THURSDAY, AUGUST 1, 1907.

ZOOLOGY AS AN EXPERIMENTAL SCIENCE.

Experimental Zoology. By Prof. Thomas Hunt Morgan. Pp. xii+454; illustrated. (New York: The Macmillan Company; London: Macmillan and Co., Ltd., 1907.) Price 12*s.* net.

THIS welcome book may be regarded as a landmark, since it vindicates the position of zoology as an experimental science. It is the modern successor of Semper's famous "Animal Life," and it has had its forerunners in various smaller books, such as De Varigny's "Experimental Evolution." But it is, we believe, the first scholarly and critical review of a large part of the enormous mass of experimental investigations which have been a feature of zoological science during the last fifteen years. Thus it gives the student a comprehensive and orderly survey (with well-selected bibliography) of a widely-scattered scientific literature; it enables him rapidly to bring himself up to date as regards experiments on the influence of environment, on hybridising, on inbreeding, on the conditions of growth and reproduction, on the determination of sex, and so on; and the data are presented in a manner so critical and stimulating that the book is bound to have a great influence in promoting experimental research, which is likely to be prominent in zoological laboratories for centuries to come. For

"while the historical study of zoology must always remain a legitimate field for activity, as human history has been a time-honoured study, there can be little doubt that the more promising and searching method of zoological study in the future will be found in experiment."

To have furthered this movement is sure to be the reward of Prof. Morgan's book, which is at once a careful balance-sheet of past results and an incentive to add to them. The author has made all zoologists his debtors, for the work is uncommonly well done. It is an interesting sign of the times that the author is "professor of experimental zoology" in one of the leading universities of the world.

The author's general point of view is thus indicated:—

"The branches of biology that have made most extensive use of the experimental method are physiology, bacteriology, and physiological chemistry. The zoologist and the embryologist have also to deal with physiological problems, and already the beginning of important experimental work has been carried out in this field; but *the most distinctive problem of zoological work is the change in form that animals undergo, both in the course of their development from the egg (embryology) and in their development in time (evolution).*"

It is to an examination of the experimental study of these changes in form that the book is mainly devoted.

"Experimental morphology would perhaps nearly indicate the field to be examined; but since the line between experimental physiology and experimental morphology is often hard to draw, and since I shall not hesitate at times to enter upon the physiological side of many problems, I have chosen the somewhat broader title of Experimental Zoology to include the subjects to be treated."

The principal topics discussed fall under six headings:—evolution, growth, grafting, the influence of the environment on the life-cycle, the determination of sex, and the secondary sexual characters; and if there are any zoologists who have not been following the recent development of experimental work, they will be amazed at the amount of profoundly interesting work that has already been done. New vistas are being opened out on all sides, and zoology is entering upon a fresh and most promising phase. It should be noted, too, that Prof. Morgan tells his tale in a style so lucid and graphic that even the uninitiated cannot fail to follow what is certainly one of the most fascinating zoological books ever published.

The main theme of the book is "the central problem of morphology—the causes of the changes in form, or at least the determination of the conditions under which changes in form occur." It must be noted, however, as the author is well aware, that the title "Experimental Zoology" is much wider than the contents of the book. He has deliberately refrained from discussing, (*a*) recent experimental work on the psychical aspects of vital phenomena as dealt with in recent works by Loeb, Lloyd Morgan, Jennings, Bethe, and others; (*b*) the study of regeneration (to which he devoted a previous excellent treatise); and (*c*) experimental embryology, which has also received comprehensive treatment in more than one recent volume. The exclusion of the last-named department is especially regrettable, though it is ungracious to say so. For, after all, the central problem of morphology is not so much concerned with the environmental production of modifications, or with the Mendelian phenomena of inheritance, or with the determination of sex, but with *morphogenesis.* Thus a treatise on experimental zoology which refrains from a thorough-going discussion of the fundamental researches of men like Roux and Wilson, Driesch and Herbst, illustrates what the experimentalists have called "autotomy." Let us hope that in subsequent editions the missing parts—absolutely necessary to completeness—may be regenerated. The author's competence to secure this is well known. Of course, a book should always be received with due consideration of the author's aim and prescribed limits, and what we have ventured to say is in no sense intended as criticism, but we may further remark that under the title of "Experimental Zoology" we may justly include not only experiments bearing on morphogenesis (individual and racial), but also those which enable us better to understand the daily life of the fully formed creature. Much of the work that has been done in comparative physiology and psychology is definitely experimental, and just as essential to an all-round outlook as the work of Mendel and de Vries.

It is of course impossible to give a summary of the author's conclusions, but we may give two or three samples.

"The experimental evidence in favour of the inheritance of acquired characters is unsatisfactory." "Used with discretion Mendel's law may still unlock many problems, but if attempts are made to force it to interpret cases that do not belong to its proper field of action, especially in regard to dissociation in the germ-cells, harm rather than good may temporarily result." "It seems arbitrary to speak of unit characters as immutable and quite unnecessary to make this idea a cardinal point of the mutation theory." "On the mutation theory selection destroys species; it does not originate them." "Admitting that all eggs and all sperm carry the material basis that can produce both the male and female, the two conditions being mutually exclusive when development occurs, the immediate problem of sex determination resolves itself into a study of the conditions that in each species regulate the development of one or the other sex. It seems not improbable that this regulation is different in different species, and that, therefore, it is futile to search for any principle of sex determination that is universal for all species with separate sexes; for while the fundamental internal change that stands for the male or the female condition may be the same in all unisexual forms, the factor that determines which of the alternate states is realised may be very different in different species."

We may be allowed to compliment the author on his highly successful execution of an arduous task; his workmanship is marked by carefulness, lucidity, and impartiality, by the salt of good-tempered criticism, and by a stimulating suggestion throughout that the whole business of experimental zoology is only beginning.

J. A. T.

BOOKS ON PATENT LAW.

(1) *The Inventors' Guide to Patent Law and the New Practice.* By J. Roberts. Pp. viii+109. (London: John Murray, 1906.) Price 1*s.* net.

(2) *Notes on the New Practice at the Patent Office.* By J. Roberts. Pp. 32. (London: Eyre and Spottiswoode, Ltd., n.d.) Price 1*s.*

(1) THIS book is intended to give inventors an explanation of the law and rules relating to the grant of patents in the United Kingdom, and information as to the proper manner of protecting inventions. The book is to a great extent an abstract from the larger book of Mr. Roberts, and, as a guide to the student of patent law, should be extremely useful. In addition to the parts of the book dealing directly with the Patent law, information is given specially for the use of an inventor who is in possession of an invention which he considers it desirable to protect; but the ordinary inventor, even with this book in his hand, would meet with considerable difficulty in drafting his specification in the best manner. It is frequently noticed that inventors themselves are quite unable to appreciate and describe what is the real point of their invention; and this difficulty cannot be met by any guide-book. The various matters dealt with in the book comprise practically the whole of the Patent Law, and the questions of the application for a patent, and procedure at the Patent Office, as well as proceedings for infringement, and other proceedings, on a patent already granted, are all referred to, and references given to other works in which fuller information is contained.

It is, of course, impossible in such a small space—about one hundred pages—to give any full account of the Patent Law, and Mr. Roberts has perhaps given as much information as possible in the space at his disposal. The reader, however, will have to refer to the larger works to get any clear ideas on the different points dealt with. It is impossible, for instance, to explain the difference between patentable and non-patentable inventions in a few pages. Every particular case must be judged on its own merits, and reference to a few cases is of little or no use on the question of sufficiency of invention.

At the end of the book, the Patents Act, 1902, is fully set out, together with the rules made under the Act. An index is given which appears to be fairly complete.

(2) This publication deals shortly with the alterations in the Patent Law introduced by the Patents Act of 1902, and the rules made under that Act. The effect of the new provisions is given very clearly, and certain controversial points arising on the construction of the Act and the rules are very fully dealt with. Among these may be mentioned the question of post-dating the specification, which is the subject of Rule 5 of 1905. This rule gives the comptroller power to post-date the application, and this power, if used against the applicant, is no doubt outside the scope of the Act of 1902. There is, however, little reason to suppose that the rule will be exercised by the comptroller to the prejudice of an applicant, and in practice the applicant may find the power of the comptroller to post-date extremely convenient in cases where he is unable to meet the Patent Office objections within the prescribed time.

Another point very fully dealt with is the question of the meaning to be given to the words "in part described" in Section 1 of the Act of 1902. The author suggests that these words should be narrowly read, and that the words "partly described" should mean that part of the invention as claimed by the applicant has already been described, so that one claim at least includes what is old. This is a reasonable construction, and is practically that adopted by the Office under the new practice.

The author also deals with the question of the compulsory insertion of references at the instance of the comptroller, and the form in which the reference is to be inserted. In the Act of 1902 there is an ambiguity as to whether the comptroller should have power to settle the form of the reference or whether he could decide only what specifications should be referred to. The view taken by the Patent Office is that they are entitled to settle the form, but the author does not consider they are justified in this interpretation. The official view, however, does not really cause any hardship to the patentee, as if there is really an invention the specification can be quite well drafted in such a way that all necessity for the compulsory reference is avoided, and the officials at the Patent Office always give great facilities for amendment to define the invention more clearly, if there is any invention of any sort contained in the application.

Mr. Roberts's notes give a very clear idea of the changes introduced in the Patent Law by the new Act and rules.

OUR BOOK SHELF.

The Efficient Life. By Dr. Luther H. Gulick. Pp. xvi + 195; illustrated. (London: W. Heinemann, 1907.) Price 3s. 6d. net.

THE "Efficient Life" is a useful addition to our stock of knowledge of how to maintain health and vigour under the conditions of the present-day manner of living. Man has become in civilised countries mostly a dweller in cities during the past fifty years, and even the small portion of human beings who follow a country life is tinged by the customs and ways of the city.

Dr. Gulick applies himself to telling us how to counteract the deteriorating effects of (town) life, and he has executed his task well. It is an artificial life we lead, and the means of ameliorating its evils must necessarily be by artificial devices. Following the chase and tilling the soil were the natural avocations of man, but these natural means of physical development cannot be followed by the majority nowadays, and we have to be content with bodily exercises, breathing exercises, games, and such substitutes as we can devise to make up for nature's plan. That we are to succeed is another question, but if we are it is by following the ideals and methods Dr. Gulick has set before us. In "The Efficient Life" the author deals with almost every phase of our daily round of life. Food, drink, fatigue, sleep, exercise, baths, and general physiological states are dealt with in an attractive and masterly style which everyone can understand and no one can study without benefit.

Although by neither proverbial quotations nor by lectures can we gain health, yet, by dint of persistence in teaching the public by means of these, great good may come; and in time the thoughts they give rise to come to be, imperceptibly perhaps, part and parcel of our daily life. In this way a better perception of how to counteract the deteriorating effects of the modern manners of living may be attained, and with such efficient guides before us as the one given by Dr. Gulick, the end may be hoped to be attained, gradually, perhaps, yet none the less surely.

Flowers of the Field. By the Rev. C. A. Johns. Revised and edited by C. Elliott. Pp. xx + 316. (London: G. Routledge and Sons, Ltd., 1907.) Price 7s. 6d. net.

JUDGING by the useful purpose it has served in the past, Johns's "Flowers of the Field" may almost be regarded as a "classic," and now it shares with the classics the fate of being produced in two versions. The opinion is often expressed that the editions bearing a date antecedent to 1899 were excellently adapted to the use of amateur collectors of flowers, but the publishers, considering it advisable to bring the book up to date, remodelled it at the same time. In the version now before us, Mr. Elliott claims that the old form is maintained except for revision, the augmentation of descriptions and the addition of new coloured plates. It is evident that the text has been subjected to considerable revision, especially in the matter of rearranging the species of some of the larger genera, but there are other places where emendations were required, such as assigning Paris to the Trilliaceæ and Acorus to the Orontiaceæ, retaining the genera Apargia and Fedia, and the binomial *Lactuca alpina*. Where the present edition differs from, and falls short of the original work is in the size and number of the cuts, and the elimination of guiding headlines under the large genera. The coloured plates are good reproductions, but in many instances the drawings are scrappy and attenuated. An apparently unimportant and yet important change is the increase in size and bulk of the volume. While recognising that Mr. Elliott has made changes for the better in the text, mistakes such as "aureole," "Hiberna," "paralias," are not infrequent. It is probable that the botanist who possesses an old edition of the book will be satisfied with his antique.

Cyclopedia of American Agriculture. Edited by L. H. Bailey. In four volumes. Vol. I.: Farms. Pp. 618 + xviii. (New York: The Macmillan Company; London: Macmillan and Co., Ltd., 1907.) Price 21s. net.

CYCLOPEDIAS seem to be coming into fashion again; Morton's "Cyclopedia of Agriculture" was one of the best books dealing with the old high farming of the middle of the last century, but it has found no successor, though we understand one is under preparation at the present time, and now we receive the first instalment of a monumental work from America. The book opens with a description of the various districts into which the continent may be divided, the cotton States, the corn-belt States, the arid States, &c., each section being contributed by a writer specially acquainted with the locality in question. Then follows an exceedingly interesting and valuable chapter on planning, stocking, and equipment of various types of farm, with a discussion of the capital required in each case. Other sections of this chapter deal with water supply, farm buildings, and machinery, this latter an article that would be of service to the English farmer. Further chapters treat of soils and fertilisers, and are of a more ordinary text-book type, as again is the last chapter dealing with the atmosphere. This, indeed, is too much a general essay on meteorology, and not at all of a character to draw the farmer to a more intelligent personal study of the weather and the forecasting which is within his own power.

The book is profusely illustrated with wood-cuts and process blocks, but while many of the photographs are of interest and are necessary to develop the text, a great many seem to have been inserted on the general encyclopedia principle of stick a picture in wherever you can, however diagrammatic and irrelevant it may be. Indeed, we are at times reminded of the delicious illustrations to "Wisdom while you wait." While we cannot recommend this cyclopedia to the English farmer, so different is the agriculture of the two countries, it should find its place on the shelves of the teacher, who can obtain from it a good many hints and suggestions for application on this side.

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.*]

Root Action and Bacteria.

THE experiments mentioned by Mr. F. Fletcher in NATURE of July 18 (p. 270) bear only on the functioning of roots once they have come into activity, not on their passage from the dormant to the active condition.

The probable analogy between the bursting of a dormant root-bud and the germination of a seed has led me to investigate the latter, and some of the results already obtained tally exactly with those obtained with trees. Seeds of *Lolium perenne*, sterilised by carbon disulphide, were planted in soil or sand which had been previously treated in various ways; the water-contents of the medium were the same in every case, and re-inoculation from the air was prevented. All the experiments were made in duplicate, and all the duplicates were remarkably concordant. The results were, that seeds in unheated earth began to germinate on the ninth day, the total germination being 65 per cent.; in earth heated to 250°, 150°, 95°, and 80°, no germination has occurred yet, although twenty-two days have now elapsed, while in the case of earth heated to only 60°, germination did not occur until the eighteenth day, and the total germination is only 30 per cent.

Dr. Russell mentioned that in his experiments he had not noticed any retardation to be produced by the sterilisation of the soil; but in his experiments, as well as in my own with apple trees, no steps were taken to guard against re-inoculation from the air, and such re-inoculation would be very easy in the case of seeds just below the surface of the soil. Another explanation may be that we have not used similar seeds; and from some experiments with mustard, now in progress, it is evident that different seeds behave differently, though the difference may be due to the imperfect sterilisation of the seeds themselves in some cases. Dr. Russell has been good enough to examine my experiments whilst in progress, and I believe that he is satisfied with the results so far as they go at present.

There is not sufficient evidence yet to show whether the bacterial action is a direct one on the seeds, or whether it is an indirect one, as Dr. Russell suggested, modifying some chemical change produced in the soil by heating. The very low temperature (60°) which suffices to affect the germination tells against the view that chemical change is one of the governing factors, as also does the fact that the results obtained with sand are similar to those obtained with earth. On the other hand, it was found that with soil which had been heated to 150°, and then re-inoculated, germination was much retarded, and was very feeble, this pointing to some chemical change which was not counteracted at once by the re-inoculation.

The view that plants in growing charge the soil with something which is toxic to other plants was put forward a year or two ago by Dr. Whitney, but the evidence adduced for it seems to have been very inconclusive; the details of Mr. Fletcher's results in this direction will, therefore, be expected with considerable interest. We have, during the last three years, been endeavouring to ascertain whether any action of this sort can account for the effect of grass on trees, trees having been grown in earth or sand in pots and watered with leachings from earth or sand in which grass was growing. The results, however, have been entirely negative.

SPENCER PICKERING.

Biological Expedition to the Birket el Qurun.

THE lake in the Fayum province of Egypt known as the Birket el Qurun has a very unique interest as the remains of the historic Lake Moeris, which was used as an artificial regulator of the Nile floods by the monarchs of the twelfth dynasty. During the last few years a good deal of attention has been paid to the lake and the whole Fayum province by Captain Lyons, F.R.S., and the staff of the Egyptian Survey Department. No detailed examination of the flora and fauna had, however, been undertaken, and it was to furnish the desired biological information that we were invited to make investigations in the spring of this year.

The Birket el Qurun is now reached with great ease from Cairo, as the railway comes within a distance of some seven miles. Consequently we had no difficulties of transport to contend with, and began our work on the lake shore on March 26. During a period of eight weeks we made careful collections in a number of different parts of the lake, and being provided with a sailing-boat of moderate size we were able to make our way about by water, camping in a number of likely places on the shore sufficiently far apart.

The lake seems to be remarkable more for the quantity of life which its waters contain than for the number of different species inhabiting it. The tow-net revealed immense swarms of entomostraca—mostly copepods and cladocera—as well as vast numbers of rotifers, while the smaller organisms form the food supply of the fish, which occur in astonishing abundance. Although the tow-nettings usually afforded a plentiful supply of the smaller animals, they contained relatively little in the way of phyto-plankton. Algæ were collected from the rocks and stones and the submerged stems of plants, while the larger representatives of the flora were also collected.

The fish were for the most part obtained from the native fishermen, and while some thirteen different species were brought home, the overwhelming majority of those taken belong to two species of the genus Tilapia. A large specimen of the Nile perch (*Lates niloticus*) was examined, which measured 120 cm. and weighed 54 lb. Only a few species of mollusca were found, with but a single lamellibranch amongst them, while the worms are represented by certain small oligochætes. The collection contains a polyzoan with circular lophophore, while among the hydrozoa, Cordylophora is found growing abundantly. Perhaps the most interesting discovery is that of a medusa, and the hydroid form with which it is associated. While the water of the lake is now slightly brackish, there is evidence that it was perfectly fresh even in historic times, so that the existence of this form here is rendered more than ever remarkable. It is a typical anthomedusan, and finds its nearest ally in the marine genus Sarsia. There are several animal groups apparently unrepresented in the Birket el Qurun which we might well expect to find, since they are common in the Nile, with which the lake is in direct communication. Such are the crabs, prawns, and sponges, of which no specimens were procured. Similarly we obtained no examples of argulidæ, leeches, or turbellaria.

In addition to the actual collecting, certain physical observations were made. The seiche alterations in water-level appear to be very slight, as is only natural where the greatest depth is but four or five fathoms. A number of readings of the water temperature were taken which prove unexpectedly interesting. The temperatures recorded show a maximum of 94°·2 in very shallow water close to shore about 2.0 p.m., and a minimum of 54°·8 as a surface reading in the early morning. The difference between the surface temperature and that of the water below may also be very considerable, as was shown in one case by a difference of 8°·8 between the reading at a fathom and that at the surface. All these figures are doubtless explained by the shallowness of the lake and the extremes of heat and cold to which it is often exposed.

W. A. CUNNINGTON, Christ's College, Cambridge.
C. L. BOULENGER, King's College, Cambridge.

The Atomic Weight of Cobalt.

IT has recently been suggested by Prof. J. J. Thomson that the accepted atomic weight of cobalt, namely 59·0, is probably too high, and that the true atomic weight of cobalt is less than that of nickel. Prof. Thomson's suggestion was founded on the results observed with secondary radiation.

We have made an attempt to determine the atomic weight electrolytically by direct comparison with silver, and obtain as the mean of fifteen determinations a value of 57·7 for the atomic weight.

We have also attempted to compare the atomic weights of cobalt and nickel directly with each other and with that of silver by placing three voltameters in series and passing the same current through them, but on account of unexpected difficulties due to secondary reactions in the case of nickel we have not yet obtained satisfactory results.

We hope later to complete the investigation and give details of the experiments.

One of us ("F. H. P.") has also compared the absorption of cobalt and nickel for the β radiation from uranium, and the results indicate a smaller atomic weight for cobalt than for nickel.

F. H. PARKER.
F. PEAKE SEXTON.
Physical Laboratories, Woolwich Polytechnic.

SINGLE-PLATE COLOUR-PHOTOGRAPHY.

THE desire has often been expressed to have a sensitive plate that might be exposed in any ordinary camera, and that would yield what has so often been called a photograph "in natural colours." Such plates are now on the market in France, and will doubtless be obtainable in this country as soon as the makers are able to meet the demand for them. It has taken the enterprising firm of Messrs. Lumière more than three years to perfect their invention and reduce the manufacture of the plates into a system suitable for the factory.

Colours are reproduced by these plates only in that limited sense which applies to all three-colour processes. The natural colours are imitated by tints, which, if successfully produced and seen by a suitable light, are not distinguishable by the unassisted eye from the original. The accuracy of the imitation depends on the choice of the dyes used, and also on the colour-sensitiveness of the emulsion taken in conjunction with the compensating screen used to reduce its excessive sensitiveness to the more refrangible light that characterises all photographic plates.

In the ordinary methods of three-colour photography the three colours are separately photographed, using coloured media that transmit only the light required, a print from each negative is obtained in its proper colour, and the three prints are superposed. For one plate to contain in itself the necessities for such a process it is obvious that its surface must be divided among the three colours, and that the separate patches of each must be so small that, as ordinarily viewed, they are not distinguishable, must be comparable, in fact, to the lines in a wood cut or the dots or grain in a photomechanical print. Further, if the print is to be complete in itself, the three colours must be an integral part of it, and not, as in Prof. Joly's method, form a separate "viewing screen."

The new plates fulfil these conditions. The coloured grained screen that has the three colours in invisibly small patches, forming a tricolour mosaic with the three colours so proportioned that the general impression they give is a neutral grey, is obtained by means of starch granules. These are selected of fairly uniform size, and dyed in separate quantities red, green, and violet. The three lots are mixed as thoroughly as possible, and in such proportions that no colour predominates, and spread upon glass as a film one layer thick. The interstices between the rounded granules are filled up by pressing and more or less crushing the grains, an improvement on the original method of filling them up with a black pigment. This three-coloured irregular mosaic is varnished, and a specially sensitised emulsion is spread on the top of it. The plate is then ready for the camera.

The exposure is made with a suitable colour screen at the lens so that the red, green, and violet lights may act upon the plate in their proper proportions in spite of the want of orthochromatism of the emulsion. The glass side of the plate is presented towards the lens, so that the light that forms the image passes first through the layer of dyed starch granules. The sensitive layer will obviously be affected behind each coloured granule so far as the light from the object is of the same colour as the granule. After development the image has to be reversed, or changed from the negative first produced into a positive. Therefore, instead of fixing in the ordinary way, the metallic silver image is dissolved out by an acid oxidising solution, and the remaining silver bromide is reduced to the metallic state by a developer. Intensification may be necessary. The result is a three-coloured grained transparency in which the truth of the colours depends upon the conditions stated above.

It is obvious that such plates must be comparatively costly, but then only one is required, while some methods of colour photography need six, or even more. The reversal of the image is more trouble than simple fixing, but only one plate has to be dealt with instead of many. The image is granulated, while other methods give results free from grain. It is therefore impossible to say much as to the practical advantage of the method until the plates can be put to actual use. There can, however, be very little doubt that this method, or a modification of it, has a future of usefulness, and no doubt at all as to the ingenuity of the idea that has given rise to it, and the admirable perseverance that has overcome innumerable difficulties in practically working it out.

C. J.

CENTENARY OF THE GEOLOGICAL SOCIETY.

