NATURE

A WEEKLY ILLUSTRATED JOURNAL OF SCIENCE.

*"To the solid ground
Of Nature trusts the mind which builds for aye."*—WORDSWORTH.

No. 2652, Vol. 105] THURSDAY, AUGUST 26, 1920 [Price One Shilling

Registered as a Newspaper at the General Post Office.]

THE UNIVERSITY OF LIVERPOOL.

SESSION 1920–21.

The AUTUMN TERM BEGINS on OCTOBER 5. *Prospectuses and full particulars of the following may be obtained free (with the exception of the Calendar, price 1s., post free 1s. 6d.) on application to the REGISTRAR :—

Joint Board Matriculation Examination.
Award of Higher School Certificates.
Award of School Certificates.
Faculties of Arts, Science, Medicine, Law, and Engineering.
School of Architecture.
Department of Civic Design.
Department of Commerce.
Institute of Archæology.
Department of Education.
Diploma in Education.
University Training College.
University Extension Board.
School of Social Studies.
School of Local History and Records.
School of Russian Studies.
Department of Public Health.
School of Tropical Medicine.
School of Veterinary Science.
School of Dental Surgery.
Doctorate in Philosophy.
Fellowships, Scholarships, Studentships, Exhibitions, Special Grants and Prizes.
Halls of Residence.
University Calendar.

* All fees for courses of study as stated in the various prospectuses, and advertised for Session 1920–21, will be increased by 33⅓% as from the beginning of the Session.

CITY OF BRADFORD EDUCATION COMMITTEE.

TECHNICAL COLLEGE.

Principal—H. RICHARDSON, M.Sc. (late Beyer Fellow of Manchester University).

DAY COURSES.

FULL-TIME (DAY) COURSES extending over three or four years, and leading to the Diploma of the College, are arranged in the following departments :—

TEXTILE INDUSTRIES.
CHEMISTRY.
DYEING.
MECHANICAL and CIVIL ENGINEERING.
ELECTRICAL ENGINEERING.

Special facilities are available for advanced study.

REGISTRATION will take place in the College Hall on September 20 and 21.

EVENING COURSES.

EVENING COURSES are also arranged, on the successful completion of which students are awarded Senior and Advanced Course Certificates.

Further particulars and prospectuses may be obtained on application to the PRINCIPAL.

BY ORDER.

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Recognised by the University of London for the preparation of Internal Students for Degrees in Science, Engineering, and Music.

Technical Day College in preparation for Engineering, Architectural, Chemical, or similar professions, and for University Examinations.

Training College of Domestic Science, recognised by the Board of Education for the Training of Teachers.

Department of Hygiene and Public Health, with recognised Courses for Sanitary Inspectors, Health Visitors, &c.

School of Art and Crafts.

Hostels for Women Students.

Evening Courses in Engineering, Pure and Applied Science, Music, Civil Service. Special subjects for women, &c.

Next SESSION begins on SEPTEMBER 21, 1920.

For particulars apply to the SECRETARY.

THE UNIVERSITY OF SHEFFIELD.

Students can be accepted in the Faculties of Pure Science, Engineering, Metallurgy, and Medicine (for the Sheffield M.B., Ch.B. courses). Early application for admission is desirable. Prospectuses free on application to the undersigned.

W. M. GIBBONS, Registrar.

CHEMISTRY LABORATORY ATTENDANTS.

—Men wanted experienced in Laboratory work. Wages £3 to £3 10s, according to experience.—Apply, with full statement of experience and references, SECRETARY, University College, London, Gower Street, W.C. 1.

PORTSMOUTH MUNICIPAL COLLEGE.

Principal—OLIVER FREEMAN, Wh.Sc., A.R.C.S., B.Sc.

Applications are invited for the following appointments :—

	Present Maximum Salary.
HEAD of MECHANICAL and CIVIL ENGINEERING DEPARTMENT	£450
SENIOR LECTURER in EDUCATION	£400
LECTURER in HYGIENE and GENERAL ELEMENTARY SCIENCE	£350
LECTURER in NATURAL SCIENCE	£350
LECTURER in ELECTRICAL ENGINEERING	£350

Commencing salary in each case will be fixed according to the candidate's qualifications and experience.

Application forms and further particulars may be obtained from the undersigned, to whom applications should be returned, as early as possible, accompanied by copies of not more than three recent testimonials.

H. E. CURTIS, Secretary.

Offices for Higher Education,
Municipal College,
Portsmouth.

UNIVERSITY OF WESTERN AUSTRALIA.

Applications, in duplicate, are invited for the following positions :—

PROFESSOR OF BIOLOGY.—The professor will be required to organise and conduct classes in Zoology and Botany leading to the Pass and Honours degrees, and generally to supervise the work of his department. Salary at rate of £900 per annum. Where qualifications otherwise are satisfactory, preference will be given to candidates who are strong on the Botanical side.

LECTURER IN GEOLOGY.—The lecturer will be required to organise and conduct classes in Geology leading to the Pass and Honours degrees, and generally to supervise the work of his department. Commencing salary at the rate of £400 per annum.

Copies of the conditions may be obtained from the AGENT-GENERAL FOR W.A., Savoy House, Strand, London.

Applications, which should be endorsed "Professor of Biology" or "Lecturer in Geology," must reach the AGENT-GENERAL FOR WESTERN AUSTRALIA, 115/6 Strand, London, W.C. 2, not later than September 15 next, and the CHANCELLOR, University of Western Australia, not later than November 8 next.

COUNTY BOROUGH OF STOKE-ON-TRENT.

CENTRAL SCHOOL OF SCIENCE AND TECHNOLOGY, STOKE-ON-TRENT.

A fully-trained CHEMIST is required for the post of ASSISTANT LECTURER in the Chemistry Department of the above School, to take classes in connection with the local industries. The post is for whole-time work, and part of this will be in the evenings.

Facilities will be given for research work.

Initial salary £300 per annum.

Applications should be forwarded as early as possible.

DR. W. LUDFORD FREEMAN,
Clerk to the Governors.

Education Offices,
Town Hall, Hanley,
Stoke on-Trent.
19/8/20. JG/IGT.

NORTHAMPTON POLYTECHNIC INSTITUTE.

ST. JOHN STREET, E.C. 1.

TECHNICAL OPTICS DEPARTMENT.

The Governing Body invites applications for the Appointment of HEAD OF THE TECHNICAL OPTICS DEPARTMENT, which was established in 1903 under the late Mr. S. D. Chalmers. The salary will be £640 per annum, rising to a maximum of £840 per annum by annual increments of £25. Under a "Comprehensive Scheme of Instruction in Technical Optics," which has been recently approved by the London County Council, in addition to the education of the usual students in technical optics, the instruction of trade apprentices will form an important part of the duties of the Head of the Department. It is of importance, therefore, that he should be a proved teacher of the required subjects. Full particulars of the duties of the post and forms of application can be obtained by letter from

R. MULLINEUX WALMSLEY, D.Sc., Principal.

NORTHAMPTON POLYTECHNIC INSTITUTE.

CIVIL AND MECHANICAL ENGINEERING DEPARTMENT.

ELECTRICAL ENGINEERING AND APPLIED PHYSICS DEPARTMENT.

WANTED, an ASSISTANT LECTURER and DEMONSTRATOR in each of the above departments. Commencing salary £300 per annum.

Conditions and forms of application, which must be returned not later than Tuesday, August 31, 1920, can be obtained from

R. MULLINEUX WALMSLEY, D.Sc., Principal.

EDINBURGH & EAST OF SCOTLAND COLLEGE OF AGRICULTURE.

The Governors will proceed to appoint at an early date a DIRECTOR of the COUNTY WORK DEPARTMENT of the College. Candidates must have a sound knowledge of Practical Agriculture, and have had a thorough scientific training; they should also possess experience in lecturing and in administrative work.

Commencing salary (including bonus) will be £673, rising according to scale.

Twenty copies of letter of application, giving full particulars of training and experience, together with twenty copies of not more than three testimonials, should be lodged with the undersigned, from whom further particulars may be obtained, not later than Friday, September 3.

THOMAS BLACKBURN, Secretary.

13 George Square, Edinburgh.
August 4, 1920.

EDINBURGH & EAST OF SCOTLAND COLLEGE OF AGRICULTURE.

ASSISTANT LECTURER IN BOTANY.

The Governors of the College will proceed to appoint at an early date an ASSISTANT LECTURER in BOTANY. Salary, including war bonus, £248. Twenty copies of letter of application, and of not more than three testimonials, should be lodged with the undersigned not later than September 17, from whom further particulars can be obtained.

THOMAS BLACKBURN, Secretary.

13 George Square, Edinburgh.
August 3, 1920.

EDINBURGH & EAST OF SCOTLAND COLLEGE OF AGRICULTURE.

The Governors will proceed to appoint at an early date a LECTURER in FARM ACCOUNTING AND BOOK-KEEPING. Salary, including bonus, £400. Twenty copies of letter of application, together with twenty copies of not more than three testimonials, should be lodged not later than September 3 with the undersigned, from whom all further particulars can be obtained.

13 George Square, Edinburgh.
August 9, 1920.

THOMAS BLACKBURN, Secretary.

TRANSVAAL UNIVERSITY COLLEGE.

(UNIVERSITY OF SOUTH AFRICA.)

Applications are invited for the post of LECTURER in GEOGRAPHY at a salary of £400, plus £64 local allowance, on the scale £400–25–£500. In addition the post carries pension rights and a war bonus will be paid until the cost of living returns to normal.

Applications must reach the undersigned on or before October 15, 1920. They should be in duplicate, containing full details as to age, degrees, experience, and should be accompanied by at least three recent testimonials. If an oversea candidate be appointed, the sum of £40 will be allowed for the voyage and free railway transport to Pretoria from the coast.

