. D. E. Smith. Part i. Pp. v+346. (London: Ginn and Co.) 3*s.*

Journal of the British Fire Prevention Committee. No. ix. (Special subject.) Table G. The Fire Resistance of Partitions. Pp. 8+1 Table. (London: The British Fire Prevention Committee.) 10*s.* 6*d.*

Annuaire Général de Madagascar et Dépendances, 1914. Pp. x+745. (Tananarive.)

X-Rays: an Introduction to the Study of Röntgen Rays. By Dr. G. W. C. Kaye. Pp. x+252. (London: Longmans and Co.) 5s. net.

I Minerali. By Prof. E. Artini. Pp. xv+422+40 Plates. (Milano: U. Hoepli.) 9.50 lire.

Beiträge zur Kenntnis der Land- und Süsswasserfauna Deutsch-Südwestafrikas. Edited by W. Michaelsen. Lief. i. Pp. 182+4 Plates. (Hamburg: L. Friederichsen and Co.) 12 marks.

Beiträge zur Kenntnis der Meeresfauna Westafrikas. Edited by W. Michaelsen. Lief 1. Pp. 84+2 Plates. (Hamburg: L. Friederichsen and Co.) 6 marks.

Lectures Introductory to the Theory of Functions of Two Complex Variables. By Prof. A. R. Forsyth. Pp. xvi+281. (Cambridge: University Press.) 10s. net.

Kinetische Stereochemie der Kohlenstoffverbindungen. By Dr. A. von Weinberg. Pp. viii+107. (Braunschweig: F. Vieweg und Sohn.) 3 marks.

Canada. Department of Mines. Memoir No. 18 E. Bathurst District, New Brunswick. By G. A. Young. Pp. 96+9+Maps. Memoir No. 26. Geology and Mineral Deposits of the Tulaween District, B.C. By C. Camsell. Pp. vii+188+10+maps. (Ottawa.)

Photography in Colours. By Dr. G. L. Johnson. Second (Revised) Edition. Pp. xiv+243+13 Plates. (London: G. Routledge and Sons, Ltd.) 3s. 6d. net.

Common British Beetles. By Rev. C. A. Hall. Pp. viii+88+16 Plates. (London: A. and C. Black.) 1s. 6d. net.

DIARY OF SOCIETIES.

THURSDAY, MAY 14.

ROYAL SOCIETY, at 4.30.—The Various Inclinations of the Electrical Axis of the Human Heart. IA.: The Normal Heart. Effects of Respiration: Dr. A. D. Waller.—Fossil Plants showing Structure from the Base of the Waverley Shale of Kentucky: Dr. D. H. Scott and Prof. E. C. Jeffrey.—The Controlling Influence of Carbon Dioxide in the Maturation, Dormancy, and Germination of Seeds. II.: F. Kidd.—The Cultivation of Human Tumour Tissue *in vitro*: D. Thomson and J. G. Thomson.—The Nutritive Conditions Determining the Growth of Certain Freshwater and Soil Protista: H. G. Thornton and G. Smith.

ROYAL INSTITUTION, at 3.—Identity of Laws: in General: and Biological Chemistry: Prof. Svante Arrhenius.

CONCRETE INSTITUTE, at 7.30.—Sand and Coarse Material and Proportioning Concrete: J. A. Davenport and Prof. S. W. Perrott.

SOCIETY OF DYERS AND COLOURISTS, at 8.—Notes on the Chemistry of Starch and its Transformations: W. A. Davis.—The Analysis of Malt Extracts: W. P. Dreaper.—Temperature and Concentration as Affecting Hydration and Soda Absorption during the Process of Formation of Cellulose Monofils: Clayton Beadle and H. P. Stevens.

FRIDAY, MAY 15.

ROYAL INSTITUTION, at 9.—Plant Animals: A Study in Symbiosis: Prof. F. Keeble.

SATURDAY, MAY 16.

ROYAL INSTITUTION, at 3.—Bird Migration: Prof. C. J. Patten.

MONDAY, MAY 18.

ROYAL GEOGRAPHICAL SOCIETY, at 3.—Anniversary Meeting.

JUNIOR INSTITUTION OF ENGINEERS, at 8.—Static Transformers, the Design and Application: F. R. Peters.

VICTORIA INSTITUTE, at 4.30.—The Composite of Races and Religions in America: Rev. Dr. S. B. McCormick.

TUESDAY, MAY 19.

ROYAL INSTITUTION, at 3.—Natural History in the Classics. I.: The Natural History of the Poets, Homer, Virgil, and Aristophanes: Prof. D'Arcy W. Thompson, C.B.

ROYAL STATISTICAL SOCIETY, at 5.—Suggestions for Recording the Life History and Family Connections of Every Individual: W. Hazell.

ZOOLOGICAL SOCIETY, at 8.30.—Notes on the Circulatory System of Elasmobranchs, I.: The Venous System of the Dogfish (*Scyllium canicula*: Dr. C. H. O'Donoghue.—Scent-organs in Trichoptera: B. F. Cummings.—Notes on Plumage Development in the African Wood-stork: G. Jennison.—A New Cestode from an Albatross (*Diomedea irrorata*): H. A. Baylis.—The Deinocephalia, an Order of Mammal-like Reptiles: D. M. S. Watson.—The Species of the Genus Paralastor, Sauss, and some other Hymenoptera of the Family Eumenidæ: Dr. R. C. L. Perkins.

ROYAL SOCIETY OF ARTS, at 4.30.—The Singing of Songs: Old and New. II.: Classical Songs: H. Plunkett Greene.

WEDNESDAY, MAY 20.

AERONAUTICAL SOCIETY, at 8.30.—Wilbur Wright Memorial Lecture: Dr. R. T. Glazebrook.

ROYAL METEOROLOGICAL SOCIETY, at 4.30.—The Reduction of Barometer Readings in Absolute Units, and a New Form of Barometer Card: E. Gold.—A Cuban Rain Record and its Application: A. Hampton Brown.

ROYAL SOCIETY OF ARTS, at 8.30.—The Channel Tunnel and its Early History: J. C. Hawkshaw.

ROYAL MICROSCOPICAL SOCIETY, at 8.—Exhibition of Microscopic Aquatic Life.

THURSDAY, MAY 21.

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INSTITUTION OF MINING AND METALLURGY, at 8.

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PHYSICAL SOCIETY, at 5.—Volatility of Thorium Active Deposit: T. Barratt and A. B. Wood.—The Passage of α-Particles through Photographic Films: H. P. Walmsley and Dr. W. Makower.—A Null Method of Testing Vibration Galvanometers: S. Butterworth.—Experiments with an Incandescent Lamp: C. W. S. Crawley and S. W. J. Smith.

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Editorial and Publishing Offices:
MACMILLAN & CO., LTD.,
ST. MARTIN'S STREET, LONDON, W.C.

Advertisements and business letters to be addressed to the Publishers.

Editorial Communications to the Editor.

Telegraphic Address: PHUSIS, LONDON.
Telephone Number: GERRARD 8830.