IN September next the Geological Society will celebrate its hundredth birthday. In honour of this interesting occasion preparations have for some time been in progress. Invitations to the celebration have been issued to all the foreign members and foreign correspondents of the society; the various geological surveys all over the globe, universities having chairs of geology or mineralogy, scientific academies, societies and museums at home and abroad have been invited to send delegates to London. The large number of acceptances already received include the names of many of the most distinguished geologists of the present day, both in the old and the new world.

It has been arranged that a series of excursions to various parts of this country shall take place before the centennial meeting, under the conduct of fellows of the society conversant with the geology of the several selected districts. These excursions will begin on Wednesday, September 18, and the excursionists will all be back in London by the evening of September 25. The celebration of the centenary, which will extend over three days, will begin on Thursday, September 26, at 11 o'clock, in the Hall of the Institution of Civil Engineers, when the chair will be taken by Sir Archibald Geikie, who has been elected president of the society for the second time in order that he may preside on this occasion. The foreign members and foreign correspondents, and the delegates from institutions at home and abroad, will then be received by him, and will present their addresses. In the afternoon, at 3 o'clock, in the same hall, the president will deliver an address, while in the evening a banquet will be given by the society to its colonial and foreign guests.

Friday, September 27, will be chiefly devoted to visits to museums, galleries, &c., concluding with an evening reception. On Saturday, September 28, short excursions have been projected to places of geological interest within easy reach of London. On Monday, September 30, the visitors will be divided into two sections, one of which will go to Oxford, the other to Cambridge. It is understood that the universities will confer honorary degrees on some of the more distinguished geologists from beyond the seas, and that college hospitality will be as abundant and hearty as usual, while those visitors who may still have energy enough left for field-work will be taken on geological excursions from both the university towns. This well-planned combination of scientific intercourse with social pleasure can hardly fail to have a lasting effect in forming and confirming friendships by bringing the geologists of many different countries into close personal relations with each other.

DR. AUGUST DUPRÉ, F.R.S.

A WELL-KNOWN name vanishes from the list of living analytical chemists by the death of Dr. A. Dupré, which occurred at Sutton on July 15.

Like a number of chemists whose names readily come to mind—Hoffmann, Schorlemmer, and Lunge, for example—Dupré was born and educated in Germany, but in early manhood crossed the North Sea to seek a sphere for his talents in England. He had studied chemistry under Bunsen; and in 1855, at the age of twenty, he graduated at Heidelberg with the degree of Ph.D. Coming soon afterwards to this country, his first appointment of importance was that of lecturer in chemistry at Westminster Hospital, in 1864. Two years later he became a naturalised British subject. Concurrently with his lecturing duties, Dupré also undertook those of chemical referee to the medical department of the Local Government Board and public analyst for Westminster; and for many years he was chemical adviser to the explosives department of the Home Office, a position which he held at the time of his death.

As might be expected, Dupré's original work in chemistry bore chiefly upon points arising in his own domain of chemical analysis. Some two dozen communications appeared during the period 1876–1902 in the *Analyst*, the Journals of the Chemical Society and the Society of Chemical Industry, and in the Proceedings of the Royal Society. None were epoch-making, but all were useful; their general character will be shown by the titles of a few of them:—"The Composition and Analysis of Butter Fat" (1876); "On Copper in Food" (1877); "The Estimation of Urea by Means of Hypobromite" (1877); "On the Estimation of Dissolved Oxygen in Water" (1885); "Changes in the Proportion of Acid and Sugar present in Grapes during Ripening"; "The Specific Heat and other Physical Characters of Mixtures of Methyl Alcohol and Water"; "The Explosion of Potassium Chlorate by Heat" (1902). In addition, Dupré made various reports upon explosives, and was joint author with Drs. Thudichum and Hake respectively of two well-known treatises, viz., "The Origin, Nature, and Varieties of Wines," and "A Short Manual of Inorganic Chemistry."

The crown of Dupré's professional career was his election to the Royal Society in 1875. To the general public, however, he was probably best known as the analyst whose dangerous duty it was to examine the explosives used in the Fenian scares of a generation ago—notably the one in which nitroglycerine was found in process of manufacture on a large scale at Birmingham in 1883.

Concerned chiefly with the practical applications of chemistry, Dupré was no leader in its philosophy, but his name is honourably associated with the advancement in this country of the profession he adopted when making this country his home.

C. S.

THE BRITISH ASSOCIATION AT LEICESTER.

THIS week sees the opening of the seventy-seventh annual meeting of the British Association, and there are indications that at Leicester the Association will receive the heartiest of welcomes, and that the deliberations of its members will be followed with deep interest by the inhabitants generally. The financial position must be very gratifying to all concerned; the whole of the promised subscriptions are in the bank, and have earned quite a good sum as interest. When it is borne in mind that no public appeal has been made, but that the money has readily been subscribed, this happy result speaks highly as to the generosity of the townspeople and the manner in which they have been approached.

The Mayor (Sir Edward Wood) is most anxious that Leicester should prove its full appreciation of having been chosen as this year's meeting place, and that the many visitors to the ancient borough should carry away a lasting impression of its hospitality and desire for comfort. The local programme tells of Sir Edward Wood's wish to come into as close touch as possible with every visitor, in its record of an evening *fête* in the Abbey Park at which it is anticipated 3000 will be present. His Worship is supplementing this by entertaining on the following evening the officials of the Corporation, the teachers of the town, infirmary nurses, &c., and he has invited the old people from the Trinity Hospital, almshouses, the cripples of the town, and others, to meet him in the same park on the Saturday—all this in commemoration of the visit—which he desires should be a lasting, pleasurable recollection.

We have already spoken of the excellent arrangements made by the local executive, with Mr. Alfred Colson as its chairman, of the sectional meetings, interesting excursions and visits to works planned to add to the enjoyment of the men of science. Each member attending the meeting is to receive a copy of the special edition of "Glimpses of Ancient Leicester," a book written by a Leicester lady, and also to have a capital guide to Leicester and neighbourhood, with a map, prepared under the direction of the publications subcommittee, and containing specially written articles by experts on Charnwood Forest; stone roads, canals, edge-railways, outramways, railways, &c., of Leicestershire; geology; the pre-Cambrian rocks; palæontology, cryptogamic flora of Leicestershire; botany; zoology; entomology; and a bibliography of town and county. These, it is hoped, will serve as memoirs of the town's welcome and a most successful week's work.

The Mayor, Recorder, Town Clerk, and others will attend the official service at St. Martin's Church on the Sunday morning, at which the Bishop of Southwark (Dr. Talbot) will preach. The Bishop of the diocese (Dr. Carr Glynn) is giving an address at St. Peter's Church, and other eminent men are preaching at various churches and chapels, so that the harmony of religion and science will doubtless receive every justice. The leading clubs of the town have freely opened their doors to "temporary members," and the full advantages of golfing and bowls are offered to all interested.

The tramcar service of the town is a most complete one, and every facility for quick transit is given. A favourite daily rendezvous will undoubtedly be the "loggia" erected adjacent to, and connected with, the town museum buildings, and here, if the weather is fine, a quiet rest, a cup of tea, and the music of the band of the Seaforth Highlanders will prove thoroughly enjoyable, and a relief to the heavier work of the sectional meetings.

Next year the Association is to meet at Dublin, and by a happy thought a deputation of the following gentlemen, Sir Howard Grubb, F.R.S., Rev. Dr. W. Delaney, and Prof. W. H. Thompson, will be the guests of the local executive at Leicester.

We hope that in a future issue we may be able to congratulate the Association on the complete success of its last annual meeting, the large attendance of its members, the high quality of the papers read and discussed and lectures given; and Leicester upon its generous welcome and hospitality.

INAUGURAL ADDRESS BY SIR DAVID GILL, K.C.B., LL.D., D.Sc., F.R.S., HON. F.R.S.E., &c., PRESIDENT OF THE ASSOCIATION.

TO-NIGHT, for the first time in its history, the British Association meets in the ancient city of Leicester; and it now becomes my privilege to convey to you, Mr. Mayor, and to the citizens generally, an expression of our thanks for your kind invitation and for the hospitable reception which you have accorded to us.

Here in Leicester and last year in York the Association has followed its usual custom of holding its annual meeting somewhere in the United Kingdom; but in 1905 the meeting was, as you know, held in South Africa. Now, having myself only recently come from the Cape, I wish to take this opportunity of saying that this southern visit of the Association has, in my opinion, been productive of much good: wider interest in science has been created amongst colonists, juster estimates of the country and its problems have been formed on the part of the visitors, and personal friendships and interchange of ideas between thinking men in South Africa and at home have arisen which cannot fail to have a beneficial influence on the social, political, and scientific relations between these colonies and the mother country. We may confidently look for like results from the proposed visit of the Association to Canada in 1909.

One is tempted to take advantage of the wide publicity given to words from this chair to speak at large in the cause of science, to insist upon the necessity for its wider inclusion in the education of our youth and the devotion of a larger measure of the public funds in aid of scientific research; to point to the supreme value of science as a means for the culture of those faculties which in man promote that knowledge which is power; and to show how dependent is the progress of a nation upon its scientific attainment.

But in recent years these truths have been prominently brought before the Association from this chair; they have been exhaustively demonstrated by Sir William Huggins from the chair of the Royal Society, and now a special guild[1] exists for their enforcement upon the mind of the nation.

These considerations appear to warrant me in following the healthy custom of so many previous presidents—viz., of confining their remarks mainly to those departments of science with which the labours of their lives have been chiefly associated.

The Science of Measurement.

Lord Kelvin in 1871 made a statement from the presidential chair of the Association at Edinburgh as follows: "Accurate and minute measurement seems to the non-scientific imagination a less lofty and dignified work than the looking for something new. But nearly all the grandest discoveries of science have been the reward of accurate measurement and patient, long-continued labour in the minute sifting of numerical results."

Besides the instances quoted by Lord Kelvin in support of that statement, we have perhaps as remarkable and typical an exemplification as any in Lord Rayleigh's long-continued work on the density of nitrogen which led him to the discovery of argon. We shall see presently that, true as Lord Kelvin's words are in regard to most fields of science, they are specially applicable as a guide in astronomy.

One of Clerk Maxwell's lectures in the Natural Philosophy Class at Marischall College, Aberdeen, when I was a student under him there, in the year 1859, ran somewhat as follows:—

"A standard, as it is at present understood in English, is not a real standard at all; it is a rod of metal with lines ruled upon it to mark the yard, and it is kept somewhere in the House of Commons. If the House of Commons catches fire there may be an end of your standard. A copy of a standard can never be a real standard, because all the work of human hands is liable to error. Besides, will your so-called standard remain of a constant length? It certainly will change by temperature, it probably will change by age (that is, by the re-arrangement or settling down of its component molecules), and I am not sure if it does not change according to the azimuth in which it is used. At all events, you must see that it is a very impractical standard—impractical because, if, for example, any one of you went to Mars or Jupiter, and the people there asked you what was your standard of measure, you could not tell them, you could not reproduce it, and you would feel very foolish. Whereas, if you told any capable physicist in Mars or Jupiter that you used some natural invariable standard, such as the wave-length of the D-line of sodium vapour, he would be able to reproduce your yard or your inch, provided that you could tell him how many of such wave-lengths there were in your yard or your inch, and your standard would be available anywhere in the universe where sodium is found."

[1] The British Science Guild.

That was the whimsical way in which Clerk Maxwell used to impress great principles upon us. We all laughed before we understood; then some of us understood and remembered.

Now the scientific world has practically adopted Maxwell's form of natural standard. It is true that it names that standard the metre; but that standard is not one-millionth of the earth's quadrant in length, as it was intended to be; it is merely a certain piece of metal approximately of that length.

It is true that the length of that piece of metal has been reproduced with more precision, and is known with higher accuracy in terms of many secondary standards, than is the length of any other standard in the world; but it is, after all, liable to destruction and to possible secular change of length. For these reasons it cannot be scientifically described otherwise than as a piece of metal whose length at 0° C. at the epoch A.D. 1906 is =1,553,164 times the wave-length of the red line of the spectrum of cadmium when the latter is observed in dry air at the temperature of 15° C. of the normal hydrogen-scale at a pressure of 760 mm. of mercury at 0° C.

This determination, recently made by methods based on the interference of light-waves and carried out by MM. Perot and Fabry at the International Bureau of Weights and Measures, constitutes a real advance in scientific metrology. The result appears to be reliable within one ten-millionth part of the metre.

The length of the metre, in terms of the wave-length of the red line in the spectrum of cadmium, had been determined in 1892 by Michelson's method, with a mean result in almost exact accordance with that just quoted for the comparisons of 1906; but this agreement (within one part in ten millions) is due in some degree to chance, as the uncertainty of the earlier determination was probably ten times greater than the difference between the two independent results of 1892 and 1906.

We owe to M. Guillaume, of the same International Bureau, the discovery of the remarkable properties of the alloys of nickel and steel, and from the point of view of exact measurement the specially valuable discovery of the properties of that alloy which we now call "invar." He has developed methods for treatment of wires made from this alloy which render more permanent the arrangement of their constituent molecules. Thus these wires, with their attached scales, may, for considerable periods of time and under circumstances of careful treatment, be regarded as nearly invariable standards. With proper precautions, we have found at the Cape of Good Hope that these wires can be used for the measurement of base lines of the highest geodetic precision with all the accuracy attainable by the older and most costly forms of apparatus; whilst with the new apparatus a base of 20 kilometres can be measured in less time and for less cost than one of a single kilometre with the older forms of measurement.

The Great African Arc of Meridian.

In connection with the progress of geodesy, time only permits me to say a few words about the Great African arc on the 30th meridian, which it is a dream of my life to see completed.

The gap in the arc between the Limpopo and the previously executed triangulation in Rhodesia, which I reported to the Association at the Johannesburg meeting in 1905, has now been filled up. My own efforts, at

6000 miles distance, had failed to obtain the necessary funds, but at Sir George Darwin's instance contributions were obtained from this Association, from the Royal Society and others, to the extent of half the estimated cost; the remaining half was met by the British South Africa Company. But for Darwin's happy intervention, which enabled me to secure the services of Captain Gordon and his party before the Transvaal Survey Organisation was entirely broken up, this serious gap in the great work would probably have long remained; for it is one thing to add to an existing undertaking of the kind, it is quite another to create a new organisation for a limited piece of work.

Since then Colonel (now Sir William) Morris has brought to a conclusion the reductions of the geodetic survey of the Transvaal and Orange River Colony, and his report is now in my hands for publication.

Dr. Rubin, under my direction, at the cost of the British South Africa Company, has carried the arc of meridian northwards to S. latitude 9° 42′, so that we have now continuous triangulation from Cape L'Agulhas to within fifty miles of the southern end of Lake Tanganyika; that is to say, a continuous geodetic survey extending over twenty-five degrees of latitude.

It happens that, for the adjustment of the international boundary between the British Protectorate and the Congo Free State, a topographic survey is at the present moment being executed northward along the 30th meridian from the northern border of German East Africa. A proposal on the part of the Royal Society, the Royal Geographical Society, the British Association, and the Royal Astronomical Society has been made to strengthen this work by carrying a geodetic triangulation through it along the 30th Meridian, and thus adding 2½° to the African arc. These Societies together guarantee 1000*l.* towards the cost of the work, and ask for a like sum from Government to complete the estimated cost. The topographic survey will serve as the necessary reconnaissance. The topographic work will be completed by the end of January next, and the four following months offer the best season of the year for geodetic operations in these regions.

There is a staff of skilled officers and men on the spot sufficient to complete the work within the period mentioned, and the Intercolonial Council of the Transvaal and Orange River Colony most generously offers to lend the necessary geodetic instruments. The work will have to be done sooner or later, but if another expedition has to be organised for the purpose the work will then cost from twice to three times the present amount. One cannot therefore doubt that His Majesty's Government will take advantage of the present offer and opportunity to vote the small sum required. This done, we cannot doubt that the German Government will complete the chain along the eastern side of Lake Tanganyika, which lies entirely within their territory. Indeed, it is no secret that the Berlin Academy of Sciences has already prepared the necessary estimates with a view to recommending action on the part of its Government.

Captain Lyons, who is at the head of the survey of Egypt, assures me that preliminary operations towards carrying the arc southwards from Alexandria have been begun, and we have perfect confidence that in his energetic hands the work will be prosecuted with vigour. In any case the completion of the African arc will rest largely in his hands. That arc, if ever my dream is realised, will extend from Cape L'Agulhas to Cairo, thence round the eastern shore of the Mediterranean and the islands of Greece, and there meet the triangulation of Greece itself, the latter being already connected with Struve's great arc, which terminates at the North Cape in lat. 70° N. This will constitute an arc of 105° in length—the longest arc of meridian that is measurable on the earth's surface.

The Solar Parallax.

Much progress has been made in the exact measurement of the great fundamental unit of astronomy—the solar parallax.

Early in 1877 I ventured to predict[1] that we should not arrive at any certainty as to the true value of the solar parallax from observations of transits of Venus, but that the modern heliometer applied to the measurement of angular distances between stars and the star-like images of minor planets would yield results of far higher precision.

The results of the observations of the minor planets Iris, Victoria, and Sappho at their favourable oppositions in the years 1888 and 1889, which were made with the co-operation of the chief heliometer and meridian observatories, fully justified this prediction.[1] The Sun's distance is now almost certainly known within one-thousandth part of its amount. The same series of observations also yielded a very trustworthy determination of the mass of the Moon.

The more recently discovered planet Eros, which in 1900 approached the Earth within one-third of the mean distance of the Sun, afforded a most unexpected and welcome opportunity for re-determining the solar parallax—an opportunity which was largely taken advantage of by the principal observatories of the northern hemisphere. Unfortunately the high northern declination of the planet prevented its observation at the Cape and other southern observatories. So far as the results have been reduced and published[2] they give an almost exact accordance with the value of the solar parallax derived from the heliometer observations of the minor planets, Iris, Victoria, and Sappho in 1888 and 1889.

But in 1931 Eros will approach the Earth within one-sixth part of the Sun's mean distance, and the fault will rest with astronomers of that day if they do not succeed in determining the solar parallax within one ten-thousandth part of its amount.

To some of us who struggled so hard to arrive at a tenth part of this accuracy under the less favourable geometrical conditions that were available before the discovery of Eros, how enviable seems the opportunity!

And yet, if we come to think of it rightly, the true opportunity and the chief responsibility is ours, for *now* and not twenty years hence is the time to begin our preparation; *now* is the time to study the origin of those systematic errors which undoubtedly attach to some of our photographic processes; and then we ought to construct telescopes specially designed for the work. These telescopes should be applied to the charting of the stars near the path which Eros will describe at its opposition in 1931, and the resulting star-coordinates derived from the plates photographed by the different telescopes should be rigorously inter-compared. Then, if all the telescopes give identical results for the star-places, we can be certain that they will record without systematic error the position of Eros. If they do not give identical results, the source of the errors must be traced.

The planet will describe such a long path in the sky during the opposition of 1931 that it is already time to begin the meridian observations which are necessary to determine the places of the stars that are to be used for determining the constants of the plates. It is desirable, therefore, that some agreement should be come to with respect to selection of these reference-stars, in order that all the principal meridian observatories in the world may take part in observing them.

I venture to suggest that a Congress of Astronomers should assemble in 1908 to consider what steps should be taken with reference to the important opposition of Eros in 1931.

The Stellar Universe.

And now to pass from consideration of the dimensions of our solar system to the study of the stars, or other suns, that surround us.

To the lay mind it is difficult to convey a due appreciation of the value and importance of star-catalogues of precision. As a rule such catalogues have nothing whatever to do with discovery in the ordinary sense of the word, for the existence of the stars which they contain is generally well known beforehand; and yet such catalogues are, in reality, by far the most valuable assets of astronomical research.

If it be desired to demarcate a boundary on the Earth's

1 "The Determination of the Solar Parallax," the *Observatory*, vol. i. p. 280.

1 "Annals of the Cape Observatory," vol. vi., part vi., p. 29.

2 Monthly Notices R.A.S., Hinks vol. lxiv. p. 725; Christie, vol. lxvii. p. 382.

surface by astronomical methods, or to fix the position of any object in the heavens, it is to the accurate star-catalogue that we must refer for the necessary data. In that case the stars may be said to resemble the trigonometrical points of a survey, and we are only concerned to know from accurate catalogues their positions in the heavens at the epoch of observation. But in another and grander sense the stars are not mere landmarks, for each has its own apparent motion in the heavens which may be due in part to the absolute motion of the star itself in space, or in part to the motion of the solar system by which our point of view of surrounding stars is changed.

If we desire to determine these motions and to ascertain something of the general conditions which produce them, if we would learn something of the dynamical conditions of the universe and something of the velocity and direction of our own solar system through space, it is to the accurate star catalogues of widely separated epochs that we must turn for a chief part of the requisite data.

The value of a star-catalogue of precision for present purposes of cosmic research varies as the square of its age and the square of its accuracy. We cannot alter the epoch of our observations, but we can increase their value fourfold by doubling their accuracy. Hence it is that many of our greater astronomers have devoted their lives chiefly to the accumulation of meridian observations of high precision, holding the view that to advance such precision is the most valuable service to science they could undertake, and comforted in their unselfish and laborious work only by the consciousness that they are preparing a solid foundation on which future astronomers may safely raise the superstructure of sound knowledge.

But since the extension of our knowledge of the system of the universe depends quite as much on past as on future research, it may be well, before determining upon a programme for the future, to consider briefly the record of meridian observation in the past for both hemispheres.

The Comparative State of Astronomy in the Northern and Southern Hemispheres.

It seems probable that the first express reference to southern constellations in known literature occurs in the Book of Job (ix. 9): "Which maketh Arcturus, Orion, and Pleiades, and the chambers of the south." Schiaparelli's strongly supported conjecture is that the expression "chambers of the south," taken with its context, signifies the brilliant stellar region from Canopus to α Centauri, which includes the Southern Cross and coincides with the most brilliant portion of the Milky Way.

About the year 750 B.C. (the probable date of the Book of Job) all these stars culminated at altitudes between 5° and 16° when viewed from the latitude of Judæa; but now, owing to precessional change, they can only be seen in a like striking manner from a latitude about 12° further south.

The words of Dante have unquestionably originated the wonderful net of poetic fancy that has been woven about the asterism, which we now call Crux.

> To the right hand I turned, and fixed my mind
> On the other pole attentive, where I saw
> Four stars ne'er seen before save by the ken
> Of our first parents—Heaven of their rays
> Seemed joyous. O thou northern site! bereft
> Indeed, and widowed, since of these deprived.

All the commentators agree that Dante here referred to the stars of the Southern Cross.

Had Dante any imperfect knowledge of the existence of these stars, any tradition of their visibility from European latitudes in remote centuries, so that he might poetically term them the stars of our first parents?

Ptolemy catalogues them as 31, 32, 33, and 34 Centauri, and they are clearly marked on the Borgian globe described by Assemanus in 1790. This globe was constructed by an Arabian in Egypt: it bears the date 622 Hegira, corresponding with A.D. 1225, and it is possible that Dante may have seen it.

Amerigo Vespucci, as he sailed in tropical seas, apparently recognised in what we now call Crux the four luminous stars of Dante; for in 1501 he claimed to be the first European to have looked upon the stars of our first parents. His fellow-voyager, Andrea Corsali, wrote about the same time to Giuliano di Medici describing "the marvellous cross, the most glorious of all the celestial signs."

Thus much mysticism and romance have been woven about this constellation, with the result that exaggerated notions of its brilliancy have been formed, and to most persons its first appearance, when viewed in southern latitudes, is disappointing.

To those, however, who view it at upper culmination for the first time from a latitude a little south of the Canary Islands, and who at the same time make unconsciously a mental allowance for the absorption of light to which one is accustomed in the less clear skies of Northern Europe, the sight of the upright cross, standing as if fixed to the horizon, is a most impressive one. I at least found it so on my first voyage to the Cape of Good Hope. But how much more strongly must it have appealed to the mystic and superstitious minds of the early navigators as they entered the unexplored seas of the northern tropic! To them it must have appeared the revered image of the Cross pointing the way on their southward course—a symbol and sign of Hope and Faith on their entry to the unknown.