English and Dutch are the official languages of the Union, and successful applicants not familiar with both will be expected to qualify within a reasonable time. Duties to commence in February, 1921.

A. A. ROBERTS, Registrar.

MINISTRY OF AGRICULTURE AND FISHERIES.

Applications are invited for posts as PROBATIONER NATURALISTS (6 Vacancies) in the Fisheries Department. The salary, inclusive of bonus, will be £300, plus travelling and subsistence expenses. Candidates should have graduated in a British, Irish, or Colonial University and should have received a general training in science, with special knowledge of Zoology, Mathematics, Chemistry, or Oceanography. Preference will be given to men who have seen active service in the war. Candidates should not be more than 30 years of age.

Application forms can be obtained from the MINISTRY OF AGRICULTURE AND FISHERIES, 4 Whitehall Place, S.W.1, and must be returned to the GENERAL SECRETARY not later than August 31.

UNIVERSITY COLLEGE OF WALES, ABERYSTWYTH.

The Council of the College will shortly proceed to appoint an ASSISTANT LECTURER in the Zoology Department, at a commencing salary of £250 to £300 (according to experience) per annum. Further particulars may be obtained of the REGISTRAR, to whom applications should be sent on or before Saturday, September 11.

Applications should be accompanied by testimonials and references.

THE REGISTRAR.

University College of Wales,
Aberystwyth.
July 21, 1920.

GOVERNMENT LABORATORY.—

TEMPORARY CHEMICAL ASSISTANTS required; salary, including present war bonus, £326 Age 20 to 25.—Apply, with copies of testimonials, GOVERNMENT CHEMIST, Clement's Inn Passage, W.C. 2.

CITY OF BRADFORD EDUCATION COMMITTEE.

TECHNICAL COLLEGE.

Applications are invited for a LECTURESHIP in ENGINEERING DRAWING.

Salary (including War Bonus of £85 16s.) up to £500 per annum to a candidate of suitable qualifications and experience.

Applications, upon forms which may be obtained from the PRINCIPAL, Technical College, Bradford, should be forwarded to the PRINCIPAL as soon as possible.

August 18, 1920. BY ORDER.

UNIVERSITY OF LONDON.

The Senate invite applications for the post of ACADEMIC REGISTRAR. Salary £900 a year, with a War Bonus of £100 for 1920–21. Applications (30 copies) must be received by the Principal Officer not later than September 15, 1920, in envelope marked "Academic Registrarship." Particulars may be obtained on application to the ACADEMIC REGISTRAR, University of London, South Kensington, S.W. 7.

E. C. PERRY, Principal Officer.

THE QUEEN'S UNIVERSITY OF BELFAST.

Applications are invited for the DEMONSTRATORSHIP in AGRICULTURAL BIOLOGY.

The Demonstrator will enter on his duties on October 1, and will work under the supervision of the Professor of Botany.

Salary £300 per annum.

Further particulars may be obtained from

J. M. FINNEGAN, Secretary.

SCHOOL OF PHARMACY OF THE PHARMACEUTICAL SOCIETY OF GREAT BRITAIN.

Applications are invited for the post of ASSISTANT LECTURER in CHEMISTRY, to take charge of the teaching of Physics and assist in the general supervision of Practical Chemistry. Salary £300 per annum.

Applications to be forwarded to the REGISTRAR of the School of Pharmacy, 17 Bloomsbury Square, W.C. 1.

BIRKBECK COLLEGE, LONDON.

The Governors invite applications for the post of LECTURER in BOTANY. Day and Evening Courses. Salary £350–£440 (£10).

Full particulars and form of application will be forwarded on receipt of an addressed envelope. Latest date for receiving applications, September 15.

G. F. TROUP HORNE, Secretary.

Birkbeck College,
E.C. 4.

UNIVERSITY OF ABERDEEN.

TWO UNIVERSITY ASSISTANTS (Demonstrators) in CHEMISTRY are required. Salary £250 per annum.

Applications, together with a full statement of qualifications and the names of at least three referees, should be sent, not later than September 15, to the SECRETARY of the University, Marischal College, Aberdeen, from whom further particulars may be obtained.

UNIVERSITY OF ABERDEEN.

A qualified LECTURE TABLE ASSISTANT is required in the Chemistry Department. Wages £3 15s. 0d. per week. Applications, with references and a statement of qualifications and experience, should be sent to the SECRETARY, Marischal College, on or before Wednesday, September 15, from whom a statement of duties may be obtained.

UNIVERSITY OF BRISTOL.

LECTURER IN PHYSICS, £400.
ASSISTANT LECTURER IN PHYSICS, £300.

For particulars send stamped addressed envelope to REGISTRAR. Candidates should state the earliest date on which they can take up their duties.

ASTRONOMY.—STATISTICAL RESEARCH, computation, development (plates), and routine work of any kind undertaken by experienced Graduate.—Box 2652, c/o NATURE Office.

FOR SALE.—Fine Mineral Collection, about 300 different specimens, including rock-forming minerals, ores, salts, precious stones, set of 50 rocks, also polished marbles, granite, etc., specially made boxes with trays and sections, £12 10s. Great bargain.—18 Lynette Avenue, Clapham Common, S.W.4.

WHAT OFFERS?—Nature, from 1869 to 1920, all bound, as new; also Royal Microscopical Journal, from 1878 to 1920, all bound, and as new, 124 copies not bound.—BERNARD, 23 Sydenham Road, Bristol.

THURSDAY, AUGUST 26, 1920.

Editorial and Publishing Offices:
MACMILLAN & CO., LTD.,
ST. MARTIN'S STREET, LONDON, W.C.2.

Advertisements and business letters should be addressed to the Publishers.

Editorial communications to the Editor.

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

The Forthcoming Census.

THE Census Act of 1920 will have one great advantage over previous Census Acts—that it will be a permanent measure, and not, as they have been, limited to the operation of taking the one census that was at the time in contemplation. We have travelled far from the days when the numbering of the people was considered to be an offence that would provoke Divine anger, and it is quite time that the old hesitating policy of passing a new enactment and creating a new staff and machinery every ten years, which doubtless had its origin in consideration for those superstitious scruples, should be definitely abandoned. The system had one indirect advantage while it lasted. For the eleven decenniums since 1801 the eleven separate Acts that have had to be passed have been gradually strengthened and made more workable, as experience has shown what improvements it has been possible to introduce into the practice, and thus have ripened into the materials for a permanent statute. All the same, the necessity for organising a scratch staff of new men every ten years, and dismissing it as soon as the census work was over, has been a great drawback to the efficiency of the Department, and it is to be hoped that one result of the new Act will be to enable the Census Office so to distribute its work over the whole decennium as usefully to retain the services of an experienced and competent staff of permanent officials. Much credit is due to the successive controllers of the census for the good work they have done under all disadvantages, and it is no disparagement to them to say that they have been hampered by circumstances.

The Act contemplates, but does not require, a quinquennial census. It enacts that no census shall be required to be taken in any part of Great Britain in any year unless at the beginning of that year at least five years have elapsed since the beginning of the year in which a census was last taken in that part of Great Britain; but it leaves to the King in Council to fix the date on which each successive census is to be taken. There can be no doubt that for some statistical purposes the interval of ten years is too long, and that not infrequently in the course of that interval events arise that materially affect the applicability of averages drawn between censuses distant ten years from each other. With careful organisation a quinquennial census might be made the rule, but the Act leaves this question entirely open. It allows, however, of a special local census being made, independent of the date of the last previous census, upon the application of a local authority through the Minister of Health to his Majesty in Council for the purpose of facilitating the due performance by the authority of its statutory duties.

An important provision of the Act is that which prohibits inquiry at a census into any particulars other than those specified in the schedule to the proposed enactment. These are:—Name, sex, age; occupation, profession, trade, or employment; nationality, birthplace, race, language; place of abode and character of dwelling; education; infirmity or disability; condition as to marriage, relation to head of family, parentage, issue; and "any other matters with respect to which it is desirable to obtain statistical information with a view to ascertaining the social or civil condition of the population." The generality of this last item would no doubt be controlled by the *ejusdem generis* principle of interpretation, and there need be little fear that any Order in Council would authorise an undesirable extension of it; but care would still have to be taken against the use of the census for indirect or partisan motives. It may be stated as a general principle that the more you increase the number of items of information that you demand, the more you diminish the probability that the information you actually obtain will be accurate. A wise investigator, therefore, while naturally anxious to get all the sound information that he can, will carefully distinguish between that which is essential and verifiable, and that which cannot be relied upon.

Much light may be expected to be derived from the census returns upon subjects that have recently been prominently before the public, such as the diminution in the birth-rate, the extent to which it has prevailed among the various strata of the community, the results of the war as affecting population and health, the effect of the shortage in housing on the general welfare, and other questions to which the events of the decade have given a new urgency; but in all these matters the principle we have just indicated of judging information, not by the number of details you are able to amass, but by the weight of accuracy and authenticity that they bear—*non numero, sed pondere*—will have to be borne in mind. The experience of the Registrar-General, backed by the enlightened enthusiasm of the Ministry of Health, will have ample exercise in these respects.

The Act is intituled "An Act to make provision for the taking from time to time of a census for Great Britain or any area therein and for otherwise obtaining statistical information with respect to the population of Great Britain." The Registrar-General, in addition to his formal Reports on the Census Returns, is to have power to supply local authorities and others concerned with statistical information derived from the census returns. The second branch of the title is provided for by section 5, which enables him also to publish statistics of the number and condition of the population derived from other sources, and for that purpose to enter into relations with other Government Departments so as to further the supply and provide for the better co-ordination of such information. If he were enabled to enter into similar relations with other countries as well, the very excellent object of obtaining uniformity in the statistics of the several nationalities might be materially promoted.