The first general knowledge of the brighter stars of the southern hemisphere we owe to Frederick de Hautman, who commanded a fleet sent by the Dutch Government in 1595 to the Far East for the purpose of exploring Japan. Hautman was wrecked and taken prisoner at Sumatra, and whilst there he studied the language of the natives and made observations of the positions and magnitudes of the fixed stars of the southern hemisphere.[1]

Our distinguished countryman Halley visited St. Helena in 1677 for the purpose of cataloguing the stars of the southern hemisphere. He selected a station now marked Halley's Mount on the Admiralty chart of the island. I have visited the site, and the foundations of the observatory still remain. Halley's observations were much hindered by cloud. On his return to England, Halley in 1679 published his "Catalogus Stellarum Australium," containing the magnitudes, latitudes, and longitudes of 341 stars, which, with the exception of seven, all belonged to the southern hemisphere.

But the first permanently valuable astronomical work in the southern hemisphere was done in 1751–2 by the Abbé de Lacaille. He selected the Cape of Good Hope as the scene of his labours, because it was then perhaps the only spot in the world situated in a considerable southern latitude which an unprotected astronomer could visit in safety, and where the necessary aid of trained artisans to erect his observatory could be obtained. Lacaille received a cordial welcome at the hands of the Dutch governor Tulbagh: he erected his observatory in Cape Town, made a catalogue of nearly 10,000 stars, observed the opposition of Mars, and measured a short arc of meridian all in the course of a single year. Through his labours the Cape of Good Hope became the birthplace of astronomy and geodesy in the southern hemisphere.

Bradley was laying the foundations of exact astronomy in the northern hemisphere at the time when Lacaille laboured at the Cape. But Bradley had superior instruments to those of Lacaille and much longer time at his disposal. Bradley's work is now the basis on which the fair superstructure of modern astronomy of precision rests. His labours were continued by his successors at Greenwich and by a long series of illustrious men like Piazzi, Groombridge, Bessel, Struve, and Argelander. But in the southern hemisphere the history of astronomy is a blank for seventy years from the days of Lacaille.

We owe to the establishment of the Royal Observatory at the Cape by an Order in Council of 1820 the first successful step towards the foundation of astronomy of high precision in the southern hemisphere.

Time does not permit me to trace in detail the labours of astronomers in the southern hemisphere down to the present day; and this is the less necessary because in a recent Presidential Address to the South African Philosophical Society[2] I have given in great part that history

[1] The resulting catalogue of 304 stars is printed as an appendix to Hautman's "Vocabulary of the Malay Language," published at Amsterdam in 1603.

[2] Trans. South African Phil. Soc., vol. xiv., part 2.

in considerable detail. But I have not there made adequate reference to the labours of Dr. Gould and Dr. Thome at Cordoba. To their labours, combined with the work done under Stone at the Cape, we owe the fact that for the epoch 1875 the meridian sidereal astronomy of the southern hemisphere is nearly as well provided for as that of the northern. The point I wish to make is that the facts of exact sidereal astronomy in the southern hemisphere may be regarded as dating nearly a hundred years behind those of the northern hemisphere.

The Constitution of the Universe.

It was not until 1718, when Edmund Halley, afterwards Astronomer Royal of England, read a paper before the Royal Society,[1] entitled "Considerations on the Change of the Latitudes of Some of the Principal Fixt Stars," that any definite facts were known about the constitution of the universe. In that paper Halley, who had been investigating the precession of the equinoxes, says: "But while I was upon this enquiry I was surprized to find the Latitudes of three of the principal Stars in heaven directly to contradict the supposed greater obliquity of the Ecliptick, which seems confirmed by the Latitudes of most of the rest."

This is the first mention in history of an observed change in the relative position of the so-called fixed stars—the first recognition of what we now call "proper motion."

Tobias Mayer, in 1760, seems to have been the first to recognise that if our Sun, like other stars, has motion amongst space, that motion must produce apparent motion amongst the surrounding stars; for in a paper to the Göttingen Academy of Sciences he writes: "If the Sun, and with it the planets and the Earth which we inhabit, tended to move directly towards some point in the heavens, all the stars scattered in that region would seem to gradually move apart from each other, whilst those in the opposite quarter would mutually approach each other. In the same manner one who walks in the forest sees the trees which are before him separate, and those that he leaves behind approach each other." No statement of the matter could be more clear; but Mayer, with the meagre data at his disposal, came to the conclusion that "the motions of the stars are not governed by the above or any other common law, but belong to the stars themselves."

Sir William Herschel, in 1783, made the first attempt to apply, with any measure of success, Mayer's principle to a determination of the direction and amount of the solar motion in space.[2] He derived, as well as he could from existing data, the proper motions of fourteen stars, and arrived by estimation at the conclusion that the Sun's motion in space is nearly in the direction of the star λ Herculis, and that 80 per cent. of the apparent motions of the fourteen stars in question could be assigned to this common origin.

This conclusion rests in reality upon a very slight basis, but the researches of subsequent astronomers show that it was an amazing accidental approach to truth—indeed, a closer approximation than Herschel's subsequent determinations of 1805 and 1806, which rested on wider and better data.[3]

Consider for a moment the conditions of the problem. If all the stars except our Sun were at rest in space, then, in accordance with Mayer's statement, just quoted, all the stars would have apparent motions on great circles of the sphere away from the apex and towards the antapex of the solar motion. That is to say, if the position of each star of which the apparent motion is known was plotted on the surface of a sphere and a line with an arrow-head drawn through each star showing the direction of its motion on the sphere, then it should be possible to find a point on the sphere such that a great circle drawn from this point through any star would coincide with the line of direction of that star's proper motion. The arrow-heads would all point to that intersection of the great circles which is the antapex of the solar motion, and the other point of intersection of the great circles would be the apex

1 Phil. Trans., 1718, p. 738.
2 *Ibid.*, 1783, p. 247.
3 *Ibid.*, 1805, p. 233; 1806, p. 205.

that is to say, the direction of the Sun's motion in space.

But as the apparent stellar motions are small and only determinable with a considerable percentage of error, it would be impossible to find any point on the sphere such that every great circle passing through it and any particular star, would in every case be coincident with the observed direction of motion of that star.

Such discordances would, on our original assumption, be due to errors of observation, but in reality much larger discordances will occur, which are due to the fact that the other stars (or suns) have independent motions of their own in space. This at once creates a new difficulty, viz., that of defining an absolute locus in space. The human mind may exhaust itself in the effort, but it can never solve the problem. We can imagine, for example, the position of the Sun at any moment to be defined with reference to any number of surrounding stars, but by no effort of imagination can we devise means of defining the *absolute* position of a body in space without reference to surrounding material objects. If, therefore, the referring objects have unknown motions of their own, the rigour of the definition is lost.

What we call the observed proper motion of a star has three possible sources of origin:—

(1) The *parallactic motion*, or the effect of our Sun's motion through space, whereby our point of view of surrounding celestial objects is changed.

(2) The *peculiar* or particular motion of the star, *i.e.*, its own *absolute* motion in space.

(3) That part of the observed or tabular motion which is due to inevitable error of observation.

In all discussions of the solar motion in space, from that of Herschel down till a recent date, it has been assumed that the peculiar motions of the stars are arranged at random, and may therefore be considered zero in the mean of a considerable number of them. It is then possible to find such a value for the Precession, and such a common apex for the solar motion as shall leave the residual peculiar motions of the stars under discussion to be in the mean = zero. That is to say, we refer the motion of the Sun in space to the centre of gravity of all the stars considered in the discussion, and regard that centre of gravity as immovable in space.

In order to proceed rigorously, and especially to determine the amount as well as the direction of the Sun's motion in space, we ought to know the parallax of every star employed in the discussion, as well as its proper motion. In the absence of such data it has been usual to start from some such assumption as the following: the stars of a particular magnitude are roughly at the same distance; those of different classes of magnitude may be derived from the hypothesis that on the average they have all equal absolute luminosity.

The assumption is not a legitimate one—

(1) Because of the extreme difference in the absolute luminosity of stars.

(2) Because it implies that the average absolute luminosity of stars is the same in all regions of space.

The investigation has been carried out by many successive astronomers on these lines with fairly accordant results as to the position of the solar apex, but with very unsatisfactory results as to the distances of the fixed stars.[1] In order to judge how far the magnitude (or brightness) of a star is an index of its probable distance, we must have evidence from direct determinations of stellar parallax.

Stellar Parallax.

To extend exact measurement from our own solar system to that of other suns and other systems may be regarded as the supreme achievement of practical astronomy. So great are the difficulties of the problem, so minute the

1 Argelander, *Mém. présentés à l'Acad. Imp. des Sciences St. Pétersbourg*, tome iii.; Lundahl, *Astron. Nachrichten*, 398, 200; Argelander, *Astron. Nachrichten*, 398, 210; Otto Struve, *Mém. Acad. des Sciences St. Pétersbourg*, vi^e série, Math. et Phys., tome iii., p. 17; Galloway, Phil. Trans., 1847, p. 79; Mädler, Dorpat Observations, vol. xiv., and *Ast. Nach.*, 566, 213; Airy, Mem. R.A.S., vol. xxviii., p. 143; Dunkin, Mem. R.A.S., vol. xxxii., p. 19; Stone, Monthly Notices R.A.S., vol. xxiv., p. 36; De Ball, Inaugural Dissertation, Bonn, 1877; Rancken, *Astron. Nachrichten*, 2482, 149; Bischoff, Inaugural Dissertation, Bonn, 1884; Ludwig Struve, *Mém. Acad. St. Pétersbourg*, vii^e série, tome xxxv., No. 3.

angles involved, that it is but in comparatively recent years that any approximate estimate could be formed of the true parallax of any fixed star. Bradley felt sure that if the star γ Draconis had a parallax of 1″ he would have detected it. Henderson by "the minute sifting of the numerical results" of his own meridian observations of α Centauri, made at the Cape of Good Hope in 1832–3, first obtained certain evidence of the measurable parallax of any fixed star. He was favoured in this discovery by the fact that the object he selected happened to be, so far as we yet know, the nearest sun to our own. Shortly afterwards Struve obtained evidence of a measurable parallax for α Lyræ and Bessel for 61 Cygni. Astronomers hailed with delight this bursting of the constraints which our imperfect means imposed on research. But for the great purposes of cosmical astronomy what we are chiefly concerned to know is not what is the parallax of this or that particular star, but rather what is the average parallax of a star having a particular magnitude and proper motion. The prospect of even an ultimate approximate attainment of this knowledge seemed remote. The star α Lyræ is one of the brightest in the heavens; the star 61 Cygni one that had the largest proper motion known at the time; whilst α_2 Centauri is not only a very bright star, but it has also a large proper motion. The parallaxes of these stars must therefore in all probability be large compared with the parallax of the average star; but yet to determine them with approximate accuracy long series of observations by the greatest astronomers and with the finest instruments of the day seemed necessary.

Subsequently various astronomers investigated the parallaxes of other stars having large proper motions, but it was only in 1881, at the Cape of Good Hope, that general research on stellar parallax was instituted.[1] Subsequently at Yale and at the Cape of Good Hope the work was continued on cosmical lines with larger and improved heliometers.[2] By the introduction of the reversing prism and by other practical refinements the possibilities of systematic error were eliminated, and the accidental errors of observation reduced within very small limits.

These researches brought to light the immense diversity in the absolute luminosity and velocity of motion of different stars. Take the following by way of example:—

Our nearest neighbour amongst the stars, α_2 Centauri, has a parallax of 0″·76, or is distant about 4⅓ light-years. Its mass is independently known to be almost exactly equal to that of our Sun; and its spectrum being also identical with that of our Sun, we may reasonably assume that it appears to us of the same magnitude as would our Sun if removed to the distance of α_2 Centauri.

But the average star of the same apparent magnitude as α_2 Centauri was found to have a parallax of only 0″·10, so that either α_2 Centauri or our Sun, if removed to a distance equal to that of the average fixed star of the first magnitude, would appear to us but little brighter than a star of the fifth magnitude.

Again, there is a star of only 8½ magnitude[3] which has the remarkable annual proper motion of nearly 8¾ seconds of arc—one of those so-called runaway stars—which moves with a velocity of 80 miles per second at right angles to the line of sight (we do not know with what velocity in the line of sight). It is at about the same distance from us as Sirius, but it emits but one ten-thousandth part of the light energy of that brilliant star. Sirius itself emits about thirty times the light-energy of our Sun, but it in turn sinks into insignificance when compared with the giant Canopus, which emits at least 10,000 times the light-energy of our Sun.

Truly "one star differs from another star in glory." Proper motion rather than apparent brightness is the truer indication of a star's probable proximity to the Sun. Every star of considerable proper motion yet examined has proved to have a measurable parallax.

This fact at once suggests the idea, Why should not the apparent parallactic motions of the stars, as produced by the Sun's motion in space, be utilised as a means of determining stellar parallax?

[1] Mem. R.A.S., vol. xlviii.
[2] Annals of the Cape Observatory, vol. viii., part ii., and Trans. Astron. Observatory of Yale University, vol. i.
[3] Gould's Zones, Vh 243

Secular Parallactic Motion of Stars.

The strength of such determinations, unlike those made by the method of annual parallax, would grow with time. It is true that the process cannot be applied to the determination of the parallax of individual stars, because the peculiar motion of a particular star cannot be separated from that part of its apparent motion which is due to parallactic displacement. But what we specially want is not to ascertain the parallax of the individual star, but the mean parallax of a particular group or class of stars, and for this research the method is specially applicable, provided we may assume that the peculiar motions are distributed at random, so that they have no systematic tendency in any direction; in other words, that the centre of gravity of any extensive group of stars will remain fixed in space.

This assumption is, of course, but a working hypothesis, and one which from the paper on star-streaming communicated by Prof. Kapteyn of Groningen to the Johannesburg meeting of the Association two years ago we already know to be inexact.[1] Kapteyn's results were quite recently confirmed in a remarkable way by Eddington,[2] using independent material discussed by a new and elegant method. Both results showed that, at least for extensive parts of space, there are a nearly equal number of stars moving in exactly opposite directions. The assumption, then, that the mean of the peculiar motions is zero may, at least for these parts of space, be still regarded as a good working hypothesis.

Adopting an approximate position of the apex of the solar motion, Kapteyn resolved the observed proper motions of the Bradley stars into two components, viz., one in the plane of the great circle passing through the star and the apex, the other at right angles to that plane.[3] The former component obviously includes the whole of the parallactic motion; the latter is independent of it, and is due entirely to the real motions of the stars themselves. From the former the mean parallactic motion of the group is derived, and from the combination of the two components, the relation of velocity of the Sun's motion to that of the mean velocity of the stars of the group.

As the distance of any group of stars found by the parallactic motion is expressed as a unit in terms of the Sun's yearly motion through space, the velocity of this motion is one of the fundamental quantities to be determined. If the mean parallax of any sufficiently extensive group or class of stars was known we should have at once means for a direct determination of the velocity of the Sun's motion in space; or if, on the other hand, we can by independent methods determine the Sun's velocity, then the mean parallax of any group of stars can be determined.

Determination of Stellar Motion in the Line of Sight.

Science owes to Sir William Huggins the application of Doppler's principle to the determination of the velocity of star-motion in the line of light. The method is now so well known, and such an admirable account of its theory and practical development was given by its distinguished inventor from this Chair at the Cardiff meeting in 1891, that further mention of that part of the matter seems unnecessary.

The Velocity of the Sun's Motion in Space.

If by this method the velocities in the line of sight of a sufficient number of stars situated near the apex and antapex of the solar motion could be determined, so that in the mean it could be assumed that their peculiar motions would disappear, we have at once a direct determination of the required velocity of the Sun's motion.

The material for this determination is gradually accumulating, and indeed much of it, already accumulated, is not yet published. But even with the comparatively scant material available, it now seems almost certain that the true value of the Sun's velocity lies between 18 and 20 kilometres per second;[4] or, if we adopt the mean value, 19 kilometres per second, this would correspond almost

[1] Rep. Brit. Assoc., 1905, p. 257.
[2] Monthly Notices R.A.S., vol. lxvii., p. 34.
[3] Publications Astron. Laboratory, Groningen, Nos. 7 and 9.
[4] Kapteyn, *Ast. Nach.*, No. 3487, p. 108; and Campbell, *Astrophys. Journ.*, xiii., p. 80.

exactly with a yearly motion of the Sun through space equal to four times the distance of the Sun from the Earth. Thus the Sun's yearly motion being four times the Sun's distance, the parallactic motion of stars in which this motion is unforeshortened must be four times their parallax. How this number varies with the amount of foreshortening is of course readily calculated. The point is that from the mean parallactic motion of a group of stars we are now enabled to derive at once its mean parallax.

This research has been carried out by Kapteyn for stars of different magnitudes. It leads to the result that the parallax of stars differing *five* magnitudes does *not* differ in the proportion of one to ten, as would follow from the supposition of equal luminosity of stars throughout the universe, but only in the proportion of about one to five.[1]

The same method cannot be applied to groups of stars of different proper motions, and it is only by a somewhat indirect proof, and by calling in the aid of such trustworthy results of direct parallax determination as we possess, that the variation of parallax with proper motion could be satisfactorily dealt with.

The Mean Parallaxes of Stars of Different Magnitude and Proper Motion.

As a final result Kapteyn derived an empirical formula giving the average parallax for stars of different spectral types, and of any given magnitude and proper motion. This formula was published at Groningen in 1901.[2] Within the past few months the results of researches on stellar parallax, made under the direction of Dr. Elkin, at the Astronomical Observatory of Yale University, during the past thirteen years,[3] have been published, and they afford a most crucial and entirely independent check on the soundness of Kapteyn's conclusions.

In considering the comparison between the more or less theoretical results of Kapteyn and the practical determinations of Yale, we have to remember that Kapteyn's tables refer only to the means of groups of a large number of stars having on the average a specified magnitude and proper motion, whilst the latter are direct determinations affected by the accidental errors of the separate determinations and by such uncertainty as attaches to the unknown parallaxes of the comparison stars—parallaxes which we have supplied from Kapteyn's general tables.

The Yale results consist of the determination of the parallax of 173 stars, of which only ten had been previously known to Kapteyn and had been utilised by him. Dividing these results into groups we get the following comparison:—

Comparison Groups arranged in order of Proper Motion.

No. of stars	Proper Motion	Magnitude	Parallax		Yale—Kapteyn
			Yale	Kapteyn	
	"		"	"	"
21	0·14	3·8	0·028	0·026	+0·002
39	0·49	6·3	0·042	0·055	−0·013
45	0·59	6·7	0·068	0·060	+0·008
46	0·77	6·5	0·047	0·074	−0·027
22	1·50	6·2	0·118	0·124	−0·006

Groups arranged in order of Magnitude.

No. of stars	Proper Motion	Magnitude	Parallax		Yale—Kapteyn
			Yale	Kapteyn	
	"		"	"	"
10	0·61	0·8	0·103	0·110	−0·007
29	0·53	3·8	0·076	0·075	+0·001
33	0·63	5·6	0·064	0·070	0·006
34	0·73	6·7	0·055	0·070	−0·017
31	0·68	7·6	0·025	0·061	−0·036
36	0·80	8·3	0·056	0·062	−0·006

[1] *Astron. Nachrichten*, No. 3487, table iii.; and *Ast. Journ.*, p. 566.
[2] Publications Astron. Laboratory, Groningen, No. 8, p. 24.
[3] Trans. Astron. Observatory of Yale Univ., vol. ii., part i.

—	No. of stars	Proper Motion	Magnitude	Parallax		Yale—Kapteyn
				Yale	Kapteyn	
		"		"	"	"
Spectral Type I.	13	0·42	4·0	0·076	0·076	0·000
,, ,, II.	81	0·67	5·3	0·067	0·074	−0·007

These results agree in a surprisingly satisfactory way, having regard to the comparatively small number of stars in each group and the great range of parallax which we know to exist amongst individual stars having the same magnitude and proper motion. In the mean perhaps the tabular parallaxes are in a minute degree too large, but we have unquestionable proof from this comparison that our knowledge of stellar distances now rests on a solid foundation.

The Distribution of Varieties of Luminosity of Stars.

But, besides the mean parallax of stars of a particular magnitude and proper motion, it is essential that we should know approximately what percentage of the stars of such a group have twice, three times, &c., the mean parallax of the group, and what percentage only one-half, one-third of that parallax, and so on. In principle, at least, this frequency-law may be obtained by means of the directly determined parallaxes. For the stars of which we have trustworthy determinations we can compare these true parallaxes with the *mean* parallax of stars having corresponding magnitude and proper motion, and this comparison will lead to a knowledge of the frequency-law required. It is true that, owing to the scarcity of material at present available, the determination of the frequency-law is not so strong as may be desirable, but further improvement is simply a question of time and the augmentation of parallax-determination.

Adopting provisionally the frequency-law found in this way by Kapteyn,[1] we can localise all the stars in space down to about the ninth magnitude.

Take, for example, the stars of magnitude 5·5 to 6·5. There are about 4800 of these stars in the whole sky. According to Auwers-Bradley, about 9½ per cent. of these stars, or some 460 in all, have proper motions between 0″·04 and 0″·05. Now, according to Kapteyn's empiric formula, the satisfactory agreement of which with the Yale results has just been shown, the mean parallax of such stars is almost exactly 0″·01. Further, according to his frequency-law, 29 per cent. of the stars have parallaxes between the *mean* value and double the mean value; 6 per cent. have parallaxes between twice and three times the mean value; 1½ per cent. between three and four times the mean value. Therefore of our 460 stars 133 will have parallaxes between 0″·01 and 0″·02, twenty-eight between 0″·02 and 0″·03, seven between 0″·03 and 0″·04, and so on.

Localising in the same way the stars of the sixth magnitude having other proper motions, and then treating the stars of the first magnitude, second magnitude, third magnitude, and so on to the ninth magnitude in the same way, we finally locate all these stars in space.[2]

It is true we have not localised the individual stars, but we know approximately and within certain limits of magnitude the number of stars at each distance from the Sun.

Thus the apparent brightness and the distance being known we have the means of determining the light-energy or absolute *luminosity* of the stars, *provided it can be assumed that light does not suffer any extinction in its passage through interstellar space.*

On this assumption Kapteyn was led to the following results, viz., that within a sphere the radius of which is 560 light-years (a distance which corresponds with that of the average star of the ninth magnitude) there will be found:—

[1] Publications Astron. Lab., Groningen No. 8, p. 23.
[2] *Ibid.*, No. 11, table ii.

					Times the light of our Sun
1 star giving from	100,000	to	10,000		
26 stars	,,	10,000	,,	1,000	
1,300 ,,	,,	1,000	,,	100	
22,000 ,,	,,	100	,,	10	
140,000 ,,	,,	10	,,	1	
430,000 ,,	,,	1	,,	0·1	
650,000 ,,	,,	0·1	,,	0·01	

The Density of Stellar Distribution at Different Distances from our Sun.

Consider, lastly, the distribution of stellar density, that is, the number of stars contained in the unit of volume.

We cannot determine *absolute* star-density, because, for example, some of the stars which we know from their measured parallaxes to be comparatively near to us are in themselves so little luminous that if removed to even a few light-years greater distance they would appear fainter than the ninth magnitude, and so fall below the magnitude at which our data at present stop.

But if we assume that intrinsically faint and bright stars are distributed in the same proportion in space, it will be evident that the comparative richness of stars in any part of the system will be the same as the comparative richness of the same part of the system in stars of a particular luminosity. Therefore, as we have already found the arrangement in space of the stars of different degrees of luminosity, and consequently their number at different distances from the Sun, we must also be able to determine their relative density for these different distances.

Kapteyn finds in this way that, starting from the Sun, the star-density (*i.e.*, the number of stars per unit volume of space) is pretty constant until we reach a distance of some 200 light-years. Thence the density gradually diminishes until, at about 2500 light-years, it is only about *one-fifth* of the density in the neighbourhood of the Sun.[1] This conclusion must, however, be regarded as uncertain until we have by independent means been enabled to estimate the absorption of light in its course through interstellar space, and obtained proof that the ratio of intrinsically faint to bright stars is constant throughout the universe.

Thus far Kapteyn's researches deal with the stellar universe as a whole; the results, therefore, represent only the *mean* conditions of the system. The further development of our knowledge demands a like study applied to the several portions of the universe separately. This will require much more extensive material than we at present possess.