Prof. Alexander's Gifford Lectures.

Space, Time, and Deity: The Gifford Lectures at Glasgow, 1916–18. By Prof. S. Alexander. (In two volumes.) Vol. i. Pp. xvi+347. Vol. ii. Pp. xiii+437. (London: Macmillan and Co., Ltd., 1920.) Price 36*s*. net.

PROF. ALEXANDER has written a book which requires more than cursory reading. It deserves careful study. For it embodies a thoroughly modern exposition of New Realism in full detail. Moreover, these two volumes are not merely the outcome of a sustained effort at accurate investigation. They are distinguished by their admirable tone and temper. The author is throughout anxious to understand and to represent faithfully the views of those with whom he is in controversy. His reading of what has been written by the great thinkers of other schools has been closer and more intelligent than that of most New Realists, and he displays no traces of arrogance. He has done all he could to appreciate the materials furnished, not merely by mathematical and physical science, but by biology and psychology; highly important fields for his inquiry.

These very merits of Prof. Alexander's method have, however, produced their drawbacks. They have driven him beyond the current conceptions of the New Realist type into others which are not always easy to reconcile with them. In the second volume, particularly, where the author is chiefly concerned with such problems as those of the nature of the tertiary qualities of reality, of value, and of deity, the treatment leaves the impression that the subject-matter passes beyond the limits which alone are for the method legitimate. None the less, the effort made to be consistent is a notable one. But under this head I must refer the reader to the book, for the only aspect of the doctrine in it with which space allows me to concern myself is its cardinal principle as applied to physical knowledge.

To begin with, it is necessary to be clear as to what is peculiar to himself and his school in Prof. Alexander's teaching. It is not sufficiently realised that to-day the New Realists comprise a variety of groups divided by differences that are of far-reaching importance. These differences relate to the nature attributed to mind. For some of the most prominent of the American New Realists mind has no characteristic at all that distinguishes it from its objective content. Seeing means colours occurring; hearing means sounds occurring; thinking means thoughts occurring. Mind is itself just a casual selection out of the field of consciousness, and has no nature distinct from that field. When we speak of a mind, the grouping arises out of relations possessed by the objective elements themselves, relations which exist quite independently of our own action in perceiving. Minds are thus subordinate groups in a larger universe of being which includes them, and which would be unaltered if minds disappeared from it. Consciousness is thus merely a demonstrative appellation.

Now for Prof. Alexander, and, I think, for most of the English New Realists, mind has a reality independent of its object. With the latter, whatever it is, it is "compresent." The act of perceiving is one reality, the object perceived is another. Left to itself, the activity which we call mind reveals the object, with its relations (which may be universals) just as they exist independently of it. But the activity is a separate reality, which does not belong to the ordinary object world, but reveals itself in consciousness, in which it is said by Prof. Alexander to be "enjoyed." Here we have dualism, a dualism which he gets over by referring the origin of the activity of mind and the object with which it is compresent, alike, to a final reality which is the foundation of both, an ultimate space-time continuum. This, inasmuch as the flow of time enters into its very essence, is not static, but dynamic. The activity which we are conscious of (in the form, not of perception, which is of objects, but of self-enjoyment) is therefore in its turn dynamic, and its character is that of a conation.

I am not sure that the Americans, notwithstanding their boldness, are not here on safer ground. They project everything, thought, feeling, and tertiary qualities, such as goodness and beauty, into what they call a non-mental world. Prof. Alexander is more cautious. With him the native hue of resolution is, at times at least, as he progresses in his enterprise, sicklied o'er with the pale cast of thought. He seems to feel that he must retain something for a mental world. Starting with space and time as having no reality apart from one another, but as mere abstractions from aspects or attributes of the foundational reality, which is space-time or motion, the "stuff of which all existents are composed," he has to account for our actual experience. His foundationally existent activity breaks itself up into the complexes of which we are aware, and which possess, as belonging to their nature, certain fundamental and all-pervasive features which we recognise as categories. There result also qualities which appear in our experience. These form

"a hierarchy, the quality of each level of existence being identical with a certain complexity or collocation of elements on the next lower level. The quality performs to its equivalent lower existence the office which mind performs to its neural basis. Mind and body do but exemplify, therefore, a relation which holds universally. Accordingly, time is the mind of space, and any quality the mind of its body; or, to speak more accurately, mind and any other quality are the different distinctive complexities of time which exist as qualities. As existents within space-time, minds enter into relations of a perfectly general character with other things and with one another. These account for the familiar features of mental life; knowing freedom, values, and the like. In the hierarchy of qualities the next higher quality to the highest attained is deity. God is the whole universe engaged in process towards the emergence of this new quality, and religion is the sentiment in us that we are drawn towards him, and caught in the movement of the world towards a higher level of existence."

I have given the general result of his inquiry as summed up in the author's own words, those used by him in concluding his final chapter. But it would be unfair to suggest that the nature of this result can be appreciated from any isolated quotation. The whole book must be read. It is admirable alike in thoroughness of method and in command of material. Still, it is obvious that the entire edifice depends for its stability on its foundation, and that the author's conception of the ultimately real as being space-time, a continuum of point-instants or pure events entirely independent of mind, is the crucial point in his reasoning. If he is right, it must be in terms of this existent that all else must be capable of expression, and it cannot itself be expressed in terms of anything beyond itself. Of course, Prof. Alexander does not dispute that when we speak of space and time as of this character we are going beyond what we learn through sense, or intuitively, and are employing constructions of reflection. He is quite entitled to do this if a non-mental world can include universals, as he insists, in common with all New Realists. Our simplest experience is, as he says, "full of our ideas." The question is whether they belong to mind or to what is not mind. We shall see presently to what path this conclusion conducts.

At this stage we have to put before us the author's analysis of the relation of space to time, an analysis that seems to me altogether admirable. Space taken in abstraction from time has no distinction of parts. Time in so far as it is purely temporal is a mere now. To find a continuum we must find distinguishable elements. Without space there would be no connection in time. Without time there would be no points to connect. There is therefore no instant of time apart from a position in space, and no point of space except in an instant of time. The point occurs at an instant, and the instant occupies a point. The ultimate stuff of the universe is thus of the character of point-instants or pure events, and it is so that we get our continuum. The correspondence is, however, not a one-to-one, but a many-one, correspondence. For one point may occur at more than one instant, and one instant may, analogously, occupy several points.

Prof. Alexander thinks that he is here in full accord with Minkowski's well-known conception of an absolute world of four dimensions, of which ordinary geometry omits the fourth, the time element. When he wrote his book Einstein's doctrine of relativity was only fully known in its first form, the "special" theory, and Prof. Alexander believes that his view of the character of the space-time continuum has left him free to accept the so-called principle of relativity in this form.

For it suggests really no more than the unification of the observations of two sets of observers who may be observing an absolute world in space-time, by means of formulas of transformation in which the observations of observers with one system of co-ordinates can be rendered in terms of the co-ordinates of observers with a different system. It may be, he says, that the formulas are not really independent, inasmuch as they are ultimately numerical, and numbers may be wholly dependent on an absolute space and time system. Thus it would be an absolutely identical set of relations which was observed from the two systems of reference, moving rectilinearly with a relative velocity which remained uniform.

But can this be accepted in the fresh light cast by the general theory of relativity, of which the special theory is now shown by Einstein to be a mere special case? Here metaphysicians have to look over a fence into ground at present mainly occupied by the mathematician. But not exclusively so occupied. The ground is in truth a borderland where mathematics and epistemology trench on each other, and the fence is not of barbed wire. We are, indeed, compelled to try to do the best we can with unfamiliar topics if we would get at the truth about the nature of reality. The relativity doctrine now extends to accelerating motion. It has also, apparently, been demonstrated that a principle of equivalence obtains according to which any changes which an observer takes to be due to what he supposes to be attraction within a gravitational field would be perceived by him in precisely the same way if the observer's system of reference were moving with the acceleration which was characteristic of the gravitation at the observer's point of observation. The combination of these principles gives us relativity of measurement in actual experience without restriction. The gravitational principle is, in addition, here based, not on a supposed elementary law of gravitational *force,* whatever that means, which would leave us in metaphysical perplexities about action at a distance, but on elementary laws of the *motion* of bodies relatively to each other in a so-called gravitational field. There is no decision either for or against Euclidean geometry as a possible special case. But there is a decision that space, as a physical thing with unvarying geometrical properties, is to be banished, just for the same sort of reasons as the æther was banished before it. Only observable things are to be recognised as real in the new system of modern physicists.

It is therefore asserted by Einstein that, all motions and accelerations being relative to the system of reference of the observer, neither space nor time has physically independent objectivity. They are not measurable in themselves. They mean only the framework in which the minds of the observers arrange physical events, according to the conditions under which observation takes place. We may choose such frameworks as we please, but in point of fact we naturally choose so that the application of our method is the one that appears best adapted to the character of what we observe. The standard used will give their physical significances to our "geodetic lines." The apparent order in space and time has no independent existence. It manifests itself only in the events that present themselves as so ordered.

But the revolution in conception does not stop here. As so-called "gravitational fields" are everywhere present, the old special theory of relativity is nowhere an accurate account of phenomena. The velocity of light, for instance, cannot really be constant under all conditions. It is the things we observe in space and time that give to these their definite structure, and the relations in them of the things depend on the system of observation. To get at the fundamental law of the change which takes place in the space-time continuum we must look for the principle which governs the motion of a point in it as of the form of a differential law for the motion of such a point, not merely in a straight line in the Euclidean sense, but in a geodetic line which will be relative to any possible form of motion and acceleration in a gravitational field. If we can reach such a differential law under the aspect of an equation sufficiently elastic in its variables, we shall be able to fit into it mathematical expressions based on actual observation which give the "gravitational potentials" required for the application of the law. The form of the differential equation which expresses the law must therefore be such as to be applicable whatever may be the four co-ordinates of reference of the observer of motion in any conceivable gravitational field. The principle of equivalence necessitates this, and we get as the result a science of motion depending on the relativity of every kind of motion. All that is required is that the co-ordinates which are the variables in the equation of motion of a point-mass moving uniformly and rectilinearly should be so expressed as to be capable of transformation into the co-ordinates, whatever their shape, of any system of reference which moves in any path and has any accelerated motion whatsoever. This appears to have been done completely. The *result* is intelligible to the epistemologist who can even do no more than look across the boundary fence. The mathematical details and scaffolding he may be wholly unable to appreciate.

But not the less does he feel compelled to take off his hat reverently before the shades of Gauss and Riemann, and before those who have been able to wield the mighty sword with which these great thinkers cut the knots that held physicists back from the unrestricted calculus of to-day, purified as it now is from the old assumptions.

Now the importance of this thorough-going application of the principle of the relativity of the character of the point-event continuum to the observer is obvious. It means relativity in significance for intelligence. As Prof. Eddington has recently remarked in a notable article in *Mind,* the intervention of mind in the laws of Nature is more far-reaching than is usually supposed by physicists. He develops this conclusion in a fashion which is impressive. Freundlich and Schick in their recent books insist on the same thesis.

But what does the word "mind" mean when used thus? Not a substance in space-time, as Prof. Alexander would have it. To start with, such an assumption would involve either the rejection of the modern doctrine of relativity as the school of Einstein has put it forward as dependent on interpretation, or something tending towards solipsism. Nor can mind mean substance in another aspect, that in which Berkeley and the Mentalists have sought to display it. Few competent students of the history of thought look on philosophy as shut up to such a view, the view which New Realism seeks to bind into the "egocentric predicament."

There is another interpretation of the meaning of mind in which it signifies neither any of these things nor yet an Absolute Mind apart from that of man, but just our own experience interpreted as being in every stage relative in its presentation, and not so merely in the relation of measurement. For Einstein's doctrine seems to be only a fragment of a yet larger and even more striking view of reality. Relativity is surely not to be confined to judgments based on the co-ordinates we employ in measurement. It may equally arise in other instances from the uncritical applications of conceptions concerned with quality as much as with quantity. From such a point of view reality, including human experience, is what it is only because we are ever unconsciously, under the influence of practical ends to be attained, limiting our systems of reference, interpreted in even a wider sense than that of Einstein. These may be limiting ends imposed on us by the mere fact that we are human beings with a particular position in Nature. The relativity of knowledge will thus assume the form of relativity of the real to general points of view, and will result in a principle of degrees extending through all knowledge and reality alike, which fall short of ideal completion. It is an old principle, as old as Greek thought. If it is true, it solves many problems and gets rid of the distinction between mental and non-mental, between idealism and realism, between mind and its object. For it accepts the "that," and confines the legitimate problem to the "what." It also gets rid of the perplexing idea of an Absolute Mind as something to be conceived as apart from us while working in us.

The idea and the method, recurring as they do in ancient and modern philosophy, are worth study by those who feel the stimulus of the new atmosphere which Einstein has provided. They may find a convenient analogue to the special principle of relativity in Kant's "Critique of Pure Reason," with its investigation of the general conditions which are required in order to render any individual experience possible. If they seek for an analogue to Einstein's general principle, they may look either in the "Metaphysics" of Aristotle or in the "Logic" of Hegel. The greatest thinkers have presented resembling conclusions in varying language.

This path is one that is not easy to tread. It is as hard to enter on as is that of the metaphysician who has to try to understand the meaning for philosophy of the absolute differential equations which Einstein employs. Prof. Alexander, however, knows the direction, if he does not now look that way. And it may be that the difficulties with which the new principle of general physical relativity seems to threaten New Realism, with its non-mental and static reality, may lead him, with his openness of mind, to consider once again whether he should not wend his steps afresh towards the wicket-gate for a further pilgrimage. But whatever the direction in which he is looking, his new book is full of stimulating material, even as it stands.

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HALDANE.

Principles and Practice of Surveying.

Surveying. By W. Norman Thomas. Pp. viii + 536. (With Answers.) (London: Edward Arnold, 1920.) Price 31*s.* 6*d.* net.

ALL British surveyors will give the heartiest welcome to this excellent book. We have become accustomed to American and German survey literature, and have relied too much upon it. The author has gone far to relieve us of this necessity. He succeeds admirably in emphasising the importance of a due appreciation of the errors involved, and his mathematical investigations and notes on the accuracy of each method are clear and convincing.

The matter sequence is curious. We start with chain surveying and do not reach triangulation until p. 377. Surveys for purely engineering ends are often limited in extent, but none the less each method has suffered from being considered on its own merits and not as part of a whole. Geodesy and topographical surveying are barely mentioned.

We start with the field work, plotting, and area computing of chain surveys. The subject is clearly put, and the investigations of errors and of the accuracy of linear measurement are particularly valuable. It is curious to find reference in this chapter to British war maps, which owed none of their characteristics to chaining. The chapter on optics and on magnetism is welcome, though it might with advantage have gone further. After a description of instruments of minor importance and of the vernier and micrometer microscope, the author deals with theodolites, omitting mention, unfortunately, of Messrs. Watts and Co.'s latest patterns, which embody many improvements. Adjustments are fully described, and are followed by a few pages on the accuracy of angular measurements and on geodetic results.

Having already dealt with linear measurement, the author confines his description of traverses mostly to angular measurement by compass, dial, or theodolite. The investigation of errors of closure is valuable and includes an interesting mathematical analysis of Bowditch's rule. The surveyor who traverses between stations of an existing triangulation will find little help, however, for the problems which then arise are practically ignored. Two consecutive chapters deal with levels, levelling, contouring, trigonometrical levelling, and various relative and absolute methods of determining altitude. Mention is made of the Zeiss patterns of level in use on the Ordnance Survey, but there is no mention of the "water level" for contouring purposes. As usual, the student will have no excuse for failing to understand the relative values of different levelling methods. There is a brief mention of precise levelling generally, including a note on the new geodetic levelling of Great Britain. Tacheometry is thoroughly dealt with, the optics and attainable results being lucidly described, and leads on to range-finders, with special reference to the "Barr and Stroud." The chapter on plane-tabling is not so convincing as the rest, and is all too short. The plane-table has been used with success in climates as difficult as our own, and is an indispensable method of survey.

Chapters on curve ranging, earthwork calculations, and hydrographic surveying contain well-arranged information rarely to be met with elsewhere. It is under hydrographic surveying, curiously enough, that one finds a description of instrumental resection. As a subject it deserves more attention than it gets, and should not be confined to a solution from three points. Triangulation and base measurement are well dealt with and illustrated by historical references. The experienced surveyor will find little fresh information on astronomical surveying (except an interesting note on Driencourt's prismatic astrolabe), but will relish the simple and yet thorough way in which the theory is put.

The concluding chapter, on photogrammetry, deals with the photo-theodolite and contains a brief reference to stereophotogrammetry and to aeroplane photography. The get-up, printing, and paper are a pleasure to see. All surveyors should possess a copy of this book.

H. S. WINTERBOTHAM.

Australian Hardwoods.

The Hardwoods of Australia and their Economics. By Richard T. Baker. (Technological Museum, New South Wales: Technical Education Series, No. 23.) Pp. xvi + 522 + plates. (Sydney: The Technological Museum, 1919.)

THE author states in the preface to this work that his object is to make known to Australians and the world generally the diversity of the hardwoods with which Nature has endowed the vast Australian continent. Such a book can scarcely have been introduced at a more opportune time, when the problem of how to provide sufficient timber for the world's growing needs has become increasingly acute since the war. It is a remarkable fact that, while Australia has probably the largest variety of hardwoods in the world, covering hundreds of thousands of square miles, the number of species they represent is comparatively few—probably less than 500. Moreover, nearly half of these belong to the genus Eucalyptus, which covers at least two-thirds of the whole surface, and supplies the bulk of hardwoods required for commercial purposes.

The book is divided into three main sections. Part i. deals with the physical properties of timber, colour, grain, taste, odour, structure, weight, durability, combustibility, and other features. The author emphasises the great aid afforded by colour in the identification of Australian woods, and the fine series of chromatic plates scattered through the volume, illustrating the newly planed surface of all the important timbers, shows in a very striking manner the great beauty and variety of these woods. The writer of this notice has had an opportunity of comparing a number of these plates with specimens in the fine collection of Australian woods at the Imperial Institute, and can vouch for their accuracy as regards both colour and delineation. Every timber has a distinct colour, though at times this is far from easy to describe in the absence of any standard colour nomenclature; in such cases coloured plates are a great help. Some of the colour terms seem to be used in a rather loose sense. The author employs eight types—(1) dark red, (2) red, (3) pink, (4) grey, (5) chocolate, (6) yellow, (7) pale, (8) white—but on comparing some of the plates we find it hard to draw the line between the types pink and pale, while some of the timbers described under the heading of white would be more correctly termed buff-coloured. The illustrations in black-and-white showing wood anatomy should also be a material aid to identification.

In part ii. we have a description of each species in botanical sequence, followed by a list of timbers arranged in grades of hardness. Part iii. contains technical articles on (i) the determination of specific timbers; (ii) nomenclature; (iii) the seasoning of timber; (iv) the preservation of timbers, concluding with an account of the economic uses of the woods. The book contains a vast amount of information useful to both foresters and students.

The typographical arrangement is somewhat open to criticism. The use of unnecessarily large types for specific names and authorities, with a wide margin, entails a great waste of space, and makes the book rather cumbersome. On the other hand, the systematic portion of the work might with advantage have been in larger type. These minor defects, however, do not detract from the general excellence of the book.