As a first further approximation the investigation will have to be applied separately to the Milky Way and the parts of the sky of higher galactic latitude. The velocity and direction of the Sun's motion in space may certainly be treated as constants for many centuries to come, and these constants may be separately determined from groups of stars of various regions, various magnitudes, various proper motions, and various spectral types. If these constants as thus separately determined are different, the differences which are not attributable to errors of observation must be due to a common velocity or direction of motion of the group or class of star to which the Sun's velocity or direction is referred. Thus, for example, the Sun's velocity as determined by spectroscopic observations of motion in the line of sight appears to be sensibly smaller than that derived from fainter stars. The explanation appears to be that certain of the brighter stars form part of a cluster or group of which the Sun is a member, and these stars tend to some extent to travel together. For these researches the existing material, especially that of the determination of velocities in the line of sight, is far too scanty.

Kapteyn has found that stars the proper motions of which exceed 0″·05 are not more numerous in the Milky Way than in other parts of the sky;[2] in other words, if only the stars having proper motions of 0″·05 or upwards were mapped there would be no aggregation of stars showing the existence of a Milky Way.

The proper motions of stars of the second spectral type are, as a rule, considerably larger than those of the first type; but Kapteyn comes to the conclusion that this difference does not mean a real difference of velocity, but only that the second-type stars have a smaller luminosity, the mean difference between the two types amounting to 2½ magnitudes.[1]

The Future Course of Research.

In the last Address delivered from this Chair on an astronomical subject, Sir William Huggins, in 1891, dealt so fully with the chemistry of the stars that it seemed fitting on the present occasion to consider more especially the problem of their motion and distribution in space, as it is in this direction that the most striking advances in our knowledge have recently been made. It is true that since 1891 great advances have also been made in our detailed knowledge of the chemistry of the Sun and stars. The methods of astro-spectrography have been greatly improved, the precision of the determination of motion in the line of sight greatly enhanced, and many discoveries made of those close double stars, ordinarily termed spectroscopic doubles, the study of which seems destined to throw illustrative light upon the probable history of the development of systems from the original nebular condition to that of more permanent systems.

But the limitations of available time prevent me from entering more fully into this tempting field, more especially as it seems desirable, in the light of what has been said, to indicate the directions in which some of the astronomical work of the future may be most properly systematised. There are two aspects from which this question may be viewed. The first is the more or less immediate extension of knowledge or discovery; the second the fulfilment of our duty, as astronomers, to future generations. These two aspects should never be entirely separated. The first, as it opens out new vistas of research and improved methods of work, must often serve as a guide to the objects of the second. But the second is to the astronomer the supreme duty, viz., to secure for future generations those data the value of which grows by time.

As the result of the Congress of Astronomers held at Paris in 1887 some sixteen of the principal observatories in the world are engaged, as is well known, in the laborious task, not only of photographing the heavens, but of measuring these photographs and publishing the *relative* positions of the stars on the plates down to the eleventh magnitude. A century hence this great work will have to be repeated, and then, if we of the present day have done our duty thoroughly, our successors will have the data for an infinitely more complete and thorough discussion of the motions of the sidereal system than any that can be attempted to-day. But there is still needed the accurate meridian observation of some eight or ten stars on each photographic plate, so as to permit the conversion of the *relative* star-places on the plate into *absolute* star-places in the heavens. It is true that some of the astronomers have already made these observations for the reference stars of the zones which they have undertaken. But this seems to be hardly enough. In order to coordinate these zones, as well as to give an accuracy to the *absolute* positions of the reference stars corresponding with that of the *relative* positions, it is desirable that this should be done for *all* the reference stars in the sky by several observatories. The observations of well-distributed stars by Kustner at Bonn present an admirable instance of the manner in which the work should be done. Several observatories in each hemisphere should devote themselves to this work, employing the same or other equally efficient means for the elimination of sources of systematic error depending on magnitude, &c., and it is of far more importance that we should have, say, two or three observations of each star at three different observatories than two or three times as many observations of each star made at a single observatory.

The southern cannot boast of a richness of instrumental and personal equipment comparable with that of the northern hemisphere, and consequently one welcomes with enthusiasm the proposal on the part of the Carnegie Institute to establish a meridian observatory in a suitable

1 Publications Astron. Lab., Groningen, No. 11.

2 Verl. Kn. Akad. Amsterdam, January, 1893.

1 *Ibid.*, April, 1892.

situation in the southern hemisphere. Such an observatory, energetically worked, with due attention to all necessary precautions for the exclusion of systematic errors, would conduce more than anything else to remedy in some degree that want of balance of astronomical effort in the two hemispheres to which allusion has already been made. But in designing the programme of the work it should be borne in mind that the proper duty of the meridian instrument in the present day is no longer to determine the positions of all stars down to a given order of magnitude, but to determine the positions of stars which are geometrically best situated and of the most suitable magnitude for measurement on photographic plates, and to connect these with the fundamental stars. For this purpose the working list of such an observatory should include only the fundamental stars and the stars which have been used as reference stars for the photographic plates.

Such a task undertaken by the Carnegie Observatory, by the Cape, and if possible by another observatory in the southern hemisphere, and by three observatories in the northern, would be regarded by astronomers of the future as the most valuable contribution that could be made to astronomy of the present day. Taken in conjunction with the astrographic survey of the heavens now so far advanced, it is an opportunity that if lost can never be made good; a work that would grow in value year by year as time rolls on, and one that would ever be remembered with gratitude by the astronomers of the future.

But for the solution of the riddle of the universe much more is required. Besides the proper motions, which would be derived from the data just described, we need for an ideal solution to know the velocity in the line of sight, the parallax, the magnitude, and the spectrum-type of every star.

The broad distinction between these latter data and the determination of proper motion is this, that whereas the observations for proper motion increase in value as the square of their age, those for velocity in the line of sight, parallax, magnitude, and type of spectrum may, for the broader purposes of cosmical research, be made at any time without loss of value. We should therefore be most careful not to sacrifice the interests of the future by immediate neglect of the former for the latter lines of research. The point is that those observatories which undertake this meridian work should set about it with the least possible delay, and prosecute the programme to the end with all possible zeal. Three observatories in each hemisphere should be sufficient; the quality of the work should be of the best, and quality should not be sacrificed for speed of work.

But the sole prosecution of routine labour, however high the ultimate object, would hardly be a healthy condition for the astronomy of the immediate future. The sense of progress is essential to healthy growth, the desire to know must in some measure be gratified. We have to test the work that we have done in order to be sure that we are working on the right lines, and new facts, new discoveries, are the best incentives to work.

For these reasons Kapteyn, in consultation with his colleagues in different parts of the world, has proposed a scheme of research which is designed to afford within a comparatively limited time a great augmentation of our knowledge. The principle on which his programme is based is that adequate data as to the proper motions, parallaxes, magnitudes, and the type of spectrum of stars situated in limited but symmetrically distributed areas of the sky, will suffice to determine many of the broader facts of the constitution of the universe. His proposals and methods are known to astronomers and need not therefore be here repeated. In all respects save one these proposals are practical and adequate, and the required cooperation may be said to be already secured—the exception is that of the determination of motion in the line of sight.

All present experience goes to show that there is no known satisfactory method of determining radial velocity of stars by wholesale methods, but that such velocities must be determined star by star. For the fainter stars huge telescopes and spectroscopes of comparatively low dispersion must be employed. On this account there is great need in both hemispheres of a huge reflecting telescope—six to eight feet in aperture—devoted almost exclusively to this research. Such a telescope is already in preparation at Mount Wilson, in America, for use in the northern hemisphere. Let us hope that Prof. Pickering's appeal for a large reflector to be mounted in the southern hemisphere will meet with an adequate response, and that it will be devoted there to this all-important work.

Conclusion.

The ancient philosophers were confident in the adequacy of their intellectual powers alone to determine the laws of human thought and regulate the actions of their fellow men, and they did not hesitate to employ the same unsupported means for the solution of the riddle of the universe. Every school of philosophy was agreed that some object which they could see was a fixed centre of the universe, and the battle was fought as to what that centre was. The absence of facts, their entire ignorance of methods of exact measurement, did not daunt them, and the question furnished them a subject of dispute and fruitless occupation for twenty-five centuries.

But astronomers now recognise that Bradley's meridian observations at Greenwich, made only 150 years ago, have contributed more to the advancement of sidereal astronomy than all the speculations of preceding centuries. They have learned the lesson that human knowledge in the slowly developing phenomena of sidereal astronomy must be content to progress by the accumulating labours of successive generations of men; that progress will be measured for generations yet to come more by the amount of honest, well-directed, and systematically discussed observation than by the most brilliant speculation; and that, in observation, concentrated systematic effort on a special thoughtfully selected problem will be of more avail than the most brilliant but disconnected work.

By these means we shall learn more and more of the wonders that surround us, and recognise our limitations when measurement and facts fail us.

Huggins's spectroscope has shown that many nebulæ are not stars at all; that many well-condensed nebulæ, as well as vast patches of nebulous light in the sky, are but inchoate masses of luminous gas. Evidence upon evidence has accumulated to show that such nebulæ consist of the matter out of which stars (*i.e.*, suns) have been and are being evolved. The different types of star spectra form such a complete and gradual sequence (from simple spectra resembling those of nebulæ onwards through types of gradually increasing complexity) as to suggest that we have before us, written in the cryptograms of these spectra, the complete story of the evolution of suns from the inchoate nebula onwards to the most active sun (like our own), and then downward to the almost heatless and invisible ball. The period during which human life has existed on our globe is probably too short—even if our first parents had begun the work—to afford observational proof of such a cycle of change in any particular star; but the fact of such evolution, with the evidence before us, can hardly be doubted. I most fully believe that, when the modifications of terrestrial spectra under sufficiently varied conditions of temperature, pressure, and environment have been further studied, this conclusion will be greatly strengthened. But in this study we must have regard also to the spectra of the stars themselves. The stars are the crucibles of the Creator. There we see matter under conditions of temperature and pressure and environment, the variety of which we cannot hope to emulate in our laboratories, and on a scale of magnitude beside which the proportion of our greatest experiment is less than that of the drop to the ocean. The spectroscopic astronomer has to thank the physicist and the chemist for the foundation of his science, but the time is coming—we almost see it now—when the astronomer will repay the debt by wide-reaching contributions to the very fundamenta of chemical science.

By patient, long-continued labour in the minute sifting of numerical results, the grand discovery has been made that a great part of space, so far as we have visible knowledge of it, is occupied by two majestic streams of stars travelling in opposite directions. Accurate and minute measurement has given us some certain knowledge as to the distances of the stars within a certain limited portion of space, and in the cryptograms of their spectra has been deciphered the amazing truth that the stars of both streams are alike in design, alike in chemical constitution, and alike in process of development.

But whence have come the two vast streams of matter out of which have been evolved these stars that now move through space in such majestic procession?

The hundreds of millions of stars that comprise these streams, are they the sole ponderable occupants of space? However vast may be the system to which they belong, that system itself is but a speck in illimitable space; may it not be but one of millions of such systems that pervade the infinite?

We do not know.

"Canst thou by searching find out God? canst thou find out the Almighty unto perfection?"

SECTION A.

MATHEMATICS AND PHYSICS.

Opening Address by Prof. A. E. H. Love, M.A., D.Sc., F.R.S., President of the Section.

I propose to use the opportunity afforded by this Address to explain a dynamical theory of the shape of the earth, or, in other words, of the origin of continents and oceans.

The theory which has for more than a century been associated with the phrase "the figure of the earth" is the theory of the shape of the surface of the ocean. Apart from waves and currents, this surface is determined by the condition that there is no up and down upon it. This condition does not mean that the surface is everywhere at the same distance from the centre of the earth, or even that it is everywhere convex, but that a body moving upon it neither rises against, nor falls in the direction of, gravity (modified by the rotation). A surface which has this character is called an equipotential surface, and the surface of the ocean coincides with part of an equipotential surface under gravity modified by the rotation. This particular equipotential surface runs underground beneath the continents. It is named the "geoid." The height of a place above sea-level means its height above the geoid. If we knew the distribution of density of the matter within the earth it would be a mathematical problem to determine the form of the geoid. As we do not know this distribution we have recourse to an indirect means of investigation, and the chief instrument of research is the pendulum. The time of vibration of a pendulum varies with the place where it is swung, and from the observed times we deduce the values of gravity at the various places, and it was shown many years ago by Stokes that the shape of the geoid can be inferred from the variation of gravity over the surface.

The question to which I wish to invite your attention is a different one. If the ocean could be dried up, the earth would still have a shape. What shape would it be? Why should the earth have that shape rather than some other? In order to describe the shape we may imagine that we try to make a model of it. If we could begin with a model of the geoid we should have to attach additional material over the parts representing land and to remove some material over the parts representing sea. Our model would have to be as big as a battleship if the elevations and depressions were to be as much as 3 or 4 inches. In thinking out the construction of such a model we could not fail to be impressed by certain general features of the distribution of continent and ocean, and we may examine a map to discover such features. Fig. 1 is a rough map of the world drawn in such a way that to every degree of latitude or of longitude there corresponds the same distance on the map. Certain very prominent features have often been remarked: the tapering of America and Africa towards the south, the disproportion between the land areas of the northern and southern hemispheres, the excess of the oceanic area above the continental area, which occupies but little more than one-quarter of the surface; the wide extent of the Pacific Ocean, which with the adjoining parts of the Southern Ocean covers nearly two-fifths of the surface. Another prominent feature is the antipodal position of continent and ocean. South America south of an irregular line which runs from a point near Lake Titicaca to Buenos Ayres is antipodal to a portion of Asia which lies in an irregular triangle with corners near Bangkok, Kiaochau, and Lake Baikal; but no other considerable parts of the continental system have continental antipodes. The Antarctic continent is antipodal to the Arctic Ocean, Australia is antipodal to the central Atlantic, and so on. Another notable feature is the skew position of South America to the east of North America; South America lies to the east of the meridian 85° west of Greenwich; most of North America lies to the west of it. But although we may observe prominent general features of the distribution, we should find it far from easy to attribute to the form of our imaginary model any-

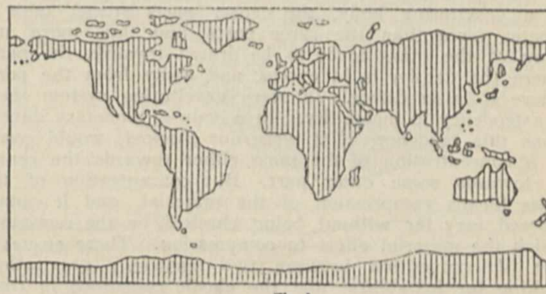


Fig. 1.

thing that could be called a regular geometrical figure. When we begin to think about the removal of material from the parts of the model which are to represent oceans and seas, we require a map which gives information about the depth of the sea in different places. Around all the coasts there is a margin of not very deep water. If some part of the sea could be dried up, so that more land was exposed around all the coasts, the area of the surface of the sea would be diminished; and it is known that the depth of water that would have to be removed in order to make the area of the sea just half the total area is about 1400 fathoms. The contour-line at this depth would divide the surface into two regions of approximately equal area—the continental region and the oceanic region. Fig. 2 represents the contour-line at 1400 fathoms, or the

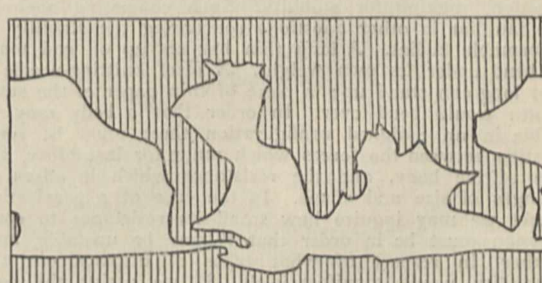


Fig. 2.

line of separation of the continental and oceanic regions. The continental region is shaded. In drawing this map I have omitted a number of small islands, and I have also omitted a few enclosed patches of deep water. Two of these are in the Mediterranean, one in the Arctic Ocean, and others are in the Gulf of Mexico and the Caribbean Sea. The Red Sea, the Mediterranean, and the Arctic Ocean belong to the continental region, and so do the Gulf of Mexico and the Caribbean Sea. At this depth Asia and North America are joined across Behring's Strait, and Europe is joined to North America across the British Isles, Iceland, and Greenland; Australia is joined to Asia through Borneo and New Guinea, and the Australasian continental region nearly reaches the Antarctic region by way of New Zealand. At this depth also South America does not taper to the south, but spreads out, and is separated from the Antarctic region by a very narrow channel. By going down to great depths our problem is very much simplified. We find that the surface of the earth can be divided into continental and oceanic regions of approximately equal area by a curve which approaches a regular geometrical shape. By smoothing away the irregularities we obtain the curve shown in Fig. 3, which exhibits the surface as divided up into a continuous continental region and two oceanic regions—the basin of the Pacific Ocean and the basin of the Atlantic and Indian Oceans. We may take our problem to be this: to account on dynamical grounds for the separation of the surface into a continental region and two oceanic regions which are approximately of this shape.

The key of the problem was put into our hands four years ago by Jeans in his theory of gravitational instability. If there are any differences of density in different parts of a gravitating body, the denser parts attract with a greater force than the rarer parts, and thus more and more of the mass tends to be drawn towards the parts where the density is in excess, and away from the parts where it is in defect. In every gravitating system there is a tendency to instability. In a body of planetary dimensions this tendency, if it were not checked, would result in a concentration of the mass either towards the centre or towards some other part. But concentration of the mass means compression of the material, and it cannot proceed very far without being checked by the resistance which the material offers to compression. There ensues a sort of competition between two agencies: gravitation, making for instability, and the elastic resistance to compression, making for stability. Such competing agencies are familiar in other questions concerning the stability of deformable bodies. A long thin bar set up on end tends to bend under its own weight. A steel knitting-needle a foot long can stand up; a piece of thin paper of the same length would bend over. In order that a body may be stable in an assigned configuration there must be some relation between the forces which make for instability, the size of the body, and the resistance which it offers to changes of size and shape. In the case of a gravitating planet we may inquire how small its resistance to compression must be in order that it may be unstable, and, further, in respect of what types of displacement the instability would manifest itself. If we assign the constitution of the planet, the inquiry becomes a definite mathematical problem. The greatest difficulty in the problem arises from the enormous stresses which are developed within such a body as the earth by the mutual gravitation of its parts. The earth is in a state which is described technically as a state of "initial stress." In the ordinary theory of the mechanics of deformable bodies a body is taken to be strained or deformed when there is any stress in it, and the strain is taken to be porportional to the stress. This method amounts to measuring the strain or deformation from an ideal state of zero stress. If the ideal state is unattainable without rupture or permanent set or overstrain, the body is in a state of initial stress. The commonest example is a golf ball made of india-rubber tightly wound at a high tension. Now the problem of gravitational instability can be solved for a planet of the size of the earth on the suppositions that the density is uniform and the initial stress is hydrostatic pressure. If the resistance to compression is sufficiently small the body is unstable, both as regards concentration of mass towards the centre and as regards displacements by which the density is increased in one hemisphere and diminished in the other. A planetary body of sufficiently small resistance to compression could not exist in the form of a homogeneous sphere. It could exist in a state in which the surface is very nearly spherical, and the mass is arranged in a continuous series of nearly spherical thin sheets, each of constant density; but these sheets would not be concentric. They would be crowded together towards one side and spaced out on the opposite side somewhat in the manner shown in Fig. 4. The effect would be a displacement of the centre of gravity away from the centre of figure towards the side where the sheets are crowded together. How small must the resistance to compression be in order that this state may be assumed by the body instead of a homogeneous state? The answer is that, if the body has the same size and mass as the earth, the material must be as compressible as granite. Granite, as we know it at the earth's surface, is not a typically compressible material. A cube of granite 10 feet every way could be compressed from its volume of 1000 cubic feet to a volume of 999 cubic feet by pressure applied to every part of its surface; but according to the recent measurements of Adams and Coker the pressure would have to be rather more than two tons per square inch. A homogeneous sphere of the same size and mass as the earth, made of a material as nearly incompressible as granite, could not exist; it would be gravitationally unstable. The body would take up some such state of aggregation as that illustrated in Fig. 4, and its centre of gravity would have an eccentric position.

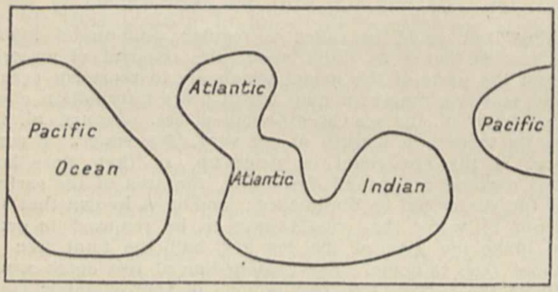


Fig.3.

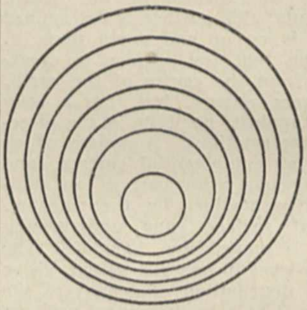


Fig.4.

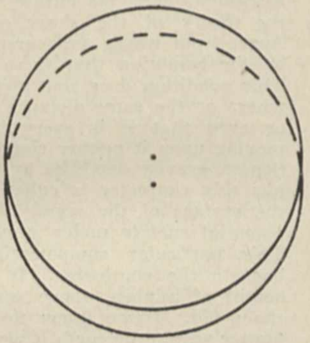


Fig.5.

Now how would an ocean rest on a gravitating sphere of which the centre of gravity does not coincide with the centre of figure? Its surface would be a sphere with its centre at the centre of gravity (Fig. 5). The oceanic region would be on one side of the sphere and the continental region on the other side. It was pointed out many years ago by Pratt that the existence of the Pacific Ocean shows that the centre of gravity of the earth does not coincide with the centre of figure. There is no necessity to invoke some great catastrophe to account for the existence of the Pacific Ocean, or to think of it as a kind of pit or scar on the surface of the earth. The Pacific Ocean resembles nothing so much as a drop of water adhering to a greasy shot. The force that keeps the drop in position is surface tension. The force that keeps the Pacific Ocean on one side of the earth is gravity, directed more towards the centre of gravity than the centre of figure. An adequate cause for the eccentric position of the centre of gravity is found in the necessary state of aggregation which the earth must have had if at one time it was as compressible as granite. The theory of gravitational instability accounts for the existence of the Pacific Ocean.

But we can go much further than this in the direction of accounting for the continental and oceanic regions. We keep in mind the eccentric position of the centre of gravity, and try to discover the effect of rotation upon a planet of which the centre of gravity does not coincide with the centre of figure. The shape of a rotating planet must be nearly an oblate spheroid; but the figure of the ocean would, owing to its greater mobility, be rather more protuberant at the equator than the figure of the planet on which it rests. The primary effect of the rotation of the earth upon the distribution of continent and ocean is to draw the ocean towards the equator, so as to tend to expose the Arctic and Antarctic regions. We have seen that both Arctic and Antarctic are parts of the continental region. But there is an important secondary effect. Under the influence of the rotation the parts of greater density tend to recede further from the axis than the parts of less density. If the density is greater in one hemispheroid than in the other, so that the position of the centre of gravity is eccentric, the effect must be to produce a sort of furrowed surface; and the amount of elevation and depression so produced can be described by an exact mathematical formula. It has been proved that this formula is a sort of expression which mathematicians name a spherical harmonic of the third degree.

The shape of the earth is also influenced by another circumstance. We know that at one time the moon was much nearer to the earth than it is now, and that the two bodies once rotated about their common centre of gravity almost as a single rigid system. The month was nearly as short as the day, and the moon was nearly fixed in the sky. The earth must then have been drawn out towards the moon, so that its surface was more nearly an ellipsoid with three unequal axes than it is now. The primary effect of the ellipsoidal condition upon the distribution of continent and ocean would be to raise the surface above the ocean near the opposite extremities of the greatest diameter of the equator. But, again, owing to the eccentric position of the centre of gravity, there would be an important secondary effect. The gravitational attraction of an ellipsoid differs from that of a sphere, and it may be represented as the attraction of a sphere together with an additional attraction. If the density was greater in one hemi-ellipsoid than in the other, the additional attraction would produce a greater effect in the parts where the density was in excess, and the result, just as in the case of rotation, would be a furrowing of the surface. It has been proved that the formula for this furrowing also is expressed by a spherical harmonic of the third degree.