Mr. Baker is to be congratulated upon a valuable addition to the literature of Australian forestry, which should bring home to Australians the importance of preserving these many valuable woods from the extinction which threatens them by a well-devised and vigorous scheme of re-afforestation. A. B. J.

The Columbian Tradition.

The Columbian Tradition on the Discovery of America and of the Part Played therein by the Astronomer Toscanelli: A Memoir addressed to the Profs. Hermann Wagner, of the University of Göttingen, and Carlo Errera, of Bologna. By Henry Vignaud. Pp. 62. (Oxford: At the Clarendon Press, 1920.) Price 3*s*. 6*d*. net.

IN various publications, especially in his "Histoire de la Grande Entreprise de Christophe Colomb" (Paris, 1911, 2 vols.), Mr. Vignaud has endeavoured to upset the traditional view of the discovery of America. According to that view, Columbus set out in 1492, not to discover unknown lands, but to reach the eastern parts of Asia by sailing westward across the Atlantic, having already in 1474 been encouraged to do so by the well-known astronomer Toscanelli of Florence. In this pamphlet Mr. Vignaud has again summed up the results of his studies and defended them against the attacks of his two principal opponents.

All we know about Columbus and the object of his first voyage comes from himself or his son or his blind admirer, Las Casas, and not one of these is a trustworthy witness, as the exposure of various falsehoods told about the family and early history of Columbus has proved. No trace exists of Columbus ever having spoken of going to Eastern Asia before he returned from his great discovery; but that idea is spoken of in a letter to the "Catholic Kings," which Las Casas placed as a preface to the log-book of the first voyage. This letter is, however, neither found nor alluded to elsewhere, and bears no date. In the log-book Columbus says that his sole object is *las Indias*, but that book was edited by Las Casas, and in the days when he wrote, this expression only meant the Antilles and neighbouring lands, and never the East Indies. Columbus, when leaving Palos, did not sail straight across the Atlantic, as would have been natural if his goal had been "Cipangu" (Japan), or "Cathay" (China); he first went down to the Canaries and then sailed straight westward along the 28th parallel. At 700 or 750 leagues west of the Canaries he fully expected to find land, and was greatly disturbed when none was seen, so that he must have had some private reason to believe that there were islands near that spot; and the discovery of these would seem to have been the sole object of the voyage. It has been objected to this that Columbus (according to Las Casas) carried with him credential letters for the "Great Khan." But it is known that his partner, Pinzon, had some idea of going in search of Cipangu. Mr. Vignaud suggests that it was to secure the indispensable co-operation of Pinzon that Columbus included the visit to Cipangu in his plan, but that when he only found land much further west than he had expected, he believed that what he had found was Cipangu, a belief which he kept to his dying day.

With regard to the alleged letter and map of 1474, attributed to Toscanelli, these were never alluded to by Columbus himself; and the copy of the letter found at Seville in 1871 was probably not written by him, but by his brother. The information in the letter (the map is lost) is such as a distinguished *savant* would have scorned to supply, while it is quite in accordance with Columbus's own geographical ideas derived from the antiquated "Imago Mundi" of Cardinal d'Ailly. The letter was probably fabricated by the family of Columbus after his death to disprove the rumour that he owed his success, not to his studies in cosmography, but to some information about unknown islands privately obtained. The true glory of Columbus is that he found what he went out to find—a New World. J. L. E. D.

Our Bookshelf.

Electricity: Its Production and Applications. By Reg. E. Neale. (Pitman's Common Commodities and Industries.) Pp. viii+136. (London: Sir Isaac Pitman and Sons, Ltd., n.d.) Price 2*s*. 6*d*. net.

THE author addresses himself to the general reader who desires to understand something of the way in which electricity is produced and is utilised in present-day industries. The generation, distribution, and storage of electric power are first explained briefly, and then the author passes on to deal successively with lighting, heating, electric driving of machinery, traction, haulage, etc. Further chapters skim lightly over the leading features of electrochemistry, electrometallurgy, electric welding and cutting, telegraphy and telephony, and medical applications. So large a field can be covered in a little volume like this only by limitation to the barest essentials, but it is remarkable how complete and accurate is the information given. The reader is, however, hurried on unpleasantly fast, and is never allowed to pause where his interest is aroused. We are not as a rule over-fond of "tabloid" education, but the ubiquitous use of electricity in industry and daily life makes it desirable for everyone to know something of its nature and scope. It will be an advantage to many to have at their disposal so well compiled a summary of the subject rather than to rely on the loose statements too often made in conversation and in the non-technical Press.

The Nature-study of Plants in Theory and Practice for the Hobby-Botanist. By T. A. Dymes. Pp. xviii+173. (London: S.P.C.K.; New York: The Macmillan Co., 1920.) Price 6*s*. net.

THE first part of this book is devoted to an explanation of the meaning of the phenomena of plant life and its interdependent functions. Wherever possible, comparisons are drawn with human life, and, in consequence, chapters are given curious titles, such as "Marriage" and "Settling Down for Life." The second portion of the book is a detailed account of the life-history of the Herb Robert and its relatives. Tables are appended showing the separation of the sexes in time, the mode of pollination, and the method of seed dispersal of British species of Cranesbills and Storksbills. The book should be a stimulus to intelligent and intensive Nature-study.

Eugenics, Civics, and Ethics: A Lecture delivered to the Summer School of Eugenics, Civics, and Ethics on August 8, 1919, *in the Arts School, Cambridge.* By Sir Charles Walston (Waldstein). Pp. 56. (Cambridge: At the University Press, 1920.) Price 4*s*. net.

A STRONG plea is made in this lecture for the organisation and development of the study of ethics, or, as the author prefers to call it, ethology. The interdependence of eugenics and civics, and the foundation of both in ethics, are discussed, and warning is given against striving to produce the perfect physical specimen of man without due consideration of character and mental attributes. Towards the end of the lecture the progressive nature of ethical codes is made clear, and great stress is laid on the importance of the establishment of our ideal of the perfect man and the teaching of such practical ethics in both schools and homes.

A Second Book of School Celebrations. By Dr. F. H. Hayward. Pp. 133. (London: P. S. King and Son, Ltd., 1920.) Price 5*s*. net.

"A FIRST BOOK OF SCHOOL CELEBRATIONS" was reviewed in NATURE for August 5. The new volume contains a further series of celebrations dealing with the military conflicts in Palestine, toleration, Alfred the Great, Pasteur and Lister, Sir Philip Sidney, G. F. Watts, Empire Day, political parties, school leaving day, work, and five of a new type, termed by the author "homage celebrations," which deal with the artist, the martyr, the musician, Ireland, and Poland.

Stories for the Nature Hour. Compiled by Ada M. Skinner and Eleanor L. Skinner. Pp. 253. (London: George G. Harrap and Co., Ltd., 1920.) Price 5*s*. net.

A NUMBER of short stories from the pens of many authors have been collected in this volume. Hans Andersen, Ruskin, and Charles Lamb are represented, and the compilers themselves have supplied eight legends. The book should be useful to the teacher giving lessons on natural history subjects to small children, and should also make interesting reading for older children.

A Manual of Elementary Zoology. By L. A. Borradaile. Third edition. Pp. xviii+616+xxi plates. (London: Henry Frowde, and Hodder and Stoughton, 1920.) Price 18*s*.

THE last edition of this work was reviewed in NATURE for April 3, 1919. The only important change made in the new edition is the inclusion of twenty-one large plates, most of which are particularly valuable for laboratory work. Plate xii, showing various breeds of British sheep, is crude, and seems unworthy of a place in a book which is otherwise remarkable for its clear diagrams and realistic illustrations.

Le Radium: Interprétation et Enseignement de la Radioactivité. Par Prof. Fr. Soddy. Traduit de l'Anglais par A. Lepape. (Nouvelle Collection scientifique.) Pp. iii+375. (Paris: Félix Alcan, 1919.) Price 4.90 francs.

THE third edition of Prof. Soddy's book, "The Interpretation of Radium," which was reviewed in NATURE for February 20, 1913, is the original from which this translation was made. The translator has added an appendix in which the work of the period 1914–19 is described, and consequent modifications of theory are indicated.

Grasses and Rushes and How to Identify Them. By J. H. Crabtree. Pp. 64. (London: The Epworth Press, n.d.) Price 1s. 9d. net.

THIS little book is a catalogue of all the grasses and rushes of the English countryside. A brief description, accompanied by an illustration, is given of each plant mentioned. The book should be of value to both farmers and students.

Experiments with Plants. A First School-book of Science. By J. B. Philip. Pp. 205. (Oxford: At the Clarendon Press, 1919.) Price 3s. net.

MOST of this book is devoted to the experimental study of the elementary physiology of seeds and plants. An account of the reproductive process is included, and the elementary physics and chemistry of soils are briefly indicated. In the appendices a sketch is given of the scientific principles which are necessary to a study of botany. An index would have been a useful addition to the book.

Aluminium: Its Manufacture, Manipulation, and Marketing. By G. Mortimer. (Pitman's Common Commodities and Industries.) Pp. viii+152. (London: Sir Isaac Pitman and Sons, Ltd., n.d.) Price 2s. 6d. net.

THIS interesting book gives a particularly good account of the numerous applications which aluminium now finds in modern industry. The technical processes for the extraction of aluminium and its adaptation, both in the pure state and in the form of alloys, to industry are carefully and fully described. The book is well illustrated, and cannot fail to be of interest to chemists, engineers, and the general reader.

Chemical Theory and Calculations: An Elementary Text-Book. By Prof. F. J. Wilson and Prof. I. M. Heilbron. Second edition. Pp. vii+144. (London: Constable and Co., Ltd., 1920.) Price 4s. 6d. net.