We are brought to the theory of spherical harmonics and the spherical harmonic analysis. Spherical harmonics are certain quantities which vary in a regular fashion over the surface of a sphere, becoming positive in some parts and negative in others. I spoke just now of making a model of a nearly spherical surface by removing material from some parts and heaping it up on others. Spherical harmonics specify standard patterns of deformation of spheres. For instance, we might remove material over one hemisphere down to the surface of an equal but not concentric sphere (*cf.* Fig. 5) and heap up the material over the other hemisphere. We should produce a sphere equal to the original but in a new position. The formula for the thickness of the material removed or added is a spherical harmonic of the first degree. It specifies the simplest standard pattern of deformation. Again, we might remove material from some parts of our model and heap it up on other parts so as to convert the sphere into an ellipsoid. The formula for the thickness of that which is removed or added is a spherical harmonic of the second degree. Deformation of a sphere into an ellipsoid is the second standard pattern of deformation. The mathematical method of determining the appropriate series of standard patterns is the theory of spherical harmonics. Its importance arises from the result that any pattern whatever can be reached by first making the deformation according to the first pattern, then going on to make the deformation according to the second pattern, and so on. If we begin with a pattern, for instance the shape of the earth, which is not a standard pattern, we can find out how great a deformation of each standard pattern must be made in order to reproduce the prescribed pattern. The method of doing this is the method of spherical harmonic analysis. Except in very simple cases the application of it involves rather tedious computations. With much kind assistance and encouragement from Prof. Turner, I made a rough spherical harmonic analysis of the earth's surface. I divided the surface into 2592 small areas, rather smaller on the average than Great Britain. gave them the value +1, or one unit of elevation, if they are above the sea, and the value −1, or one unit of depression, if they are below the 1400-fathom line. To the intermediate areas I gave the value 0. The distribution of the numbers over the surface was analysed for spherical harmonics of the first, second, and third degrees.

Any spherical harmonic of the first degree gives us a division of the surface into two hemispheres—one elevated, the other depressed. The spherical harmonic analysis informs us as to the position of the great circle which separates the two hemispheres, and also as to the ratio of the maximum elevation of this pattern to the maximum elevation of any other pattern. The central region of greatest elevation of this pattern is found to be in the neighbourhood of the Crimea, and the region of elevation

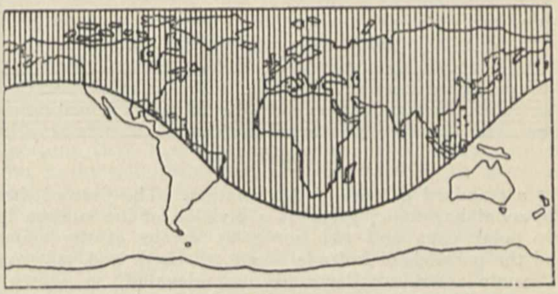


Fig. 6.

contains the Arctic Ocean and the northern and central parts of the Atlantic, Europe, Africa, Asia, most of North America, and a small part of South America. When the surface is mapped on a rectangle in the same way as before, the chart of the harmonic is that shown in Fig 6.[1] The actual disproportion between the amounts of continental area in the northern and southern hemispheres is associated with the result that the central region of elevation, as given by the analysis, is about 45° north of the equator; and the extension of the Pacific Ocean and adjoining Southern Ocean to much higher southern than northern latitudes is associated with the corresponding position of the central region of greatest depression about 45° south of the equator. In regard to harmonics of the second degree, the spherical harmonic analysis informs us as to the ellipticity of the equator and the obliquity of

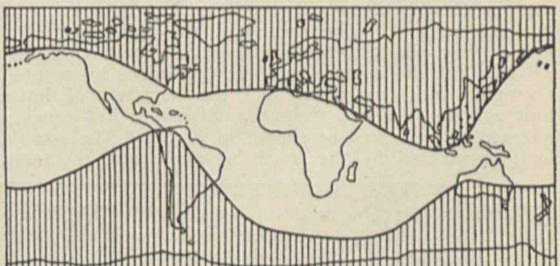


Fig. 7.

the principal planes of that ellipsoid which most nearly represents the elevation of the surface above or its depression below the surface of the ocean, or the geoid. The result is an equatorial region of depression, which spreads north and south unequally in different parts and forms a sort of immense Mediterranean, containing two great basins, and separating a northern region of elevation from a southern. The northern region of elevation occupies the northern part of the Atlantic Ocean and runs down to and across the equator in the neighbourhood of Borneo. The southern region of elevation occupies the southern part of the Pacific Ocean, and it runs up to and across the equator in the neighbourhood of Peru. The chart of the harmonic is shown in Fig. 7. The equatorial regions

[1] In this figure, and in the following figures, regions of elevation are shaded, and regions of depression are left blank.

of elevation given by the analysis are near the ends of a diameter, as we should expect.

It has not been necessary to enter into a minute description of the harmonics of the first and second degrees, because they represent very simple things—a shifting of the surface to one side and a distortion of it into an ellipsoid. The harmonics of the third degree are not so familiar. There are essentially four of them, each specify-

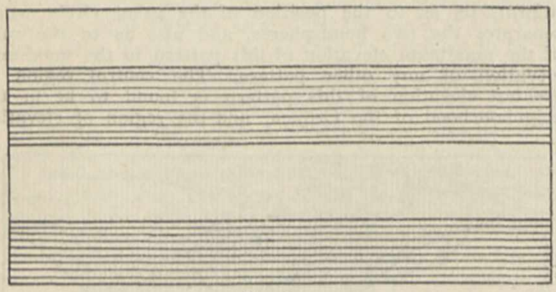


Fig.8.

ing a standard pattern of deformation. The first of these, the zonal harmonic, gives us a division of the surface into two polar caps and two zones by means of the equator and the parallels of latitude about 51° north and 51° south. Alternate zones are depressed and elevated, as shown in Fig. 8. The existence of an Antarctic continent and an Arctic Ocean is specially associated with the presence of this harmonic, and the disproportion of the continental

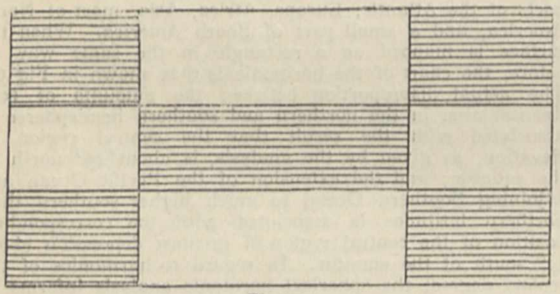


Fig.9.

areas in the northern and southern hemispheres is also connected with it. The second of the harmonics of the third degree, the tesseral harmonic of rank 1, gives us a division of the surface into six half-zones by means of a complete meridian circle and the parallels of latitude about 27° north and 27° south. Alternate half-zones are depressed and elevated as shown in Fig. 9. The combined effect represented by the zonal harmonic and the tesseral

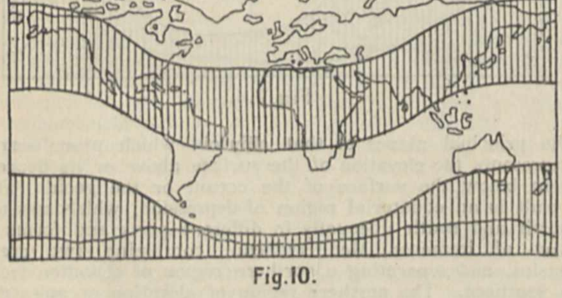


Fig.10.

harmonic of rank 1 is a furrowed surface with an Arctic region of depression extending southwards in the direction of the Atlantic, a zone of elevation which runs across the Atlantic, South America, and Africa, and then turns northwards at either end, a zone of depression with the same kind of contour, and an Antarctic region of elevation which extends northwards in the direction of Australasia. These regions are shown in Fig. 10. I have recorded the result of combining these two harmonics because they represent the particular effects that would be produced by the interaction of two causes—the rotation, and the eccentric position of the centre of gravity. The third type of harmonics of the third degree, the tesseral harmonic of rank 2, gives us a division of the surface into octants by means of the equator and two complete meridian circles. Alternate octants are elevated and depressed as shown in Fig. 11. We

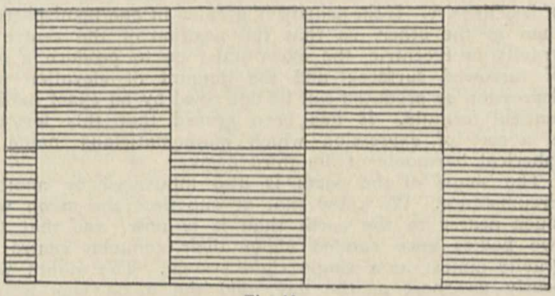


Fig.11.

can name the octants where there is elevation: Asia, Australasia, North America, South America. The harmonic of this type is certainly prominent. It is specially associated with the skew position of South America to the east of North America. The fourth type of harmonics of the third degree, the sectorial harmonic, gives us a division of the surface into six sectors by means of three complete meridian circles. Alternate sectors are depressed and

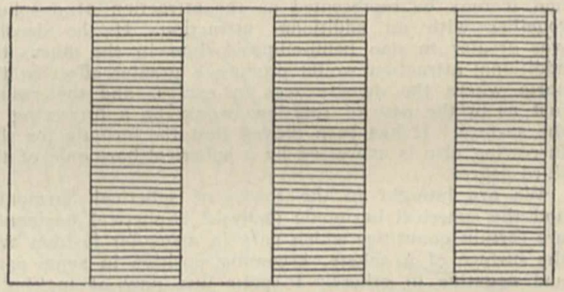


Fig.12.

elevated as shown in Fig. 12. The southward tapering of Africa is specially associated with the harmonic of this type. The combined effect of all the harmonics of the third degree is shown in Fig. 13. It represents the sphere deformed into a sort of irregular pear-shaped surface. The stalk of the pear is in the southern part of Australia and contains Australasia and the Antarctic continent. This is surrounded on all sides but one (towards South America)

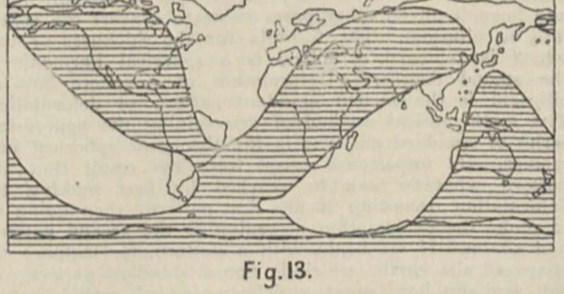


Fig.13.

by a zone of depression, the waist of the pear. This, again, is surrounded on all sides but one (towards Japan) by a zone of elevation, the protuberant part of the pear; and finally we find the nose of the pear in the central Atlantic between the Madeiras and the Bermudas. I do not, however, wish to emphasise the resemblance of the surface to a pear or any other fruit, but prefer to describe it as an harmonic spheroid of the third degree. Another way of regarding it would be as a surface with ridges and furrows. From a place in the South Atlantic there run three ridges: one north-westwards across America, a second north-eastwards across Africa and Asia, and the third southwards over the Antarctic continent, continuing northwards across Australia nearly to Japan. From the Sea of Okhotsk there run three furrows: one south-westwards across Japan, the Malay Peninsula, and the Indian Ocean; a second south-eastwards across the Pacific; and the third northwards over the Arctic Ocean, continuing southwards by way of the Atlantic. Harmonics of the first and third degrees have in common the character of giving depression at the antipodes of elevation; the harmonics of the second degree give depression at the antipodes of depression and elevation at the antipodes of elevation. The maxima of the harmonics of the first and third degrees are found to be rather greater than the maximum of the harmonic of the second degree. Of three quantities to be added together the two larger ones agree in giving depression at the antipodes of elevation; a result which is in accordance with the fact that most continents have oceanic antipodes.

When we superpose the effects represented by all the various harmonics of the first, second, and third degrees, so as to make, as it were, a composite photograph of all the various elevations and depressions represented by them severally, each in its appropriate amount as determined by the harmonic analysis, we find the curve shown in Fig. 14 as the theoretical curve of separation between regions of elevation and depression which are approximately equal in area. I showed before a smoothed curve (Fig. 3) which I proposed to take as representing the facts to be

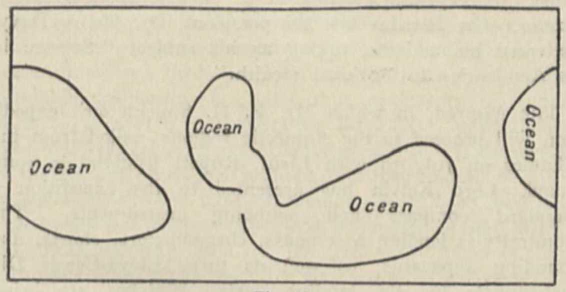


Fig. 14.

accounted for. The resemblance of the two curves seems to be striking. Incidentally it has been noticed how the prominent features of the distribution of continent and ocean are associated with the presence of various harmonics. As regards the contour of the great ocean basins, we seem to be justified in saying that the earth is approximately an oblate spheroid, but more nearly an ellipsoid with three unequal axes, having its surface furrowed according to the formula for a certain spherical harmonic of the third degree, and displaced relatively to the geoid towards the direction of the Crimea.

As regards the amount of elevation and depression in different parts, the agreement of the theory with the facts is not so good. The computed elevation is too small in Southern Africa, Brazil, and the southern part of South America, too great in the Arctic regions, to the south of of Australasia, and in the Mediterranean region. There are many reasons why we could not expect the agreement to be very good. One is the roughness of the method of harmonic analysis that was used. But there is also the fact that many causes must have contributed to the shaping of our actual continents and oceans besides those which have been taken into account in the theory. It appears, however, that the broad general features of the distribution of continent and ocean can be regarded as the consequences of simple causes of a dynamical character: eccentric position of the centre of gravity, arising from a past state of inadequate resistance to compression, an inherited tendency, so to speak, to an ellipsoidal figure, associated with the attraction of the moon in a bygone age, the rotation, and the interactions of these various causes.

In attempting to estimate the bearing of the theory on geological history we must be guided by two considerations. The first is that the earth is not now gravitationally unstable. From observations of the propagation of earthquake shocks to great distances, we can determine the average resistance to compression, and we find that this resistance is now sufficiently great to keep in check any tendency to gravitational instability. The eccentric position of the centre of gravity must be regarded as a survival from a past state in which the resistance to compression was not nearly so great as it is now. The second guiding consideration is that, according to the theory, the inequalities which are expressed by spherical harmonics of the third degree are secondary effects due to the interaction of the causes which give rise to inequalities expressed by harmonics of the first and second degrees. We should expect, therefore, that the inequalities of the third degree would be much smaller than those of the first and second degrees; but the harmonic analysis shows that the three inequalities are entirely comparable. We must conclude that the harmonics of the first and second degrees which we can now discover by the analysis are survivals from a past state, in which such inequalities were relatively more important than they are now. Both these considerations point in the same direction, and they lead us to infer that certain sæcular changes may have taken place in the past, and may still be going on. Sixty-nine years ago Charles Darwin wrote: "The form of the fluid surface of the nucleus of the earth is subject to some change the cause of which is entirely unknown, and the effect of which is slow, intermittent, but irresistible." Forty-two years later Sir George Darwin showed that any ellipsoidal inequality in the figure must be gradually destroyed by an irreversible action of the same nature as internal friction or viscosity. The same may be said of a state in which the centre of gravity does not coincide with the centre of figure when the resistance to compression is great enough to keep in check the tendency to gravitational instability. The state would be changed gradually in such a way as to bring the centre of gravity nearer to the centre of figure. A symptom of such changes might be the occurrence of great subsidences in the neighbourhood of the Crimea, where we found the maximum of the first harmonic. Such subsidences are supposed by geologists to have taken place in rather recent times. Symptoms of the diminution of the inequalities expressed by harmonics of the second degree would be found in the gradual disappearance of seas forming part of the great depression which was described above as a sort of immense Mediterranean (*cf.* Fig. 7), in the destruction and inundation of a continent in the northern Atlantic and in a gradual increase of depth of the Southern Pacific. The disappearance of seas from a vast region surrounding the present Mediterranean basin, and containing the Sahara and Southern Asia as far east as the Himalayas, is one of the best ascertained facts in geological history; and the belief in the destruction of a north Atlantic continent is confidently entertained. In parts of the Southern Pacific a depression represented by harmonics of the third degree is superposed upon an elevation represented by harmonics of the second degree, and we should therefore expect to find the depth of the ocean to be increasing gradually in this region. The region in question is that of the coral reefs and coral islands, such as Funafuti, and the result is in accord with Darwin's theory of the formation of coral reefs. So far as the general distribution of the mass within the earth is concerned, the reduction of the inequalities of the first and second degrees would seem to have already proceeded very far; for we are assured by geodesists that harmonics of the first degree, and those of the second degree which do not represent the effect of the rotation, are far from prominent in the figure of the geoid—much less prominent than we found them to be in the distribution of continent and ocean. We infer that the inequalities of the first and second degrees must have been progressively diminished in comparison with those of the third degree. The general result of such changes would be a gradual diminution of the depths and extents of the oceans which correspond with the harmonics of the first and second degrees, and a compensating increase in the depths and extents of the oceans which correspond with the harmonic of the third degree. To see the character of the changes which would thus be brought about, we may examine a figure which shows the composite elevations and depressions that are represented by harmonics of the first and second degrees, and, separately, those which are represented by harmonics of the third degree. In Fig. 15 the composite elevations of the first and second degrees are shaded vertically, and the elevations of the third degree are shaded horizontally. The deep parts of the Atlantic that border the coasts everywhere from Brazil to Ashanti are regions in which a depression represented by the third harmonic is superposed upon an elevation represented by the other two harmonics, and the same is true of the deep parts of the Indian Ocean which border the shores of Africa and Asia from Madagascar to Burmah. The deep parts of the Pacific that border the western coast of America from Alaska to Chili are regions in which an elevation represented by the third harmonic is superposed upon a depression represented by the other harmonics. These observations suggest that in the greater part of the Atlantic and the northern and western parts of the Indian Ocean the direction of sæcular change may have been that of an advance of the ocean to encroach upon the continental region, while in the Pacific Ocean on the American side the direction of sæcular change may have been that of a retreat of the ocean, permitting an extension of the continental region. This difference would lead us to expect different types of coast in the two regions, and such a difference has been observed. Whereas in the Atlantic region, with few exceptions, the coast cuts across the directions of the mountain chains, in the Pacific region on the American side the coast generally corresponds

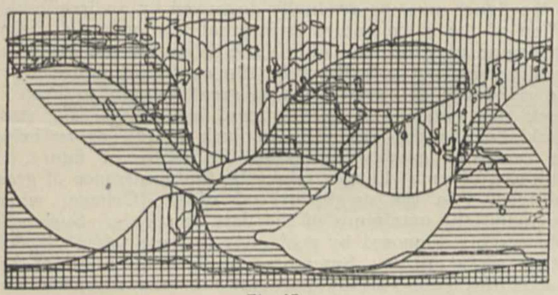


Fig. 15.

in direction with the neighbouring mountain chains of the continent. The deep parts of the Pacific which are nearest to the Asiatic coast from Kamchatka to Siam are regions where a moderate depression represented by the third harmonic is superposed upon a moderate elevation represented by the other harmonics. These shores of the Pacific are distinguished by the wide margin which separates the deep ocean from the coast of the continent. It might perhaps be desirable to recognise in this region a type of coast differing from the two main types associated with the Atlantic and the American side of the Pacific. The analysis does not represent South Africa or the southern parts of South America sufficiently well to warrant us in expecting these regions to exhibit one type rather than the other; but the way in which Australia is represented, as an elevation of the third degree superposed upon a depression of the first, suggests that the coasts of Australia, and especially the eastern coast where the elevation in question is greater, should be of the same type as the American shores of the Pacific; and it is the fact that the mountain chains of Queensland and New South Wales run parallel to the neighbouring coasts. There seems therefore to be much evidence to support the view that the direction of sæcular change has been that of diminishing the prominence of the inequalities of the first and second degrees in comparison with those of the third degree. The process by which such changes would be brought about would be of the nature of relief of strain, expressing itself in occasional fractures of no very great magnitude; and such fractures would be manifested at the surface as earthquakes. Seismic and volcanic activities constitute the mechanism of the process of change. These activities are spasmodic and irregular, but the effect of them is cumulative. For this reason they tend in the course of ages to transform the shape of the earth from one definite type to another. The diminishing speed of the earth's rotation is another cause of change which appears to produce an alternating rather than a cumulative effect. On the one hand it tends to diminish that tendency, which we noted above, to draw the waters of the ocean towards equatorial regions; on the other hand it must result in an actual reduction of the equatorial protuberance of the earth's figure. This reduction can only be effected by seismic activity expressed by subsidences in equatorial regions. The effect which would in this way be produced in the distribution of continent and ocean would appear to be that there would be long periods in which the ocean would tend to advance towards the Arctic and Antarctic regions, interrupted by shorter periods in which it would tend to retreat towards the neighbourhood of the equator.

The theory which I have tried to explain is a tentative one, and further investigation may prove it to be untenable; but it is to its credit that, besides tracing to dynamical causes the existing distribution of continent and ocean, it offers an explanation of the difference between the Atlantic and Pacific types of coast, it gives indications of a possible account of those alternations of sea and land which first led to the study of geology, and it suggests an origin for Charles Darwin's unknown force the operation of which is slow and intermittent, but irresistible.

NOTES.

NEXT year's meeting of the British Medical Association will be held at Sheffield under the presidency of Mr. Simeon Snell. This year's meeting is at present in progress at Exeter. On Tuesday last the president, Dr. Henry Davy, delivered his address, taking as his subject "Science in its Application to National Health."

THE *Nimrod*, in which Mr. E. H. Shackleton's expedition will proceed to the Antarctic regions, sailed from the Thames on July 30 with Lieut. Rupert England in command. Lord Kelvin has presented to the expedition a standard compass and sounding instruments. The Admiralty is lending a compass, chronometers, charts, and sounding apparatus, as well as three Lloyd-Creak Dip instruments for the landing party. Watches are being supplied by the Royal Geographical Society, and, in addition, the vessel will be equipped with a liquid steering compass and a special pole compass. The members of the expedition on board the *Nimrod* are Mr. James Murray, the biologist of the expedition; Mr. W. A. Michell, surgeon and zoologist; and Mr. A. F. Mackay, the junior surgeon of the landing party, who will also engage in zoological work. At Lyttelton, New Zealand, the remaining members of the expedition will join the ship. These include, besides Mr. Shackleton, Mr. E. Marshall, senior surgeon of the shore party and cartographer of the expedition; Lieut. Adams, R.N.R., who will be in charge of the meteorological work; and Sir Philip Brocklehurst, for survey work and field geology. Dr. David, professor of geology in Sydney University, has arranged to accompany the expedition south to King Edward VII. Land.

THE weather still continues very cool for the time of year, but on the whole the conditions lately have been somewhat dry. At Greenwich there has been no year since 1888 with so few warm days in July, and the thermometer has not once touched 80°. The total rainfall for the month is less than an inch, whilst the average for the past sixty years in July is 2·40 inches. The aggregate rainfall for the first eight weeks of summer, to July 27, is less than the average in the north-east, east, and south of England, and in the Channel Islands, but in every other district of the United Kingdom it is in excess of the normal. The greatest excess for the summer is 2·42 inches, in the north-west of England, whilst the greatest deficiency is 1·17 inches, in the east of England, the measurements being respectively 7·21 inches and 2·88 inches, and the rainy days respectively forty-one and twenty-six. Both the temperature and the sunshine for the summer have, so far, been below the average.

THE experiments which have been in progress in the Congo State for some time past in training the African elephant for domestic work are progressing satisfactorily. During the first three months of the present year, eight young elephants were captured, bringing the stud up to a total of thirty. At first the wild elephants suffer in health on confinement, but this depression soon passes off. Similar experiments are being made in the British territory of Uganda, but so far the results there are uncertain.