THIS is an admirable collection of problems covering a wide range, and including many of an advanced character. A pleasing feature is the brief but lucid account of chemical theory, including a short section on atomic numbers. The book should prove of great service to teachers and to students preparing for degree examinations. It is distinctly better than most books on chemical arithmetic, since it aims at a higher standard.

Letters to the Editor.

[*The Editor does not hold himself responsible for opinions expressed by his correspondents. Neither can be 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.*]

University Grants.

I AM glad to see that the very urgent necessity for the provision of increased University grants which was so ably stated in your leading article of August 5 has led to the position in Leeds and Birmingham being brought forward so clearly by Sir Michael Sadler and Principal Grant Robertson in NATURE of August 12 and 19. There can be no doubt that every university in the country is feeling the need of largely increased financial assistance, without which it will be impossible to carry on efficiently, if at all, departments such as those of science, which must always be a source of large expenditure and financial loss to any university.

It is probably generally true that the higher the efficiency of a department, the greater is its cost of maintenance, and, consequently, the greater the financial loss to the university. Therefore, so long as reasonable economy in administration is practised, the expenditure of money on a successful department should be welcomed and encouraged, and every effort made to provide funds so that its work may have free scope and not be hampered in any way. Only under conditions of proper equipment as regards both staff and material and freedom from financial worry can a department be expected to develop to its fullest extent and to produce knowledge.

In the *Times* of August 18 Prof. Soddy and I directed attention to the critical condition of science at Oxford, and pointed out that there is actually no proper accommodation here even for the teaching of physical and inorganic chemistry. The antiquated buildings which are now used for the purpose are quite out of date, besides being far too small to cope with the large number of students who are presenting themselves for the honours degree.

The case of organic chemistry is also very serious because, although the laboratory which was built four years ago, largely owing to the generosity of Dr. C. W. Dyson Perrins, is modern and well-equipped, it is far too small.

A new extension is in course of construction, but the funds necessary to pay for it are not available, and must be borrowed, and there is, moreover, no adequate endowment to provide for upkeep when the buildings are completed. A similar state of things is to be found in connection with the new chair of biochemistry recently endowed through the generosity of Mr. Edward Whitley. There are no laboratories associated with this chair, and in the meantime accommodation must be provided in the already overcrowded physiological laboratories. A careful estimate of the cost of urgently required new buildings shows that at least 250,000*l*,. as well as an endowment bringing in 10,000*l*. per annum, must be forthcoming if the study of chemistry is to be placed on a firm basis in this University.

I have dealt more particularly with chemistry because it is generally admitted that the most pressing need in this University is that chemistry shall be placed on such a footing that teaching and research may be done under conditions very different from those which prevail at the present time. But the other branches of physical science are also urgently in need of financial assistance, partly for new buildings and partly to provide funds sufficient to maintain and work them.

There are clearly only two sources from which the very large sums required by the universities can be obtained, and those are (1) Treasury grants and (2) private benefactions.

You have pointed out that the proposed Treasury grant of 1,500,000*l*. included in the Estimates for 1921–22 is quite inadequate, and it is obvious that this must be the case. It is, therefore, to be hoped that careful inquiry into the needs of the universities by the Treasury will result in this sum being substantially augmented. With regard to private benefaction, I think we may look forward with confidence to very liberal response in the near future from generous individuals, and more particularly from wealthy firms interested in the progress of science and education. The action of Messrs. Brunner, Mond, and Co. in setting aside 100,000*l*. as a contribution to the universities is an example which will certainly be followed by other firms who owe much of their success to the work of chemists, engineers, and others sent to them from the universities.

If it were to become a recognised practice for firms who can afford to do so to set aside yearly some comparatively small sum as a contribution to the universities, the combined effort would go far to solve the difficulties in which we find ourselves at the present time. W. H. PERKIN.

The University Museum, Oxford, August 22.

Use of Sumner Lines in Navigation.

MAY I venture to point out, in the interests of navigational science, that although the article by Capt. Tizard in NATURE of July 1 under the above title is an admirably clear and concise account of the application of Sumner lines in navigation at the date given in his examples, it is scarcely descriptive of the best practice of to-day?

Of the two methods of drawing the lines described by Capt. Tizard, the first, or "original Sumner method," is now merely of academic interest, and is seldom practised outside schools and examination-rooms. Its defects are, first, that each sight has to be worked out twice (once for each of the two assumed latitudes), and, secondly, that it is inapplicable to sights taken near the meridian. It may also be remarked that unless the two assumed latitudes are very close together, the true circle of position may differ considerably from the straight line joining the two points found on the Mercator chart.

The second method described by Capt. Tizard, usually known as the "chronometer method," is still used to some extent. It avoids the double working out of each sight, but gives good results only for observations taken on large bearings; it is inapplicable to sights taken near the meridian.

For observations near the meridian what is called the "ex-meridian method" may be used to draw the position-lines. In this method the longitude is assumed, and the sight is worked out as a latitude observation; the position-line is then drawn, at right angles to the bearing, through the point where the meridian of the assumed longitude is cut by the parallel of the observed latitude. This method gives good results for sights near the meridian, but fails on large bearings.

A combination of the last two methods is sometimes employed, the sights near the meridian being worked out by the "ex-meridian method," and those on large bearings by the "chronometer method." This combined procedure has been advocated by several writers, especially by Capt. Blackburne, who undertook the immense labour of computing tables specially adapted for the purpose. The main objection to it is that the procedure is not uniform for all sights.

A much better method of drawing the Sumner lines than any of the above, and one which seems destined to replace all others, being now in extensive use by navigators of all nations and recognised as the standard method in the Royal Navy, is known as the Marcq Saint-Hilaire method, or the "new navigation." It consists in assuming a dead-reckoning position in both latitude and longitude, and then finding how much the observed zenith-distance of a heavenly body differs from that calculated on the assumption that the dead-reckoning position was correct. The difference between the observed and calculated zenith-distances is laid off from the assumed position in a direction to or from the observed object (according as the observed zenith-distance is less or greater than the calculated one), and the position-line is then drawn through the point so found at right angles to the bearing. The great advantage of this method is that it is perfectly *general*; it gives equally good results whatever the bearing of the object sighted.

Though called the "new navigation," the Marcq Saint-Hilaire method of drawing the Sumner lines is by no means a recent invention, having been used in the French Navy for more than forty years. Its advantages were advocated so long ago as 1888 by that indefatigable worker for the advancement of navigation, the Rev. William Hall, R.N., and have since been frequently pointed out by other English writers on navigation. Its superiority over all other methods for drawing the Sumner lines or position-lines being indubitable, there is a little difficulty in understanding its comparative neglect by British navigators up to recent times. One reason, no doubt, is conservatism; the British seaman usually prefers to use time-honoured methods with which he is familiar rather than to adopt new-fangled notions, and fears to risk his ship by the possibility of making a mistake in a process with which he has not been made acquainted during his early training. Another reason which operated powerfully until within the last twenty years or so was the absence of any tables for facilitating the calculation of altitudes comparable in scope with the tables of Davis and Burdwood, which so greatly helped in the rapid reduction of sights by the "chronometer method." This last difficulty was removed by the publication of the excellent "Altitude Tables" of my namesake, the Rev. F. Ball, M.A., of the Royal Navy, and at the present time it is just as simple a matter to work out sights by the "new navigation," with the aid of these tables, as it was to work the old "chronometer method" with the help of Burdwood and Davis.

Until within the last decade it was seldom worth while to attempt to fix a ship's position at sea within a mile or two, because so long as the longitude, whether found by Sumner lines or by any other method, was dependent entirely on the Greenwich time as found by the transport of chronometers over long distances, it was usually impossible to be sure of the longitude within that amount, no matter how accurately star observations were made. This difficulty affected the hydrographic surveyor as well as the navigator; and, indeed, it provides the explanation why so many charted longitudes—down the Red Sea, for instance—are in error by a mile or more. But nowadays, when wireless time-signals enable the error of a ship's chronometer to be found daily with an accuracy of a few tenths of a second anywhere on the seas, there is no reason why the longitude should ever be uncertain by so much as the tenth of a mile, provided only that sights can be taken with a corresponding degree of accuracy. Thus the advent of wireless telegraphy, by removing at one stroke the most serious of all pre-existing limitations to precision in the results, has made it worth while to improve the methods of position-finding at sea. Simultaneously progress has been made in the construction of charts and instruments adapted for navigation, giving to the navigator another stimulus towards attaining that refinement of method by which alone he may hope to steer his ship from port to port not only in safety, but also with that economy of time and fuel which is demanded by modern competition.

As regards the number of position-lines required to determine a ship's position, it is obvious that if only two sights are taken, no matter how favourable the angle at which the position-lines cut each other, the position found will be correct only if the observations are free from instrumental and other errors, and if dip and refraction are correctly allowed for. With only two sights a large unknown centring error in the sextant employed, or abnormal refraction, or a mistake in one of the sights, may render the position found quite false, and there is no means of detecting the error. If the two sights are not simultaneous or nearly so, there will, of course, be an added uncertainty in the position due to the difficulty in accurately estimating the ship's run in the interval. If *three* sights are taken constant errors can be eliminated, but accidental errors cannot be readily detected. If *four* sights are taken, however, as nearly as possible simultaneously, on bearings differing by approximately 90°, not only will a constant error of even two or three minutes in the measured altitudes, or in the allowance for dip, be without influence on the accuracy of the result, but if a mistake has been made in one of the sights the fact can readily be detected. This is a powerful argument for making the astronomical determination of a ship's position depend, whenever possible, on at least four Sumner lines or position-lines deduced from observations of four stars differing by approximately 90° in bearing.

It can easily be proved geometrically that when the altitudes of three or more stars have been equally accurately observed, the most probable position is the centre of that circle which most nearly touches all the position-lines, and in which the directions of the stars from the points of contact are either all towards or all away from the centre; also, that the radius of the circle gives the amount of any constant error in the observed altitudes, whether due to errors of the sextant employed or to error in the assumed dip of the horizon or refraction. If with more than three sights no circle can be drawn satisfying the condition of approximately touching all the position-lines, while at the same time having the star-directions from the points of contact pointing either all towards or all away from its centre, then it is certain that a mistake has occurred in one or more of the observations; either an altitude or a time has been wrongly recorded or one of the stars wrongly identified, or else there has been a mistake in the calculation for one or more of the sights.

The importance of considering the directions of the stars, as well as the position-lines themselves, is well illustrated by reference to the first of the examples given by Capt. Tizard. If the non-intersection of the three position-lines in his Fig. 1 is due to a constant error in all the altitudes, caused either by instrumental error or by error in the tabular allowance for dip or refraction (as will usually be the case in sights taken by a practised observer), then the true position is not, as might at first be thought, within the little triangle formed by the crossing of the lines, but *outside it*; and the true longitude is not 145° 4′, as Capt. Tizard concludes, but 145° 5′. For, as will be seen by Fig. 1, on which I have indicated the star-directions by arrows, no other circle than the one shown can be described so as to touch all three position-lines, while the three star-directions from the points of contact point either all towards or all away from its centre.

So great is the importance of accuracy in the fixing of the ship's position at sea in modern navigation, and so well is the "new navigation" with four position-lines crossing at about 90° adapted to secure this accuracy, that at the recent International Hydrographic Conference in London it was proposed by an eminent authority, Comdr. Alessio, of the Royal Italian Navy, that it would be desirable for the conference to prescribe as a fundamental rule of navigation that "the normal astronomical determination of a ship at sea must be made with the method of four Sumner lines by observing four stars the position-lines of which cut at approximately 90°." It was decided that the prescribing of rules for navigation did not fall within the scope of the 1919 Conference,

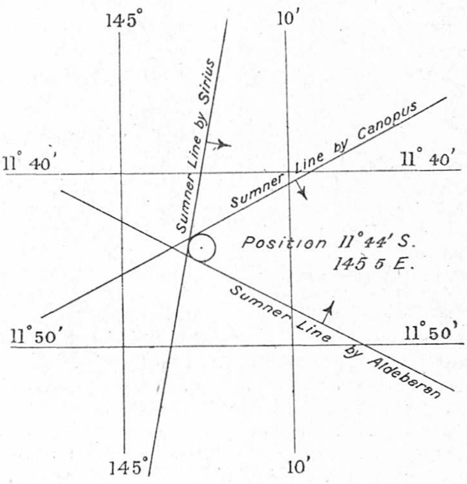

FIG. 1.

and consequently the matter was not further discussed. But there can be no doubt that if navigators of all nations could be persuaded to follow so excellent a rule as that suggested by Comdr. Alessio, it would add greatly to the safety of shipping. The method is so simple, and affords such security against error, that if it were once systematically taught in schools of navigation and included in the Board of Trade requirements for masters' certificates, it would probably by its own merits displace all other processes for fixing positions at sea under normal conditions. It would, of course, still be advisable to retain the ordinary meridian or ex-meridian sights for latitude and the morning or afternoon sights for longitude as a stand-by against the possibility of clouds or fog interfering with the twilight observations of stars, but whenever the suggested rule could possibly be followed it could be trusted to give far more accurate results than any observations of the sun.

A word may perhaps be added as to the manner of calculating the altitudes in the "new navigation." Comdr. Alessio (Report of the International Hydrographic Conference, London, 1919, p. 230) recommends logarithmic calculation with five-place tables, using a formula which permits of a ready check. This only takes about five minutes for each sight, and is, no doubt, the best way; in fact, it is the only safe way where a very considerable degree of precision is aimed at. But most navigators prefer to avoid computation so far as possible by the use of tables, and in ordinary circumstances the altitude tables used in the Royal Navy will give sufficiently accurate results. The great defect of the tabular method is that one has to round off the dead-reckoning latitude to the nearest degree for the assumed position in order to enter the tables, and consequently the position-lines may extend over so great a distance on the chart that their curvature cannot properly be neglected. With logarithmic calculation, on the other hand, the actual dead-reckoning position can be taken as the assumed position, and the position-lines will then be so short that their curvature can be neglected without any perceptible loss of accuracy.

It may not be out of place to remark in conclusion that the utility of the Sumner line or position-line principle is not confined to position-fixing with a sextant at sea. I have shown in two recently published papers ("Notes on the Working of the New Navigation," Cairo, 1918, and "The Prismatic Astrolabe," *Geographical Journal*, July, 1919, p. 37) that the "new navigation" is capable of useful application on land in conjunction with theodolite observations and wireless time-signals, and that determinations of geographical position of very considerable accuracy may be made in this way. The method has since been put into practice by Dr. Hamilton Rice on exploratory land surveys in South America (see the *Geographical Journal* for July, p. 59) with satisfactory results.

JOHN BALL.

Survey of Egypt, Cairo, July 24.

Relativity and Hyperbolic Space.

OBSERVATION tells us that while gravitation dominates the history of a lump of matter moving in the vast ocean of free æther, it has practically no effect on the history of a pulse of light in similar circumstances. Since last mail I have investigated the bearings of space being hyperbolic on light-rays.

The central-projection map of the space, used before, in which $r=\tanh\Theta$, where r is the radius vector of the map and $R\Theta$ the radius vector in the space, will be called a gnomonic map; planes are mapped as planes. If the projection used be given by $r=2\tanh\frac{1}{2}\Theta$, the map will be called stereographic; small regions are mapped in correct shape, spheres and planes as spheres, and the two sheets of a pseudo-sphere as two spheres intersecting and making equal angles with the sphere representing the median plane, in a circle lying on the absolute, $r=2$. (A pseudo-sphere is the locus of a point at a given distance from a given plane, called its median plane. The characteristic of the map-sphere which represents a plane is that it cuts the absolute $r=2$ orthogonally.) A point (x, y, z) on the gnomonic map becomes $[x/(1+\frac{1}{4}r^2), \quad y/(1+\frac{1}{4}r^2), \quad z/(1+\frac{1}{4}r^2)]$ on the stereographic map.

The behaviour of a ray of light is fully described by saying that its path on the gnomonic map may be put in the form $x^2/a^2+y^2=1$, where a is less than 1, and that the eccentric angle is t/R, where t is co-ordinate time. This ellipse really represents the two branches of a pseudo-circle; the ray goes out to infinity (in the space) along one branch and returns along the other, the complete circuit having the period $2\pi R$. The median line of the pseudo-circle passes through the origin—that is, through the observer.

If from a given point rays start in all directions there will be a definite wave-front. For a finite time before t attains the value of a quarter-period, $\frac{1}{2}\pi R$, this front will form the single sheet of a true sphere the centre of which recedes to infinity, whereupon the front develops the two sheets of a pseudo-sphere, the one proceeding in the same direction as before, and the other, together with the median plane, returning from infinity, having been reflected back by the absolute. By the time $t=\frac{1}{2}\pi R$ the median plane has just reached the origin, and the reflected sheet is chasing both the other sheet and the median plane back on the way to infinity. In the next quarter-period these motions are reversed in order of time, in direction of motion, and in position relative to the origin. At the time $t=\pi R$ the front has contracted down to a point focus situated on the opposite side of the origin from the radiant point at a distance equal to that of the point. At the time $t=2\pi R$ the original circumstances recur, and everything is about to be repeated. A ray always moves normal to the front, although the centre of the true sphere and the median plane of the pseudo-sphere themselves move from and to infinity in a finite time.

All these motions can be exactly imitated in Euclidean space. Let, at a given point in such a space, the velocity of light be $1+r^2/4R^2$, the same in all directions, and let the sphere $r=2R$ be a perfect reflector. Then light will in this medium behave exactly as does the light in the stereographic map (when the scale of that map is increased in the ratio of R to 1). Indeed, this seems the easiest method to get the differential equation of the path of a point in the hyperbolic space, for which $\int dt$ is stationary. I may remark, however, that when the equation is obtained, later work is much simplified by changing the dependent to a form corresponding to the gnomonic map.

In the stereographic map the rays after an even number of reflections, by the absolute, form a system of coaxial circles through the radiant point and that point on the *opposite* side of the origin which is inverse to the sphere $r=2$. (For radiant point let $0=x-a=y=z$. Then for the second point mentioned it is meant that $0=x+4/a=y=z$. Ordinary inverse point would be $0=x-4/a=y=z$.) After an odd number of reflections they are similarly related to the focus mentioned above. The fronts are the spheres cutting these coaxial circles orthogonally.

ALEX. McAULAY.

University of Tasmania, June 10.

The Antarctic Anticyclone.

IN NATURE for August 5 Mr. R. F. T. Granger remarks: "The same conditions, *i.e.* the surface outflow and the central descent of air, exist in Prof. Hobbs's polar ice-cap anticyclone; the only difference is the physical origin."

In the case of the ice-cap there are other differences as well; the temperature is lower in the case of an ice-cap than in an anticyclone. The ice-cap conditions which resemble those of an anticyclone are, as Mr. Granger says, "surface outflow and the central descent of air." The differences are low temperature, low pressure, and different physical origin. My suggestion was that these differences made it inadvisable to call them both anticyclones.

R. M. DEELEY.

Tintagel, Kew Gardens Road, Surrey, August 18.

A Method of Reaching Extreme Altitudes.

By ROBERT H. GODDARD, Professor of Physics, Clark College, Worcester, Mass.