As illustrating further the want of sympathy with scientific research shown by the Indian administrative authorities, to which Prof. Ronald Ross, F.R.S., directed attention in an exhaustive article contributed to our issue of June 13, an Indian correspondent writes concerning the rules of the India Office regulating the supply of apparatus to Government colleges. According to these rules, our correspondent states, any piece of apparatus of European manufacture—costing more than 3*l.* 7*s.*—can only be obtained by requisitioning through the Secretary of State. Requisitions are prepared once a year, and, as a rule, eighteen months elapse between writing a demand and the arrival of the apparatus. It is nearly impossible to foresee everything that may be required during the prosecution of a research, and it happens sometimes that a man of science must wait three years for necessary material. The reasonable contention is made that professors in India should be permitted to spend their laboratory funds themselves and to deal with manufacturers direct. It is surely not taking too much for granted to suppose that men in responsible positions, who presumably have been selected for their posts with great care, may be trusted to administer their funds honestly and to the best advantage of the institutions with which they are connected. The system of having to requisition scientific instruments and materials a year or more in advance is not confined to India, and it is both discouraging to scientific work and wasteful in practice.

IT is interesting to find that the traditional date assigned to one of the great cycles of national legend is confirmed by independent evidence, and this in the case of the oldest existing literature of any of the peoples who dwelt to the north of the Alps. According to the native annals of Ireland, the Celtic heroes, Conchobar and Cuchulainn, flourished about the beginning of the Christian era, and though some authorities have supposed Cuchulainn to be a degraded Celtic god, there can be no reasonable doubt that he and his uncle lived and fought on earth. This traditional date is supported by the fact, already well recognised by scholars, that, though the poems were at a later date modified by their ecclesiastical transcribers, their spirit is essentially pagan. Prof. Ridgeway, in a paper recently submitted to the British Academy, has approached the problem from the point of view of the archæologist. From an elaborate investigation of the ethnology of this heroic race, their methods of fighting, their use of chariots—unknown to the later Ossianic poems—their arms and armour, and their dress and jewellery, as described in the Cuchulainn Epic, he is able by a comparison of remains of the La Tène period discovered in Ireland to decide that this cycle of culture is here represented; that, as is asserted in the Irish traditions, a tall, fair-haired, grey-eyed race of Celts, like those of Britain and the Continent, invaded Ireland in the centuries immediately before the birth of Christ, and that the poems themselves took shape when the La Tène form of culture was still flourishing in the country, which can hardly have been much later than 100 A.D. The evidence of tradition and archæology thus happily combines to establish the date of this important Saga literature.

ACCORDING to the report of the Northumberland Sea-fisheries Committee for the past year, the prospects of the fisheries under its supervision are very satisfactory, the marked falling-off in the products of trawling, which has been so noticeable for many years, having at length given place to a distinct upward tendency. It was discovered some time ago that an extensive migration from the south of female crabs takes place during winter, and it is now ascertained that a similar state of affairs exists in the case of flounders, which travel when fully adult into Scotch waters. Means for extending the mussel-beds of the district have been carefully sought, but at present with no great success. The main reasons for the unsatisfactory state of the mussel-supply appear to be the crowded condition of some of the beds, the action of storms on others, and the destruction caused by whelks and starfishes.

JUDGING from the report for 1906, the Zoological Gardens at Giza, near Cairo, enjoy great popularity among native Egyptians, the number of visitors showing an increase of twenty-five per cent. on the previous year, which was itself a record season. At the close of last year the gardens contained a remarkably fine collection of African big game animals, inclusive of six Sudani elephants, nine beisa oryx, three addax, and three kudu.

THE skeleton of a wonderful new horned rodent, *Epigaulus hatcheri*, from the Miocene of Kansas, is described by Mr. J. W. Gidley in the Proceedings of the U.S. National Museum, No. 1554 (pp. 627–636). The total length of the mounted skeleton in a straight line is about 14 inches. From the allied Ceratogaulus, the genus differs by the larger and more backwardly directed horns, the reduced molars, and larger premolars. Although presenting some resemblances to the beavers and squirrels, it appears to be most nearly related to the sewellels (Haplodontidæ). The paper concludes with speculations as to what possible use horns can be to a burrowing animal.

THE porcupines of the Malay Peninsula and Archipelago form the subject of a paper by Mr. M. W. Lyon in the Proceedings of the U.S. National Museum, No. 1552 (vol. xxxii., pp. 575–594), in which the generic grouping is revised and several new forms are described. For the large Malay and Java porcupines, commonly known as *Hystrix brachyura* and *H. javanica*, F. Cuvier's genus Acanthion is reinstated. These porcupines differ from the typical Hystrix by the absence of a nuchal crest, the shorter quills, and much shorter nasal bones in the skull, which extend backwards only so far as the line of the lachrymals, instead of to the hind root of the zygomatic arch. A new species from Sumatra is made the type of a separate genus, as *Thecurus sumatrae*, differing from Acanthion by the smaller capsule-like extremities of the tail-bristles, often closed at the end, and the smaller quills, which are replaced on the lower part of the rump by grooved spines like those on the back. The remaining species are referred, as before, to the genera Atherura (or Atherurus) and Trichys.

FROM Prof. H. F. Osborn we have received copies of a number of papers published in the Bulletin of the American Museum of Natural History, *Science*, &c., from which the following are selected for notice. In vol. xxii., art. 13, of the first-named serial is described the milk-dentition of the hyracoid from the Egyptian Eocene known as Saghatherium, the teeth at that age serving to confirm previous conclusions as to the systematic position of the genus. A restoration of the skeleton and external form of the remarkable Permian reptile Naosaurus forms the subject of vol. xxiii., art. 14. The enormous neural spines of the dorsal vertebræ, armed with transverse spikes, are considered to have supported a sail-like expansion of skin, but no reference is made to the probable object of this structure; the creature measured about 8½ feet in length. A magnificent skeleton of the Columbian mammoth (*Elephas columbi*), discovered in Indiana in 1903, and now mounted in the American Museum of Natural History, is described in art. 12; the tusks are remarkable for their great curvature and the crossing of the tips. The extinct mammals of Patagonia, and American exploration in the vertebrate beds of the Fayum Eocene, form the subjects of two of Prof. Osborn's contributions to *Science*.

IN referring to a scientific expedition sent out by the University of Colorado to study the natural history of the north-eastern part of the State, it is mentioned that, owing to the diversity of climatic conditions, the flora of Colorado is only exceeded in numbers by the flora of the State of California, and possibly of Florida. The object of the expedition was to collect plants, birds, and fossils. Leguminous plants, notably *Psoralea tenuiflora* and species of Astragalus, were prolific in the dry localities. Varieties of Populus known as cotton wood were abundant along the streams. Details appear in vol. iv., No. 3, of the University of Colorado Studies, where Mr. F. Ramaley contributes a second article on the silva of Colorado, treating of the species of Populus.

AN official notice which has been issued by the Inspector-General of Forests in India, intimating that the series of Forest Bulletins initiated in 1905 will be superseded by two publications to be known as the Indian Forest Records and Indian Forest Memoirs, furnishes another proof of the recognition by the Government of India of the importance of the department. Similarly to the Records and Memoirs of the Geological Survey of India, the former, that will be issued as material accumulates, will be devoted to short articles, notes, and preliminary announcements; the latter will contain memoirs or monographs, and will also appear irregularly as occasion arises.

THE report for 1906 of the Director of Agriculture in the Federated Malay States has been received. In connection with rice cultivation, experiments have been instituted to test the value of rotation crops. The position of the rubber industry is reviewed, and the opinion is expressed in favour of pushing the manufacture of block rubber, since it approximates more nearly to the smoke-dried Brazilian product. On the subject of soils and the expense incurred by weeding, Mr. Carruthers recommends the cultivation of a suitable leguminous crop, such as *Mimosa rudica*, the sensitive plant, on rubber lands, that would not only increase the nitrogen in the soil, but would also tend to conserve the surface.

DR. J. C. WILLIS contributes a paper to the Annals of the Royal Botanic Gardens, Peradeniya (vol. iv., part i.), on the occurrence and origin of certain endemic plants on Mt. Ritigala in Ceylon and elsewhere, providing in his opinion strong evidence against the theory of the origin of species by natural selection of infinitesimal variations. Comparing a number of allied species, such as *Coleus elongatus*, an endemic on Mt. Ritigala, with *Coleus barbatus*, a plant widely spread through Ceylon and S. India, Dr. Willis controverts the view that the specific characters of the endemic have developed as adaptations by means of infinitesimal variations, and prefers the mutation theory as affording a more feasible explanation.

FRUIT enters largely into the dietary of Americans, and this wholesome practice has been encouraged by the United States Department of Agriculture by means of bulletins indicating the nutritive value of fruit to the consumer and the economic value as a crop to the farmer. A Farmer's Bulletin, No. 293, compiled by Mr. C. T. Langworthy, provides a rational summary of available data on the composition, food value, and place of fruit in the human diet.

A CATALOGUE of the plants of New Zealand, similar to the London catalogue of the British Isles, has been prepared by Mr. T. F. Cheeseman for the Education Department of that dominion. The arrangement is that of the author's recently issued "Manual of the New Zealand Flora"; the indigenous and naturalised plants are grouped separately, and the distribution is broadly indicated.

IN the Journal of the Royal Society of New South Wales (vol. xl.), Mr. R. H. Mathews gives some details of the organisation of the Kurnu tribe in the north-west of New South Wales, of their rules as to sharing food, of the organisation of the Chauan tribe near the north-east border of Western Australia, and of the language of tribes about Alice Springs; he also gives a Loritcha vocabulary and some details as to avenging parties in Victoria. We learn more as to the "blood" divisions of the Kurnu, of which Mr. Mathews was the discoverer; but an actual genealogy of a small tribe thus organised would be of far more value than many explanations, provided totems, phratries, classes, bloods, and shades were duly noted. It might also enable us to discover whether the present irregularity in marriage regulations is of old standing. The class system of the Chauan tribe seems to be aberrant, so far as the form of the names goes; only two show any close relation to those prevailing among the more easterly eight class tribes; the names are arranged by Mr. Mathews on the supposition that matrilineal descent prevails, but this assumption can only be substantiated by the discovery of phratry names for the two groups of class names, and all the phratry names so far recorded indicate that patrilineal descent is the rule in the north. Mr. Mathews has also published a paper on the Australian tribe in the *Zeitschrift für Ethnologie*, 1906, pp. 939–946. His contributions are now so numerous that he would do well to attempt a general review of the facts he has published, which are otherwise not easy to piece together. It is clear from a paper by Mr. Mathews in vol. xxxvii. of the *Mitteilungen* of the Vienna Anthropological Society that he hardly realises the importance of exhaustiveness or of the localisation of his facts; to take one example, the paper professes to deal with Australian ethnography; the shields described are those of south-east Australia, but there is not a hint that the statements are not true of the whole of the continent.

THE great accuracy which has been attained in the measurement of electric current by the current balance at the National Physical Laboratory will in all probability lead to a more extended use of balances depending on the attraction of co-axial solenoids. A valuable series of papers by E. B. Rosa and L. Cohen dealing with the mutual inductance, and therefore attraction, of such circuits, has appeared in the May Bulletin of the Bureau of Standards at Washington. In one of these the various expressions which have been given for the mutual inductance of co-axial solenoids, from that due to Maxwell to the one Mr. A. Russell gave in the April number of the *Philosophical Magazine*, are compared and tested. Unfortunately, none of them appears to be at the same time accurate and easy of numerical calculation, while in one or two of them the authors have detected small errors.

PUBLICATION No. 62 of the Carnegie Institution of Washington consists of an account by Prof. Carl Barus of the work he has done on the condensation of vapour as induced by nuclei and ions. The condensation is effected in a cylindrical glass fog chamber 6 inches in diameter and 18 inches long, by exhaustion into a vacuum chamber through a stop-cock 4 inches in diameter. The coronas produced in transmitted light by the fog are observed through a goniometer. Different gases have been tried as well as different saturating vapours. In all cases there appear to be three types of condensation nuclei, dust particles, transient bodies which when charged are the ions, and lastly, excessively minute and persistent "colloidal" nuclei, on which condensation only takes place at the higher exhaustions. Prof. Barus has not found any daily period in the number of colloidal nuclei present in the atmosphere which could be ascribed to cosmical radiation. In this respect they differ from the ions, which have been shown by Messrs. A. Wood and A. R. Campbell (NATURE, vol. lxxiii., p. 583) to be present to the maximum extent about 9 a.m. and noon, and to reach a minimum about 3 p.m.

DR. E. GRIMSEHL describes in the *Physikalische Zeitschrift* for July 15 a simple apparatus suitable for demonstrating the principal properties of electric oscillations. Condensers of various sizes are formed by placing two sheets of tinfoil between three sheets of ebonite and vulcanising the whole together, leaving metal ears projecting so that each condenser can be hung on two bare wires which form part of the circuit. Variable inductances are made of solenoids of hard copper wire, one end of each being fixed and the other attached to a slide which can move parallel to the axis of the solenoid, so as to vary the length. The spark gap is formed by two aluminium spheres at the ends of two brass screws which pass through opposite sides of an ebonite box. With this apparatus and, for waves in wires, a simple Hertz generator capable of being tuned, almost all the fundamental experiments on electric oscillations can be performed.

THE curious differences of colour exhibited by the thin films of gold produced on the surface of a glass plate near which a gold wire is slowly disintegrating owing to the passage of an electric current through it, have been explained by M. L. Houllevigue in a communication to the Société Française de Physique at the last meeting (July 15). Films which appear blue in transmitted light are composed of a hydride of gold, stable at ordinary temperatures, but unstable above 130° C., when it loses 7 per cent. to 8 per cent. of its weight. Such a film when heated is converted into the more commonly known form, which appears to be identical with beaten gold leaf, and is green in transmitted light. Several other properties of these films find a simple explanation in M. Houllevigue's discovery.

THE Board of Agriculture has issued the ninth part of the memoir descriptive of the South Wales coalfield (Memoirs of the Geological Survey, price 8*d*.). The volume covers fifty pages, and is an explanation of the new series map, sheet 246, which includes West Gower and the country around Pembrey. The report has been drawn up by Dr. A. Strahan, F.R.S., in part from notes by Messrs. B. S. N. Wilkinson, T. C. Cantrill, and E. E. L. Dixon. The dominant feature in the structure of the district is the anticline which throws up the Old Red Sandstone to form Cefn-y-Bryn. The Old Red Sandstone appears under an aspect that was quite unexpected. The red marls that form the lower half of the formation around most of the coalfield are absent in parts of Gower, whilst the conglomerates at the top attain a remarkable development, and Silurian rocks come to the surface as an inlier. The Carboniferous Limestone is well developed. On the coast between Llanelly and Pembrey, the lower part only of the Pennant series is exposed, but the whole of the Lower Coal series probably exists under the estuary of the Loughor. The probable effect of various anticlines and synclines upon the extent of the Coal-measures under that estuary is taken into consideration and illustrated in a map. The only coal seams hitherto worked are those which are developed in the Pennant series in the western part of the South Wales coalfield, and the value of the concealed and unproved coalfield is lessened by the fact that the strata are likely to be highly inclined and much disturbed. The superficial deposits include the Raised Beach, which is so finely exhibited in East Gower, and glacial deposits, both presenting features of great interest.

WE have received the eleventh of a series of bulletins published by the Engineering Experiment Station of the University of Illinois. It deals with the effect of scale on the transmission of heat through locomotive boiler tubes, and has been drawn up by Prof. E. C. Schmidt and Mr. J. M. Snodgrass. Of late years there has been much discussion on the subject, and statements as to the extent to which deposits of scale affect the conductivity of a tube or sheet have been made from time to time, and have differed widely. The results of the authors' tests lead to the following conclusions:—Considering scale of ordinary thickness, say of thicknesses varying up to ⅛ inch, the loss in heat transmission due to scale may vary in individual cases from insignificant amounts to as much as 10 per cent. or 12 per cent. The loss increases somewhat with the thickness of the scale. The mechanical structure of the scale is of importance equal to or greater than the thickness in producing this loss. Chemical composition, except in so far as it affects the structure of the scale, has no direct influence on its heat-transmitting qualities.

WE have received from Mr. R. Lavachery, a Belgian engineer residing at Chapultepec, Mexico, drawings of an ingenious appliance invented by him for life-saving at sea. It consists of a rifled cannon from which a projectile is fired; to the projectile are attached a cable, an anchor, and a rocket. The mechanism is very simple, and for humanitarian reasons the inventor has not patented it.

BENJAMIN ROBINS, F.R.S., is remembered as the inventor of the ballistic pendulum and as the founder of the modern science of gunnery. As the details of his life and work are not generally known, opportunity is taken by *Engineering* (July 19), in the year of the 200th anniversary of his birth, to give detailed particulars of his career. Though he only lived to the age of forty-four, yet in that time Robins was in turn mathematical tutor, civil engineer, scientific experimenter, political pamphleteer, editor of "Anson's Voyages," and, at last, engineer-in-chief to the

East India Company. He was among the foremost mathematicians of his day, and had his life been prolonged he would undoubtedly have risen to greater fame.

No. 76 of the Publications of the Carnegie Institution contains an account of a series of researches by Prof. Theodore W. Richards, in conjunction with Messrs. W. N. Stull, F. W. Brink, and F. Bonnet, on the compressibility of a large number of the elements. A very ingenious apparatus was devised for making the measurements, and the results obtained show that the compressibility of an element is a periodic function of the atomic weight, and probably associated with the same causes which determine atomic volume and volatility.

THE July number of the *Journal of Hygiene* (vii., No. 3) is devoted to reports on plague investigation in India. Further experimental evidence is detailed of the transference of plague through the intermediary of the flea. It is shown that close and continuous contact of plague-infected animals with healthy animals, if fleas are excluded, does not give rise to an epizootic among the latter, and that when fleas are present the epizootic, if it does start, varies in severity and rate of progress according to the season of the year and the number of fleas present. The season in which epizootics were readily produced experimentally, and spread rapidly, corresponds with that of the plague epidemic.

A SECOND edition of vol. iii. of the "Descriptive and Illustrated Catalogue of the Physiological Series of Comparative Anatomy contained in the Museum of the Royal College of Surgeons of England" has been published. The volume is sold by Messrs. Taylor and Francis. It contains descriptions of the specimens in the section comprising the nerves of vertebrates not dealt with in vol. ii., and also those in the section including the organs of special sense.

THE eleventh edition, revised, of Mr. W. T. Lynn's "Celestial Motions" has just been published by Messrs. Samuel Bagster and Sons, Ltd. The price of this handy little book of astronomy is 2*s*. net.

AN interesting article, by Mr. E. V. Heward, upon the physical features of Mars, with particular reference to the habitability of the planet, appears in the August number of the *Fortnightly Review*.

OUR ASTRONOMICAL COLUMN.

ASTRONOMICAL OCCURRENCES IN AUGUST:—

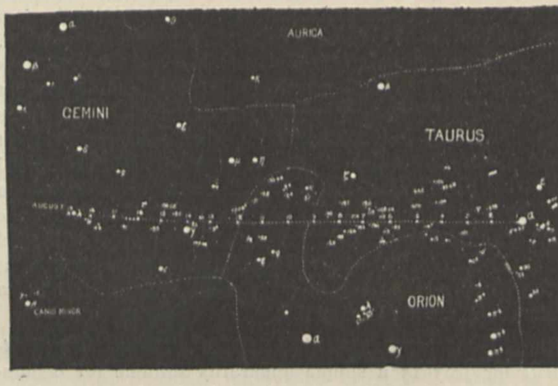
Aug. 1. 4h. Venus and Jupiter in conjunction. Venus 0° 18′ N.
,, Daniel's comet very near Aldebaran.
2. 12h. 6m. Central transit of Saturn's Satellite Titan.
4. 12h. Vesta in conjunction with the Moon. Vesta 0° 52′ S.
,, 15h. 38m. to 16h. 20m. Occultation of χ^1 Orionis (mag. 4·7).
,, Juno very closely S. of ϕ Virginis (mag. 4·9).
10. 14h. Mercury and Jupiter in conjunction. Mercury 2° 6′ S.
10–13. Epoch of August shooting stars, Radiant 45°+57°.
11. Uranus 1° S. of 28 Sagittarii (mag. 5·6).
14. Daniel's comet near γ Geminorum.
17. 16h. 53m. to 20h. 26m. Transit of Jupiter's Sat. III. (Ganymede).
18. 9h. 51m. Central transit of Saturn's Satellite Titan.
20. 12h. 42m. Minimum of Algol (β Persei).
23. 9h. 31m. Minimum of Algol (β Persei).

DANIEL'S COMET (1907*d*).—Herr Kritzinger's ephemeris for comet 1907*d* is extended to August 19 in No. 4191 (p. 259, July 23) of the *Astronomische Nachrichten*, and a part of it is given below:—

Ephemeris 12h. (M.T. Berlin).

1907	α (true) h. m.	δ (true) ° ′	log *r*	log Δ	Brightness
Aug. 3	4 50·1	+16 37·5	9·9453	9·8812	13·8
,, 5	5 8·9	+16 57·8			
,, 7	5 27·8	+17 12·0	9·9116	9·8878	15·6
,, 9	5 46·5	+17 20·0			
,, 11	6 4·8	+17 22·0	9·8763	9·9021	17·2
,, 13	6 22·8	+17 18·3			
,, 15	6 40·3	+17 9·3	9·8399	9·9234	18·5
,, 17	6 57·3	+16 55·6			
,, 19	7 13·6	+16 38·0	9·8036	9·9499	19·3

An observation made on July 19 gave corrections of +4s. and +1′·9 to the ephemeris, and on that date the magnitude of the whole comet was recorded as 4·0.



Apparent path of Daniel's Comet (1907*d*). August 1–19, 1907.

From the accompanying chart it will be seen that during the period August 1–19 the comet's apparent path lies between α Tauri and λ Geminorum, its declination varying but by a small amount. On the former date the comet will rise about four hours, and on the latter about three hours, before sunrise.

THE HELIOMICROMETER.—For the purpose of determining the heliographic positions of flocculi on spectroheliograms, quickly and accurately, Prof. Hale has devised an apparatus which he calls the heliomicrometer, and of which he gives a preliminary description in No. 5, vol. xxv., of the *Astrophysical Journal* (p. 293, June).

Briefly, it is a modification of an earlier instrument in which the spectroheliogram was projected on to a bright globe divided by meridians of latitude and longitude, the positions of the flocculi being read off directly from the globe. The angular diameter of the latter as seen from the projecting lens was, essentially, equal to the angular diameter of the sun as seen from the earth.

In the present apparatus, images of the photograph and the globe are viewed with two similar telescopes, the two images being brought into the same eye-piece. Immediately in front of the plate to be measured cross-hairs are mounted, and their intersection may be set on the particular flocculus to be measured by the observer operating from the eye-piece; during this process the bright image of the globe is occulted. The image of the properly adjusted globe is then admitted, and, by means of fine motions—again operated from the eye-piece—the intersection of the central meridian and the equator is brought into coincidence with the intersection of the cross-hairs. The amount that the globe has been rotated in each coordinate is then read off from circles fitted with verniers, and thus the latitude and longitude of the flocculus are obtained directly without any computation.

In testing the heliomicrometer method against that of the ordinary measuring machine, it was found that the results were in good agreement, and that the actual operations occupied the same amount of time, thus saving, with the former, the time taken by the computations from the polar coordinates in the latter.

SEARCH-EPHEMERIDES FOR COMET 1894 IV. (E. SWIFT).—Owing to the possibility of its identity with the lost comet of De Vico, Swift's comet of 1894 is of particular interest.

During its return of February, 1901, it was very unfavourably placed for re-discovery, and was not seen, but in the hope that it may be re-discovered during its present return, Prof. Seares publishes two search-ephemerides in Bulletin No. 12 of the Laws Observatory, University of Missouri. The former is based on elements indicating July 9 as the time of perihelion passage, whereas the second takes July 25; both show that the comet will attain its maximum brightness, as seen from the earth, about the beginning of October. It is of interest to note that the present position of this comet is near to that of comet 1907*d* (Daniel), although there is no possibility of the identity of the two objects.

According to the ephemerides, the position of Swift's comet on August 1·5 (Berlin M.T.) will be (1) 2h. 25·7m., +12° 31′, or (2) 1h. 51·7m., +8° 31′.

A QUICKLY CHANGING VARIABLE STAR.—A star having the position α=9h. 45m. 39·8s., δ=+12° 20′·3 (1900·0), and situated +12·1s. in R.A. and 1′·9 in dec. from B.D.+12°.2105, has been found by Mr. Metcalf, of Taunton (Mass.), to change its magnitude from 13·5 to 11·5 in four days. The range of variability is confirmed by the Harvard plates of this region, but the exact period has not yet been ascertained. The designation of this object is 66.1907 Leonis. (*Astronomische Nachrichten*, No. 4191, p. 260, July 23).

THE VARIATION OF THE POLE.—The provisory results obtained by the International Latitude Service during the year 1906·0–1907·0 are published by Prof. Th. Albrecht in No. 4187 of the *Astronomische Nachrichten* (p. 177, June 29). The diagram giving the projected path of the pole from 1899·9 to 1907·0 shows that during the year 1906 a further diminution of the amplitude of the variation from the mean pole took place.

UNIVERSITY REFORM.

THE discussion in the House of Lords on July 24 concerning the present state of the Universities of Oxford and Cambridge serves again to bring prominently before the public the importance of well-equipped universities to the nation. The Bishop of Birmingham asked the Government to appoint a Royal Commission "to inquire into the endowment, government, administration, and teaching of the Universities of Oxford and Cambridge and their constituent colleges, in order to secure the best use of their resources for all classes of the community." The Earl of Crewe announced at the end of the discussion that the Government requires time to consider the question, and that for the present a Commission will not be appointed. The Bishop of Birmingham unerringly exposed many of the weak points in the older universities as they are administered to-day. "The system of prize fellowships as it was established by the last Commission is," he remarked, "a mistake—post-graduate endowments should be used to subsidise either those who are to be teachers or those who are engaged in researches such as are worthy of advanced students." There were, of course, many champions to defend the present condition of things, but both sides expressed themselves as appreciative of the value to the community of higher learning in all departments of knowledge.

It was not sufficiently realised, however, that the existence of generously staffed and handsomely housed universities is ultimately a question of funds. In directing attention in these columns to the recent appeals made by both Oxford and Cambridge for funds, it was pointed out that, until as a nation we are prepared to make sacrifices comparable with those undertaken in Germany, the United States, and other countries, our older universities will continue to be a "playground for the sons of the wealthier classes" in order to secure money which is elsewhere provided by the State. There are many inquiries awaiting a Commission when it is appointed, and among them may well be a comparison of the amounts provided by the State for university work in the great countries of the world. The subjoined summary of the *Times* report of the debate in the House of Lords contains the substance of the Bishop of Birmingham's plea for a Royal Commission, the Bishop of Bristol's remarks relating to it, and the reply made by the Earl of Crewe on behalf of the Government.

The Bishop of Birmingham said, in the course of his remarks, that undoubtedly within the last thirty years immense changes had taken place in the higher education of the country—changes so immense that, unless the University was to fall out of the relation which it ought to hold to the whole education of the country, it was inevitable that reforms should be required. To an even greater extent, a fundamental change in the balance of power in the classes which formed the English nation had taken place. It had always been the honour and the pride of the old universities that they trained the governing classes of the country. The term "governing classes of the country" had, however, received a very wide extension. For example, it included now the working classes. There was a very real desire for the diffusion of higher education, and it was hardly possible to exaggerate the need for permeating those classes which were playing, and were destined to play, so increasingly an important part in the government of the country with the best education which we had to offer. Could not the university be brought into more immediate, direct, and effective relations to all those who really desired to be students and to profit by the best education the country could afford?

There could be no reasonable doubt that at present our ancient universities were allowed to become to an extent altogether beyond what ought to be tolerated a playground for the sons of the wealthier classes. As at present constituted, the universities were to a very large extent not in any serious sense places of study at all. There were a vast number of young men who never in any kind of way attained to the position of students—they never acquired the instinct or the power of getting knowledge out of books. The universities should have far more stringent and effective machinery for getting rid of those who had neither the ability nor the intention of becoming students. If those who had no real intention of becoming students were got rid of, the teachers would have more time for study and for the teaching which more properly belonged to a university; and a great deal more teaching power would be liberated for the system of university extension in the real sense—namely, for the purpose of teaching, not popular audiences, but trained and sifted students in different parts of the country, so that the influence of the university might be extended to those who were hungering and thirsting for that sort of knowledge and training which a university was able to supply.

He supposed it would not be denied that a very large part of the endowments of scholars and exhibitioners at the present time went to those who could in any case be at Oxford or Cambridge. It had been calculated recently that two in five of the scholars of the colleges did not, in fact, need the endowment in order to enable them to go there. He did not think it could be denied that the unlimited belief in open competitive examinations which characterised the last Commission had had effects which the reformers of those days never contemplated. Open competition had not really proved to be competition open to all classes; it had given an immense advantage to those whose parents were in a position to supply them with education of the more expensive kind. As a matter of fact, he expected it would be found that the universities did less now than they did generations ago to provide the crown of the educational ladder of the country. If the universities could get rid of the great body of those who had not the slightest intention of using the university as a place of study, there would be room for the employment of the endowments to do what they would all admit was the highest function of a university—namely, to provide a centre for the educational aspirations and desire for knowledge of the whole country. What they wanted was that the universities should be so re-organised and that their endowments should be so used as that, whatever there was of real intellectual aspiration and real desire for knowledge, should find its home and instruction in Oxford and Cambridge; and that, and nothing else, should be the real object which the universities manifestly existed to serve. As to the use of post-graduate endowments, there seemed to be wide agreement that the system of prize fellowships as it was established by the last Commission was a mistake —that post-graduate endowments should be used to subsidise either those who were to be teachers or those who were engaged in researches such as were worthy of advanced students. In order to redress the balance between the wealth of the colleges and the poverty of the university the principle had been established that the colleges should contribute to the needs of the university. But there was a widespread idea that certain colleges had in recent years grown very wealthy, and that the subsidies from the colleges to the university were in a number of cases very inadequate. If another Commission were appointed, it would be part of the duty of that Commission to inquire into the uses made of the college endowments, as well as the university endowments, and, perhaps, carry further the principle established by the last Commission of contribution from the colleges to the university.

The Bishop of Bristol spoke against the proposal, so far as Cambridge was concerned. He endeavoured to show that Cambridge had adapted itself to modern conditions, and he hoped that, as regarded Cambridge, the Government would not trouble the Commissioners with an inquiry. Last year the endowment of the University of Cambridge from its own property, which it could spend as it would, was half as much again as when he left the University, and it had now reached the large sum of 1965*l.* 6*s.* 4*d.* The quarterly payments from members were 14,500*l.*, fees for degrees 28,000*l.*, and oddments 1000*l.*, which, with 30,300*l.* received from the colleges, made a total receipt of 75,000*l.* or 76,000*l.* There were besides trust funds for various professorships, scholarships, studentships, and prizes. The estates of the colleges provided 220,000*l.*, while fees, rent of rooms, &c., amounted to 90,000*l.* The estate management of that 220,000*l.* cost only 7 per cent., but the management, rates, taxes, improvements, and cost of the national monuments came to 130,000*l.* This left a net amount for all purposes of 180,000*l.* Of this, scholarships absorbed 32,000*l.* It was difficult to imagine that Cambridge could have adapted itself more completely to modern conditions. But if a Commission were issued, it would be received, not only respectfully, but willingly; for a Commission could cut some knots which the University could not, or would not, cut for itself. One of these was the question of Greek. Science students ought to be allowed to pass their examinations without a knowledge of Greek. He suggested a small statutory Commission which would be able to make statutes having the force of law. It should be composed of experts who were not faddists and who had full sympathy for the new as well as full respect for the old. The Government might, perhaps, issue two Commissions, one for Oxford and one for Cambridge. Let them give the Bishop of Birmingham all he asked for; but not one-tenth part was necessary for Cambridge. The Government might well, in grateful recognition of the wonderful manner in which Cambridge had adapted itself, in spite of restricted means, to modern conditions, declare that they would secure to the University an additional 75,000*l.* a year.

In replying on behalf of the Government, the Earl of Crewe said:—There is no doubt that for some time what may be called university reform has been in the air. That is due to a variety of causes. The fields of study have been widely expanded in the manner so fully described by the Bishop of Bristol. Then there has been the upspringing of the new provincial universities with all their consequences; and there has within the last few years been impressed upon the public mind the whole question of university extension and the methods by which the endowments of the universities can in some way be applied for the benefit of those poorer citizens of this country for whom, as has been so truly said, they were originally intended.

The appointment of a Commission is urged upon various grounds. We are told that it is important to deal with the problems of the government and constitution of the universities, and to deal with the problems of study, both as regards the nature of the different studies carried on and what I may call the financial side of the question—such matters as scholarships and prize fellowships. Then, again, it is urged that the relations between each university and its colleges, and between college and college—witn special relation, of course, to endowments—demand a close inquiry. We are reminded, too, that it is almost thirty years since the last Commission sat, and that even if the universities desired to reform themselves from within, yet it would not be possible for them to do so without the intervention of a Royal Commission. And it is further pointed out that the very work of the last Commission has in some cases proved to be of an actually hampering nature, and that the errors into which as human beings the commissioners in some cases naturally fell could only be set right by legislation founded on the report of a further Commission. Those are the reasons for which we are told that a Commission ought to be appointed. On the other hand, certain objections have been made, both in the course of the debate and outside. Lord Burghclere specially alluded to the requests which have been made by the Chancellors of both universities publicly for those who have been educated at each respectively to come to their aid. They no doubt bear in mind the fact that if such a movement is to succeed it must be to some extent of a national character, because the old universities cannot make those appeals to local patriotism which have been responded to so freely in the case of the newer universities. I have no doubt, also, that they compare the state of things somewhat sadly with what obtains in the United States, where it is estimated that during the last thirty years 48 millions sterling have been privately subscribed for the benefit of the universities of America. And my noble friend argued that, if we were now to accede to the request for the appointment of a Royal Commission, the flow of money which has come in to some extent, and which, it is hoped, will come in to a greater extent, would be, if not stopped altogether, seriously checked. Then, further, it is urged against the appointment of a Royal Commission that, although it is true that there are certain things in the direction of allowing greater flexibility to colleges and universities which the new Commission might do by undoing what has been done by the last one, still you cannot have any guarantee that the Royal Commission would undertake that duty, and that it might not imitate its predecessor in making very distinct and positive suggestions which would have to be carried out, and some of which might prove, as former ones have proved, to be erroneous and unfortunate. And, again, we have been told that really more time is wanted to watch the effect upon our national life and our education generally of the foundation of the new universities. It is urged that it is only after some experience of their work that we can decide what place Oxford and Cambridge really ought to take in our national life. Everyone will, I think, agree that we do not wish these universities to plunge into a competition of science and technology with such universities as those of Leeds and Birmingham, and consequently we are asked to wait in order to see what the next few years at any rate may bring.

Those are the various opposing views which are set before His Majesty's Government. I may remind the House that the Government, as such, has only had the opportunity of considering this matter at all for about ten days, and we certainly do feel that the appointment of a Royal Commission, like other important events in life, is one which is not to be undertaken lightly or inadvisedly. We have, as a matter of fact, only what I may call casual evidence of the feeling which actually exists either at Oxford or Cambridge, such intimations as people have been kind enough to send before this debate began, and we have learned very much from what the various speakers in the course of the discussion itself have said. But it is important for us, before arriving at a final conclusion, to know what the most thoughtful and the most competent opinion at both universities really demands, and we also must either inform ourselves or be informed exactly what the universities cannot do of their own motion and for what purposes legislation would be required on the recommendation of a Commission, and we should also desire to be informed as to whether there does exist at the universities anything like a deadweight of obstruction against reforms which is of the character which could only be removed by statute. Consequently, therefore, we desire time to consider this matter in the light of the best information which we can receive, and we look with confidence for help and suggestions as to the best methods of proceeding from those of both universities who are most competent to give it. In the meantime, I am quite confident that this discussion will of itself have done good and have been useful. This is one of the subjects on which, in Carlyle's famous phrase, "if we differ we differ only in opinion." It is merely a question of honest differences of opinion as to what the best way to proceed is in order to do what we all wish to be done; and certainly it does seem to me that the best minds of those who are either at the universities or who are interested in the universities cannot possibly be applied to a higher object than that of putting these ancient homes of learning, which many of us so deeply venerate, with all their splendid traditions, to the fullest possible use, and, where necessary, of bringing them into closer conformity with the needs of the country and with what, in the opinion of those best qualified to judge, is the truest conception of learning as it should exist to-day.

ARCHÆOLOGICAL EXPLORATIONS IN CHINESE TURKESTAN.

FURTHER news of Dr. M. A. Stein's archæological explorations in Chinese Turkestan has now been received. After leaving Keriya at the beginning of the winter, he proceeded eastwards 1200 miles along the borders of the Taklamakan desert to the Lop-nor region, where he intended to excavate. On the way he made further investigations at the Rawak Stupa, in the Hanguya Tati, and at the Domoko desert site, where he found remains of the Dandan-Uiliq period, the eighth century A.D. At the desert-site north of Niya, where in 1901 he had discovered the remains of a settlement buried in the third century A.D., renewed excavations brought to light more interesting and important antiquities of the same kind as those discovered in 1901, especially noticeable being the wooden tablets inscribed in Kharoshthi. Among the clay seals of these tablets, impressions from Græco-Roman intagli are the commonest.

Dr. Stein passed the scene of his former work at Endere on his way eastwards, and also made further investigations there. Evidence was now found that this site also was originally occupied in the time of the Indian "Kharoshthi"-using kingdom, and had been abandoned and re-occupied by the Chinese in the seventh century, only to be abandoned again after the Tibetan conquest a century later. During the period of their first abandonment, the Endere settlements were seen as ruins by the great Chinese pilgrim Hiuen-Tsang.

Similarly, the oasis of Cherchen, which Dr. Stein reached after leaving Endere, has undergone various vicissitudes of settlement and desolation, having come into being again only a few years ago, when, after the re-conquest of Turkestan, the Chinese made it a penal station for refractory Turkis and Tibetans. Since Marco Polo's day it had been abandoned, but then it was a flourishing province, which had grown up since the time of Hiuen-Tsang, who had seen but the desolate and uninhabited ruins of what had once been a town, where in 519 A.D. a previous Chinese pilgrim had found a hundred families living. The Taklamakan desert now encroaches, now recedes; now there is plenty of water, now little, and so the southern oases wax and wane and wax and wane again.

Dr. Stein's objective being the Lop-nor region, he passed on beyond Cherchen to Charkhalik, in the Tarim basin, finding various Mohammedan remains on the way. From Charkhalik he marched to Abdal, and thence more than a hundred miles northward into the salt desert, to an ancient site discovered by Dr. Sven Hedin in 1900. As it is only in winter that explorations in these deserts can be conveniently carried on, the rigours of the Central Asian winter had to be faced by Dr. Stein now as in the Taklamakan six years before, and 48° F. of frost, coupled with an icy boreal wind, were the usual weather.

On December 17 Dr. Stein reached the site, and pitched his camp at the base of the ruined stupa of the ancient town. This turned out to be very like Niya, and is of the same date (third century A.D.). Not only were masses of Chinese correspondence of that period found, but also, what was really unexpected, large numbers of Kharoshthi documents, which show that the Indian kingdom of Khotan included, not merely Cherchen, but the distant Lop-nor district in its dominion. The whole, then, of the Tarim basin must have been ruled by the Indian maharajas of Khotan in the third century A.D. This is a new contribution to history.

This eastern extension of the Buddhist kingdom of Khotan, which took its origin from that of Gandhara, explains more and more the close original connection between the hellenised art of India and that of China, and shows how the sculpture and painting styles of Gandhara passed, with their Greek character, which they derived from the influence of the Seleuoid kingdom, easily by way of Turkestan to northern Tibet and so to China and Japan.

The Lop-nor settlement was occupied by the Chinese in order to control the road from Turkestan to Kansu; Sha-chau, the nearest Chinese town, lies 300 miles east of the Lop-nor district.

Among the most important and interesting of Dr. Stein's discoveries have been those made at Miran, an ancient site in the Charkhalik district, which throw light on the connection between Græco-Indian and Chinese art. In the débris mounds of a fort and stupa-shrines he has found this time frescoes in which the influence of classical art is reflected with surprising directness.

"The main paintings, which illustrate scenes of Buddhist legend or worship, are remarkable for clever adaptation of classical forms to Indian subjects and ideas. But even more curious are the figures represented in the elaborate fresco dados. They are so thoroughly Western in conception and treatment that one would expect them rather on the walls of some Roman villa than in Buddhist sanctuaries on the very confines of China. One cycle of youthful figures, in a gracefully-designed decorative setting, represents the varied joys of life—a strange contrast to the desolation which now reigns in the desert around the ruins and, in fact, through almost the whole of this region. Kharoshthi inscriptions, painted by the side of the frescoes, and pieces of silk bearing legends in the same script, indicate the third century A.D. as the approximate period when these shrines were deserted."

From this account the importance of Dr. Stein's further archæological discoveries is evident, and both he and his German imitators in the Turfan district, 200 miles north of the Lop-nor, have added by their work a new chapter to history. We cannot doubt that Dr. Stein has added more to our knowledge by his fortunate expeditions to Turkestan than had he, as he tells us his dearest wish was to do, devoted himself to the exploration of Iranian antiquities in northern Persia. We knew much about Persia, nothing about the ancient Indian kingdom in Chinese Turkestan which Dr. Stein has discovered.

Dr. Stein's minor object, the control of a trigonometrical survey of the northern slopes of the Kuen-lun for the Indian Government, has also been carried out with success by Surveyor Rai Ram Singh. The net of the Indian trigonometrical system has been extended from the headwaters of the Keriya River along the mountain slopes above Surghak and along the chain which Continental geographers call the "Russian," with its peak dubbed "Tsar Liberator," right through to the mountains between Cherchen and Charkhalik. This is a great achievement.

Why, by the way, our Continental friends call this range "the Russian chain" is not quite apparent. Russia is still a long way off, and Japan has rendered it improbable that Russian earth-hunger will ever be able to extend the dominion of the White Tsar, as was once hoped by his subjects, to the borders of Tibet. The "Yellow Tsar," the "Bogdo-khan" in Peking, still rules the lands which his ancestors held two thousand years before St. Petersburg was built, and that his subjects are worthy to administer this dominion is evident from what Dr. Stein tells us of the civilised rule of the Chinese, and of the constant friendliness of the Imperial authorities to his mission and their keen interest in his archæological discoveries. The thanks of Western science are due to the Chinese for their ever-ready help to Dr. Stein, without which his discoveries would have been impossible to achieve.

NEW HIGH VACUUM PUMP.

NO laboratory, either chemical or physical, can be carried on to-day without a vacuum pump of some form or other, and in many laboratories it is essential that the pump shall be capable of producing the very

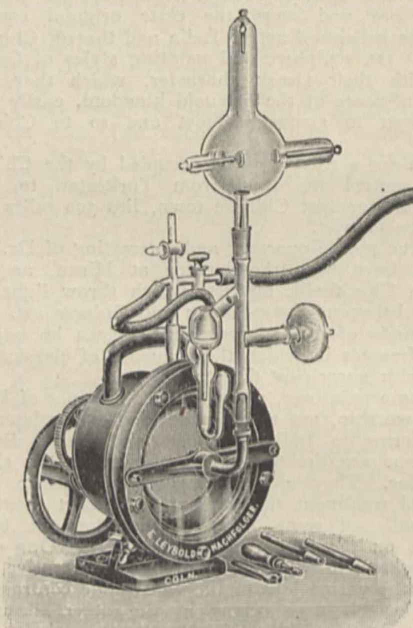


FIG. 1.

highest degree of evacuation. Not only is it necessary to be able to produce a high vacuum, but it is also eminently desirable that it should be possible to produce the state of evacuation as rapidly as possible.

The new high vacuum pump of Dr. Graede, manufactured by E. Leybold's Nachfolger, Cologne, would appear to meet these desiderata. It is claimed that with this pump the highest vacua yet obtainable are secured in a minimum of time. The pump is also simple and compact, and may either be mechanically or hand driven.

The pump which is illustrated in Fig. 1 consists of an iron vessel, half filled with mercury, in which a porcelain drum divided into three chambers rotates. When the drum is rotated the chambers into which it is subdivided are filled alternately with air and mercury. In the first place the chambers suck the air from the receiver, and during further rotation the air is expelled and its place taken by mercury. Fig. 2 shows a section of the pump, one-fourth the actual size. G is the cast-iron casing, which is glazed inside and is cast on to a strong base. The front of the pump consists of a thick plate of glass cemented into the frame P. It is then screwed tightly on to the frame against rubber rings, in order to make an air-tight joint. Three holes are bored into the glass plate, by means of which the two tubes R and R′ and the tap at the bottom are attached. The tube R is connected by means of the glass apparatus, Fig. 3, with the receiver, and R′ with a second pump which serves for preliminary exhaustion. The tap is for introducing mercury into the pump and also for emptying it. The auxiliary pump may be a water injector or any other suitable form of pump which is

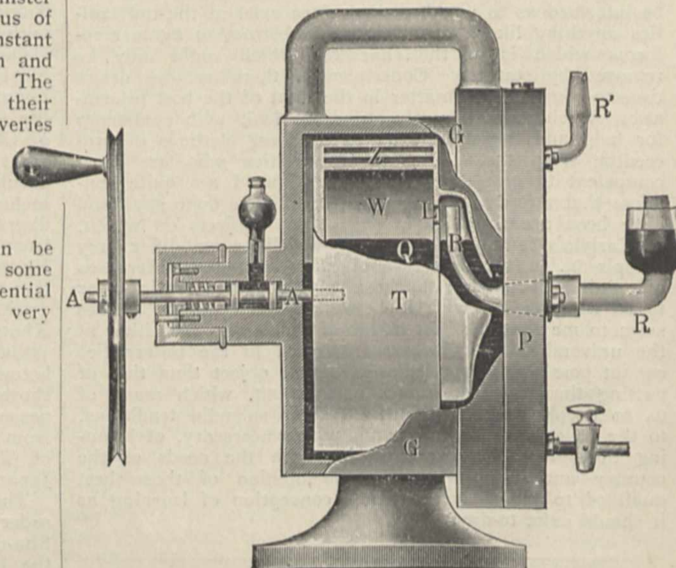


FIG. 2.

capable of giving a vacuum of from 15 to 20 mm. T is the porcelain drum which is attached to the axle A, passing through the casing by means of an air-tight joint, to which is attached the driving wheel.

In using the pump, exhaustion up to 15 to 20 mm.

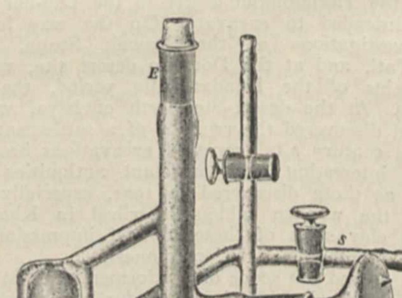


FIG. 3.

is first produced by means of the auxiliary pump; the drum is then slowly rotated in a direction contrary to the hands of a clock. The space W thus increases in size and air is sucked through the opening L. As rotation is continued the opening L passes below the level of the mercury, and the air in the chamber is no longer in connection with the receiver. But as the drum contains three chambers, one of them is always above the mercury; hence the action is continuous. As the chamber revolves W becomes more and more immersed in the mercury, and the air is forced out through the channels Z into the space between the drum and casing, from whence it is removed by the auxiliary pump.

Fig. 3 illustrates the glass attachment, which can be fitted on to the tubes R and R′, Fig. 2, by means of the ground pieces L and L_1. The receiver to be exhausted is attached at E. A manometer H, with a drying chamber P filled with phosphorus pentoxide, is employed to measure the pressure. It also serves as an automatic valve; at atmospheric pressure the orifice O is open; therefore the auxiliary pump connected at S exhausts the receiver fitted at E, directly through the opening O and the connecting tube P. On a vacuum of 20 mm. being attained, the mercury sinks in the right-hand limb, and, rising on the left, closes the opening O as illustrated in the figure; the mercury pump is then started.

Figures are supplied showing the extreme vacuum which can be obtained in a few minutes. Thus in five minutes the MacLeod gauge registered only 0·027 mm., and after fifteen minutes 0·000003 mm. This shows that the pump works extremely rapidly and very efficiently. If it is capable of doing all that is claimed for it, the Gaede pump should prove of great value either for research work or for showing lecture experiments with high vacua.

THE CAUSE OF EARTHQUAKES.

AMONG the results produced by the San Francisco earthquake of April 18, 1906, must be reckoned a memoir, by Prof. T. J. J. See, covering 140 pages of the Proceedings of the American Philosophical Society (vol. xlv., October–December, 1906), on the cause of earthquakes, mountain formation, and kindred phenomena. The explanation adopted is a development of an old-fashioned idea, and is supported by quotations from the writings of natural philosophers from Aristotle down to Charles Darwin. Earthquakes, with volcanoes and mountain ranges, are all ascribed to the explosive power of steam formed within or just beneath the heated rocks of the earth's crust, chiefly by the leakage of sea water through the ocean beds; the pressure of this steam forces the lava in a lateral direction, and its subsequent condensation leads to the subsidence of the sea bottom often observed after great earthquakes; the lava forced aside may either break out through volcanic vents or may lift the overlying rocks into mountain ranges, and, when the movement is sudden, give rise to faults and fractures which are the result, not the cause, of earthquakes.

It is round these last words, italicised by Prof. See, that criticism naturally centres, and the first consideration which arises is the verbal one of what is an earthquake and what is a cause. An earthquake, as ordinarily understood, is a shaking of the earth, and this shaking is due, wholly in the great majority of cases, and very largely in the remainder, to the molecular movements involved in the transmission of elastic wave motion. In the case of great earthquakes, fractures of the solid rock, accompanied by more or less displacement of the opposite sides of the fissure, are often found, and as the shaking of the earth is greatest near these, and the disturbance is propagated outwards from them, they have been regarded as the cause of earthquakes. In other cases, where no actual fissure is observed at the surface, there is good reason to suppose that the earthquake was caused by an underground fracture, which did not reach the surface, and there can be no doubt that this explanation is adequate in almost, if not quite, every case; but even if the fracture is the immediate cause of the disturbance which is commonly known as an earthquake, the explanation is still incomplete, for we have not reached the cause of the fracture.

It is to this ultimate cause that Prof. See appears to apply the term earthquake, and he is probably right in rejecting the tectonic hypothesis either in the form in which it presents itself to him or in the more ordinary one which regards the fractures as the result of compressional strains, largely due to the secular contraction of the earth, but his explanation fails to account for the remarkable connection between the irregular shifting of the earth's axis and the occurrence of great earthquakes. That these irregular movements of the axis are greatest when large earthquakes are most frequent is a certain, but as yet unexplained, fact; it seems to necessitate displacements of matter in the earth on a far larger scale than is indicated by the differential measurements which alone are open to us. Prof. See's explanation, though it provides for lateral and vertical displacements of matter, necessitates the elevations and depressions being so closely contiguous as practically to neutralise each other's effects, and, therefore, fails as an explanation of the ultimate cause of earthquakes, while it in no way affects the current acceptance of fracture as their immediate cause.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

Leeds.—The retirement of Prof. Miall, F.R.S., from the chair of biology, which he has occupied in the Yorkshire College, and subsequently in the University of Leeds, since the year 1876, was recently made the occasion for expressing in a tangible way the esteem and regard in which he is held by his colleagues and friends. A testimonial committee, of which the Vice-Chancellor (Dr. Bodington) was chairman, was formed, and a ready response was obtained to the circular inviting subscriptions for this purpose. Among the testimonials to Prof. Miall which have been thus provided is a portrait by Mr. Frederick Yates, intended to be hung in the hall of the University. The presentation of this portrait was made at a recent meeting in the University library, when a large number of his colleagues and friends were present. The Vice-Chancellor, who presided and made the presentation, spoke in warm and feeling terms of the eminent services which Prof. Miall had rendered to the college and University, as well as to the cause of science, and described him as having been original as a teacher, eminent as a scientific worker, and active as a business colleague. Subsequent speakers included Mr. S. P. Unwin, Dr. Eddison (emeritus professor of the University), and Prof. Smithells. Prof. Miall, in acknowledging the presentation, gave a short historical sketch of the foundation of the Yorkshire College of Science and its development into the Yorkshire College and subsequently into the University of Leeds.

The chair of biology will in future be divided into the professorships of zoology and of botany. To the former has been appointed Dr. Walter Garstang. Prof. Garstang has held research fellowships in zoology at Owens College, Manchester, and subsequently at Lincoln College, Oxford, where he has filled various appointments as lecturer and examiner. He is at present chief naturalist to the Marine Biological Association in charge of the Lowestoft Laboratory.

To the chair of botany Mr. V. H. Blackman has been appointed. Prof. Blackman was sometime fellow of St. John's College; he has held an assistantship in the British Museum, having charge of the collection of fungi, and he is at present engaged in botanical teaching, being a recognised teacher of that subject in the University of London.

In connection with the new department of fuel and metallurgy under Prof. Bone, F.R.S., the Institute of Gas Engineers has established a research fellowship of the value of 100*l*. a year.

The extensions of the University buildings upon which the council is at present engaged comprise:—(1) an extension of the main building in College Road for the better accommodation of biology and of arts teaching; (2) an extension of the civil and mechanical engineering department; (3) the erection of a detached block for the department of electrical engineering; (4) an extension of the cloth finishing department; (5) the completion of the block of buildings for the mining and metallurgical departments. The last-mentioned block will be ready for occupation by the students at the beginning of next session, in October. In addition to these buildings, the University is erecting a new boiler house and lavatories; is proposing to extend the refectory; is adapting a large dwelling house for the purposes of an extension of the geological department, and is uniting the house by means of a bridge at the first-story level with the present geological department of the University; and is adapting other dwelling houses for the use of women students and for seminar work.

THE second International Congress on School Hygiene will be opened on August 5, at the request of the King, by Lord Crewe. The complete success of the meetings seems to be assured. The German Government has not only decided to send delegates to the congress, but, by permission of the Kaiser, Prince Eitel Friedrich has accepted the office of a vice-patron of the congress. While still adhering to its resolution not to issue official invitations to foreign Governments to send delegates, the Board of Education has arranged with the Foreign Office to take such steps as are likely to remove any misunderstanding which might have prevented some foreign delegates from accepting the invitations issued. The meetings will be held at the University of London, and will last until August 10. Sir Lauder Brunton, F.R.S., the president, will deliver the inaugural address on August 5. The sectional meetings will commence on the following day. There are eleven sections in all; their subjects and the name of the president in each case are as follows:—(1) The physiology and psychology of educational methods and work, Sir James Crichton Browne, F.R.S.; (2) medical and hygienic inspection in school, Prof. W. Osler, F.R.S.; (3) the hygiene of the teaching profession, Dr. T. J. Macnamara, M.P.; (4) instruction in hygiene for teachers and scholars, Sir William J. Collins, M.P.; (5) physical education and training in personal hygiene, Sir John W. Byers; (6) out-of-school hygiene, holiday camps and schools: the relation of home and the school, Lord Kinnaird; (7) contagious diseases, ill-health, and other conditions affecting attendance, Sir Shirley F. Murphy; (8) special schools for feeble-minded and exceptional children, Mr. W. H. Dickinson, M.P.; (9) special schools for blind, deaf and dumb children, Lord Crewe; (10) hygiene of residential schools, Dr. Clement Dukes; (11) the school building and its equipment, Mr. T. E. Colcutt. An exhibition of school building and furnishing appliances has been arranged in connection with the congress.

SOCIETIES AND ACADEMIES.

LONDON.

Royal Society, June 6.—"On the Two Modes of Condensation of Water Vapour on Glass Surfaces, and on their Analogy with James Thomson's Curve of Transition from Gas to Liquid." By Prof. Fred. T. **Trouton,** F.R.S.

Experiments made with glass wool to determine the amount of water condensed on the surface of glass when in equilibrium with various vapour pressures showed that below a critical pressure, which is about 50 per cent. saturation, there are two distinct modes in which the condensed water can exist.

Thus for the same vapour pressure, if the condensation is in one of these forms, called for convenience the α type, there is much less condensed material present on the surface than in the other form, called the β type; or, to put it in another way, for the same amount of condensed vapour the pressure is greater when the condensation is of the α form than when it is of the β form.

Condensation will take place of the α type if the surface has been thoroughly dried at high temperatures, while of the β type if the drying has only been effected at ordinary temperatures, though in that case also the vapour pressure may be zero.

When the condensation is of the β type the curve, connecting pressure with the amount of condensed water, is found to be very similar to that for wool or cotton, but when the condensation is of the α type the curve is quite different. Thus, starting with the surface very dry, the pressure runs up quickly for relatively little condensation until a critical pressure is reached; after that, on further additions to the surface condensation, the pressure diminishes. This is attributed to a transformation into the β state supervening at this point, when consequently the vapour pressure is in excess of equilibrium, and thus a depletion of the vapour in the surrounding space results, with a corresponding fall in vapour pressure. If moisture be continuously supplied the pressure will, after reaching a maximum, begin to rise, and ultimately pass to saturation.

The analogy with James Thomson's curve of transition from gas to liquid is pointed out. In the one case there is attraction between water-vapour particle and water-vapour particle, in the other between glass and water vapour. The condensation of the α type corresponds to the supersaturated vapour stage in the transition curve, while the β corresponds to its liquid stage.

Where the surface is not completely dry, the fact that the condensation is in the β form, on vapour coming in contact with the surface, is attributed to there being an example of that type already on the surface; but if this is not present, that is, if the surface is desiccated, the condensation is of a type allied to supersaturated vapour rather than to the liquid.

A paradoxical consequence of there being these two modes of condensation is pointed out, namely, that a relatively wet surface is capable of drying one wetter than itself.

As an illustration of the phenomenon a simple experiment is given, in which two dishes of phosphorus pentoxide are placed under a bell jar, with only this difference, that one of the dishes is first made dry by heating. It is then found that the pentoxide which can initially obtain some moisture from contact with the damp dish absorbs the moisture in the bell jar, and ultimately runs liquid, while the other remains dry.

"On the Velocity of Rotation of the Electric Discharge in Gases at Low Pressures in a Radial Magnetic Field." By Prof. H. A. **Wilson,** F.R.S., and G. H. **Martyn.**

The apparatus used in this investigation was a small vacuum tube consisting of two concentric glass tubes cemented into aluminium discs. The discs served as electrodes, and the discharge was passed between them through the annular space between the glass tubes.

An iron bar was fixed along the axis of the vacuum tube, and could be magnetised so as to produce a radial field in the space between the glass tubes.

The discharge was produced by a large secondary battery, and its velocity of rotation round the annular space was measured. The variation of the velocity with the strength of the magnetic field, with the pressure of the gas, and with the current carried by the discharge, was investigated in air, nitrogen, and hydrogen.

The velocity was found to be nearly proportional to the strength of the magnetic field and inversely proportional to the gas pressure. The velocity in hydrogen was about thirteen times the velocity in air or nitrogen.

It is shown that theoretically the velocity should be proportional to the product of the two ionic velocities, and the results obtained, together with previous measurements of the Hall effect, enable the velocities of both the positive and negative ions to be calculated. The negative ions are found to have much higher velocities than the positive ions.

June 13.—"*Miadesmia membranacea*, Bertrand; a New Palæozoic Lycopod with a Seed-like Structure." By Dr. M. **Benson.** Communicated by Dr. D. H. Scott, F.R.S.

The vegetative organs of this interesting new type were discovered by Bertrand in 1894. He found them in sections of a calcite nodule from the Gannister beds of Hough Hill, England. A large quantity of new material has become available, and now not only are more details known as to the vegetative organs, but a fairly complete knowledge of the reproductive organs is possible.

Miadesmia was exceedingly minute, its stem slender and without any trace of skeletal tissue. It is the first Palæozoic Lycopod of herbaceous character known structurally. The megasporophylls, which were identified by Dr. D. H. Scott, F.R.S., in 1901, show a more advanced type of seed habit than has hitherto been met with in Cryptogams. The megasporange gives rise to but one thin-walled spore, which in development and structure resembles an embryo sac and germinates *in situ*. An integument surrounds the sporange, leaving but a small orifice as micropyle. This is surrounded by numerous long processes of the integument, which formed a collecting and incubating apparatus for the microspores. There is no trace of an envelope about the microsporange. The carpellary leaf was shed at maturity, and resembles a winged seed.

Disregarding the structural modifications of the megasporophyll, the nearest affinity of Miadesmia among forms so far known seems to be with the non-specialised species of Selaginella, such as *Selaginella selaginoides*, but the foliage leaves show the archaic leaf-base comparable with that of Lepidodendreæ.

"The Inhibitory Action upon Subsequent Phagocytosis, exerted on Active Normal Serum by Inactive Normal Serum through which Bacilli have been passed." By J. C. G. **Ledingham.** Communicated by Dr. C. J. Martin, F.R.S.

When inactivated normal serum is digested with tubercle bacilli, and finally freed therefrom by the centrifuge, it is found that the supernatant fluid has the property of inhibiting to a great extent the opsonic action of fresh normal serum, not only towards the tubercle bacillus, but also towards the *Staphylococcus pyogenes aureus*. The author interprets the phenomenon thus:—The amboceptors of heated normal serum combine with the tubercle bacilli and also with their free receptors, which remain in the supernatant fluid after removal of the bacilli. When this supernatant fluid containing the "free receptor amboceptor" combination, is added to fresh normal serum, the latter's complement becomes fixed, and consequently in the presence of fresh bacilli, opsonic action is inhibited. The experimental results obtained lend support to the view that the opsonic action of normal serum depends on the cooperation of complement with normal amboceptor.

June 20.—"Preliminary Note on a New Method of Measuring directly the Double Refraction in Strained Glass." By Dr. L. N. G. **Filon.**

If a plane wave of light be passed horizontally through a rectangular slab of glass under flexure in a vertical plane, it is broken up into two components polarised horizontally and vertically.

The light of either component suffers, owing to the stress, an additional retardation proportional to its distance from the "neutral axis," *i.e.* the mid-level of the slab. Thus the wave-front on emergence is no longer vertical, but has suffered a deviation proportional to the bending moment applied. The two components, however, are deviated by different amounts.

If the light be then analysed by a grating, the lines of the spectrum formed will be shifted, in consequence of the change in the angle of incidence. In addition, owing to the different shifts of the two components, each line appears doubled.

Experiment shows that the effect is quite measurable, and provides a new method for measuring directly the doubly refracting effect of stress, giving, not only the difference between the retardations of the two components, but the absolute amounts of each.

With a grating of 14,000 lines to the inch, the maximum separation of the components, for lines in the yellow, was about the distance between the two D-lines.

"On the Origin of the Gases evolved by Mineral Springs." By the Hon. R. J. **Strutt,** F.R.S.

It has long been known that thermal springs, such as those at Bath, give off considerable quantities of gas, which bubbles up with the water, and consists, for the most part, of nitrogen. Of recent years, interest in this subject has been revived by Lord Rayleigh's observation that helium and argon are present along with nitrogen.

It has been found that such gases, when fresh, are rich in radium emanation, and that the deposit thrown down by the water on standing contains a notable quantity of radium. It is natural to connect this observation with the discharge of helium by the springs. The author was formerly inclined to think that the facts were most easily explained by supposing that the supplies of helium and radium were derived from the disintegration of uranium lodes at a great depth by the water, but this view scarcely seems compatible with the universal presence of helium and radium in mineral springs, which has since been brought to light; for uranium lodes are very rare near the earth's surface, and there are fatal objections to supposing that metal to be generally more abundant at greater depths.

The unexpectedly large quantities of radium found in common rocks led the author to suspect that perhaps they might after all be able to supply the helium and radium products, as well as the ordinary gases and saline constituents of the spring. With the view of deciding this question, he has examined the inert portion of the gases given off by several varieties of rock on heating. The subject has attracted some attention from previous experimenters.

The results for two normal rocks were as follows:—

Matopo Granite. Quantity taken, 850 *grams.*

The inert residue consisted of

Nitrogen	11 c.c.
Argon	0·14 c.c.
Helium	0·04 c.c.
Neon	traces

Syenite Rock, Mt. Sorrel, Leicestershire. Quantity taken, 900 *grams.*

Inert residue—

Nitrogen	9 c.c.
Argon	0·026 c.c.
Helium	0·010 c.c.
Neon	traces

In both these cases, the vacuum tube, after removal of argon, gave a brilliant yellow helium glow.

We may compare these analyses with the composition of the Bath gas, as a type of the gases evolved by mineral springs. The total volume of inert gas (mainly nitrogen) is taken as 100.

Gas	Argon Per cent.	Helium Per cent.	Neon
Bath spring	1·5	0·12	traces
Matopo granite	1·27	0·36	traces
Syenite, Mt. Sorrel	0·29	0·11	traces

These figures make it fairly clear that there is a general resemblance between the gases of mineral springs and the gases of rocks, so far as nitrogen and the other inert constituents are concerned.

In addition to these constituents, rocks give off hydrogen, carbonic oxide, carbonic acid, and a little methane. The two former are probably secondary products, produced by chemical actions set up on heating. Carbonic acid is represented at the spring by the dissolved carbonates of the mineral water, while methane is present in the evolved gases. The author thinks, therefore, that we may consider that the disintegration and partial solution of ordinary rocks by water at a high temperature accounts for the gaseous, as well as the solid, products, delivered by springs such as those at Bath.

With regard to the primary origin of the argon and neon contained in rocks, the author has no theory to offer. It is natural, however, to associate the helium of rocks with the radium they contain. The relative quantities are quite in accordance with such a view, for the ratio is of the same order as in the strongly radio-active minerals. The author hopes to discuss this subject in detail in a future paper. He has found at least traces of helium in almost all of a considerable collection of ores and other minerals, but hitherto only one case has been found—in certain beryls—where there seems to be sufficient reason to look for any other cause than traces of the radio-active elements to explain its presence. The evidence so far obtained is not favourable to the view that the ionising radiation from ordinary substances is accompanied by production of helium.

June 27.—"On a Standard of Mutual Inductance." By Albert **Campbell**. Communicated by Dr. R. T. Glazebrook, F.R.S.

The author has designed a standard of mutual inductance of such a nature that its value is accurately calculable from the dimensions, and large enough to give good sensitivity in actual use. A high enough value (say 0·01 henry) can be got by having one of the associated circuits a coil of many layers. The objections to such a coil are overcome as follows:—

The primary circuit is a pair of single-layer coils wound on a single marble cylinder; their dimensions can be accurately determined. The secondary is a coil of many layers co-axial with, and midway between, the two primary coils, and of such radius that the mutual inductance is a maximum for change of radius. A series of curves is given from which the proper dimensions were chosen. All round the mean circumference of the secondary coil the magnetic field due to the current in the primary coils is zero, and is very nearly so over the section of the winding, thus allowing accurate calculation. The principle is applicable to other problems involving mutual inductance.

PARIS.

Academy of Sciences, July 22.—M. A. Chauveau in the chair.—A phenomenon resembling the spheroidal state: G. **Lippmann**. A strip of plaster of Paris adhering to a plane surface of glass becomes detached on raising the temperature above 100°, sliding over the surface with the greatest ease.—The effect of oxygen, osmotic pressure, acids, and alkalis in experiments on parthenogenesis: Yves **Delage**. The presence of oxygen is not necessary for the determining of parthenogenesis in starfish—it is even harmful; the presence of divalent ions is not at all essential, a solution of sodium chloride being often sufficient among sea-urchins. The requisite condition of parthenogenesis among certain of the latter consists in the treatment of the eggs by an acid solution, afterwards an alkaline, the first coagulating, the second liquefying certain constituents of the egg protoplasm.—The dielectric cohesion of helium: E. **Bouty**. By repeated purifications, the value of the dielectric constant was found to be reduced from 61·8 to 18·3.—The effect indicated by the electrolytic detector: M. **Tissot**.—A new optical property of magnetic bi-refraction belonging to certain non-colloidal organic liquids: A. **Cotton** and H. **Mouton**. Nitrobenzene shows a magnetic bi-refraction of positive sign, increasing proportionally to the square of the field and the thickness traversed. This property is more or less marked throughout the aromatic series, but not among aliphatic compounds.—The spectrophotography of minerals in different regions of the spectrum; galena and argyrite: A. **de Gramont**.—The coagulation of albumins by the actions of ultra-violet light and radium: Georges **Dreyer** and Olav **Hanssen**. Both serous and egg albumin are coagulated under the action of a prolonged intense light. The serum of the horse is only slightly coagulated by light; a solution of peptone remains clear, though becoming yellow, the same effect being also noticeable with casein. These results are all due to the ultra-violet portion of the light. Radium coagulates vitellin, but apparently no others.—The heats of formation of alkaline protoxides: E. **Rengade**.—A mixed anhydride of sulphuric and nitric acids: Amé **Pictet** and Georges **Karl**. Nitric anhydride dissolves with evolution of heat in freshly distilled liquid sulphuric anhydride. The product distils entirely at 218°–220°, and analysis shows it to have the composition $(SO_3)_4N_2O_5$.—The combination of nickel and cobalt with boron: Binet **du Jassonneix**. Compounds have been obtained of the composition NiBo and CoBo (already described by M. Moissan), Ni_2Bo, Co_2Bo, $NiBo_2$, and $CoBo_2$.—A new silicide of platinum: P. **Lebeau** and A. **Novitzky**. This compound, of the formula SiPt, can be obtained by direct union, is crystallisable, and chemically resembles platinum. —A general method of preparation of anhydrous metallic bromides, with oxides as a starting point: F. **Bourion**. The simultaneous use of sulphur chloride and hydrogen bromide gas provides a convenient means to this end. —The alloys of nickel and tin: Em. **Vigouroux**.—The effect of electric sparking upon a mixture of nitrogen and oxygen at low temperatures: E. **Briner** and E. **Durand**.—Discontinuities observed in the molecular conductivity of dissolved chromium sulphates: Albert **Colson**. —The rotatory power of the proteids extracted from the flour of cereals by aqueous alcohol: M. **Lindet** and L. **Ammann**.—Menthane 1:8-dicarboxylic acid and a new dicyclic ketone: Ph. **Barbier** and V. **Grignard**.—The origin of the deposits of colouring matter in red wine: V. **Martinand**.—Malic acid in wine must, and its destruction in fermentation: W. **Mestrezat**.—The liquefaction by diastase of fecula starch: A. **Fernbach** and J. **Wolff**.—Living reagents and diffusion: Michel **Yégounow**.—A new genus of Sapotaceæ in West Africa, with seeds containing an edible fatty matter: Aug. **Chevalier**. This tree provides a fine red well-veined wood, of density almost equal to unity.—The Pachypodium of Madagascar: MM. **Costantin** and **Bois**.—New researches on the cytology of the seeds of Graminaceæ: A. **Guilliermond**.—The morphological value of the caruncle of *Notopygos labiatus*: A. **Malaquin** and A. **Dehorne**.—The destructive function of the spleen towards trypanosomes: A. **Rodet** and G. **Vallet**. In the case of infection by *Trypanosoma brucei*, the spleen actively destroys the parasites.—The injection of artificial serums: C. **Fleig**. Those containing iron have been used with success in many cases of chlorosis.—The activity of Etna: A. **Riccò**.

CALCUTTA.

Asiatic Society of Bengal, July 3.—Notes on the Pollination of flowers in India. Note No. 4. On cotton in Behar: I. H. **Burkill**. The flowers of *Gossypium neglectum* and *G. intermedium* in Behar are a little visited by insects, chiefly small Hymenoptera of the genera Ceratina and Halictus, which seek honey in vain, and may collect pollen. Longer tongued insects, such as Xylocopa, Anthophora, and a few Lepidoptera only rarely go to the flowers. Plants intermediate between the two species, which are grown mixed, testify to the occurrence of cross-fertilisation; but they are rare, and the very early self-pollination in the flowers shows how much more the cotton crop depends on spontaneous self-fertilisation than on pollination by insects or other external agency.

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