IT is the purpose of the present article to state the general principles and possibilities of the method of reaching great altitudes with multiple charge rockets, from which the exploded gases are ejected with high efficiency.

Fundamental Principle.

The basic idea of the method, briefly stated in general terms, is this: Given a mass of explosive material of as great energy content as possible, what height can be reached if a large fraction of this material is shot downwards, on exploding, with as high a speed as possible? It is evident, intuitively, that the height will be great if the fraction of material that remains is small and the velocity of ejection of the gases is high.

A theoretical treatment of the subject shows that, provided the speed of ejection of the gases is high, and the proportion of propellant is large, the initial masses necessary to raise a given mass to great heights are surprisingly small, but are enormously large if these conditions are not satisfied.

Principles to be Applied in Practice.

(1) In order to apply practically the general principle above stated, there are three conditions that must be realised experimentally: First, the gases produced by the explosion must be ejected downwards with the greatest efficiency possible. This requirement must be met by burning the explosive in a strong combustion chamber, to which a tapered nozzle is attached, in order to obtain the work of expansion of the gases.

The apparatus used in the first experiments is shown in Fig. 1, in which P is the charge of dense smokeless powder, and B is the wadding. Three steel plugs were used, to vary the size of the powder chamber. The velocity of the gases

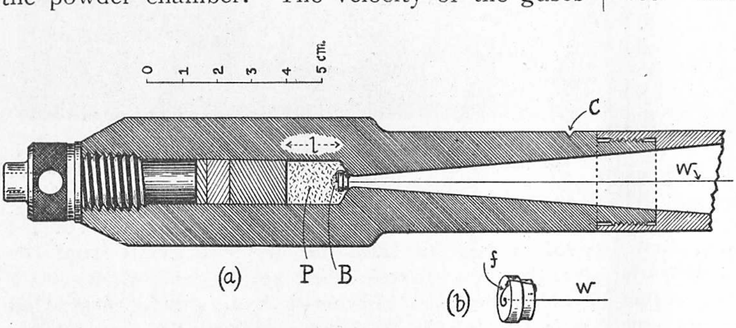

FIG. 1.—Chamber used in early experiments.

was measured by supporting the chamber in a ballistic pendulum, and observing the motion of the recoil.

It was found, by experiment, that the energy of motion of the ejected gases as compared with the heat energy of the powder could be increased very greatly over that for ordinary rockets, the highest velocity being nearly 8000 ft.-sec., produced by the chamber shown in Fig. 2, whereas

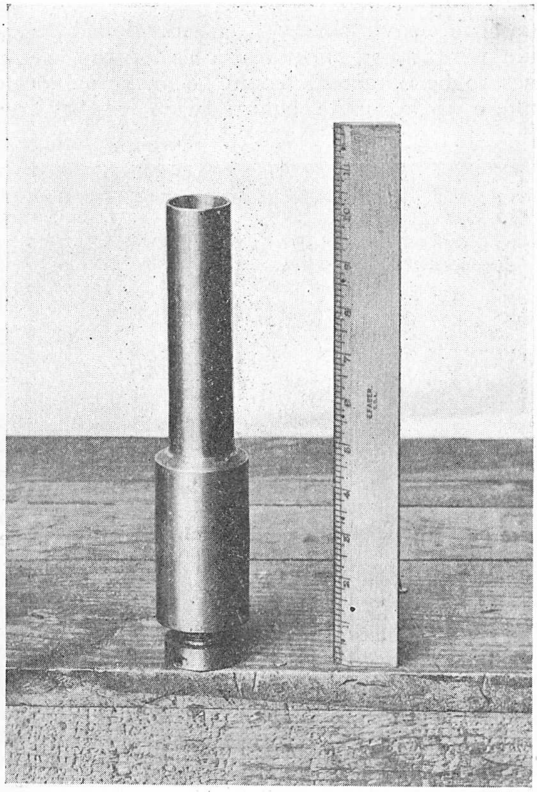

FIG. 2.—Chamber by which ejected gases were given a velocity of nearly 8000 ft. per sec.

for ordinary rockets the velocity is but 1000 ft.-sec. Incidentally, the energy of motion of the gases in the case under discussion is more than 64 per cent. of the heat energy of the powder, whereas for ordinary rockets the efficiency thus defined is but 2 per cent.

An interesting way of emphasising the magnitude of the velocity, 8000 ft.-sec., is to compare it with the "velocity of escape," or the "parabolic velocity" of planets. This velocity of escape is the velocity a body would require, projected upwards from a planet, in order to escape to infinity, and is a perfectly definite velocity, depending only upon the mass and diameter of the planet. For the moon the velocity is 1·5 miles per second, and for the planet Mars 3·0 miles per second. Thus if the chamber shown in Fig. 2 were placed upon the surface of the moon and fired, *most of the gases would escape from the moon's attraction.* The highest velocity gases would without doubt (since 8000 ft.-sec. is only the *average* velocity) escape from Mars, if the planet had no atmosphere.

It should be remarked that, as shown by experimental results, the best form of nozzle has not yet been made, so that even 8000 ft.-sec. can be exceeded by further research.

(2) The heavy chamber, as mentioned above, while permitting high velocities of the ejected gases to be obtained, would be an actual disadvantage if a single charge were to be fired,

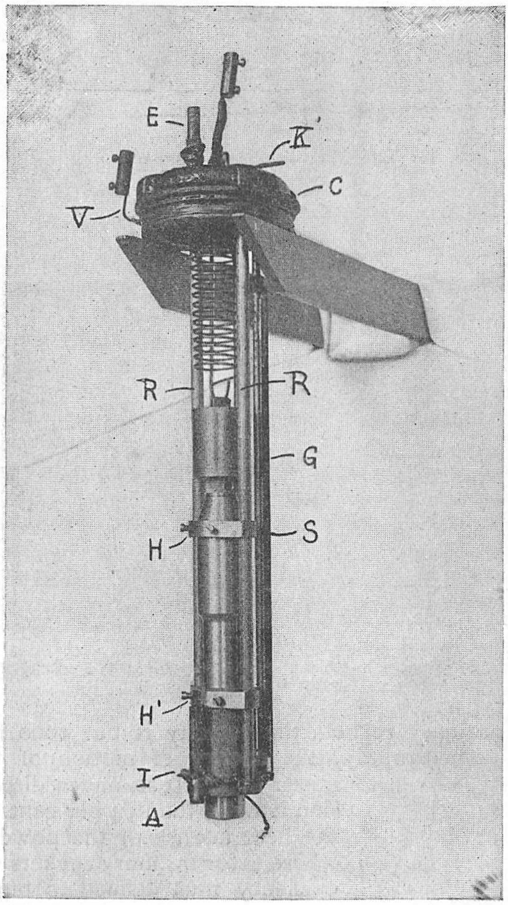

FIG. 3.—Chamber held in a support to test influence of air upon the propulsion of a rocket.

because of the large weight. It is necessary, then, that some means should be employed whereby *charges may be fed successively into the same combustion chamber.* If this is done it is evident that *most of the rocket can consist of propellant,* which is one of the conditions necessary for the attainment of great altitudes.

(3) When the magazine containing the charges just mentioned is nearly empty, it is easily seen that the propellant is no longer a large fraction of the entire mass of the apparatus. Hence, in order that the fraction shall remain large, it is necessary that one or more rockets, really copies in miniature of the larger primary rocket, should be used if the most extreme altitudes are to be reached, in order that the above fraction will, *at no time during the ascent,* become small.

Summary of Results to Date.

The theoretical work, done at Princeton University in 1912, was not followed by experimental tests until 1915, at Clark University. The work has since been continued at Clark University, in the magnetic laboratory at the Worcester Polytechnic Institute, and at the

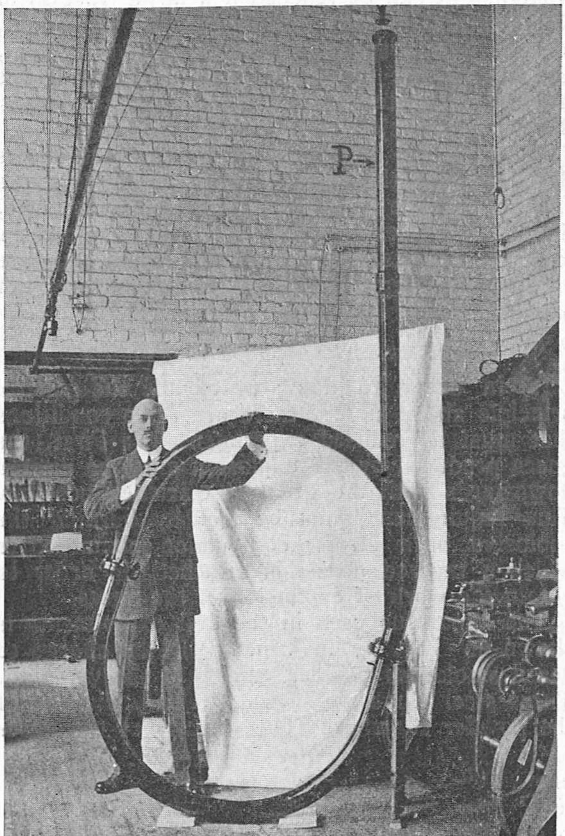

FIG. 4.—Pipe into which chamber was fired to a tank exhausted to a low pressure, the gases moving in a circular path until stopped by friction.

Mount Wilson Observatory in California—for the greater part of the time under a grant from the Smithsonian Institution.

The results of this work have shown, first, that most of the heat energy of even so powerful a propellant as dense nitroglycerine smokeless powder can be converted into kinetic energy of the ejected gases. They have demonstrated, secondly, that a multiple charge rocket can be made which will fire several charges in succession, is light and simple, and travels straight.

In order to demonstrate whether or not the rocket depended for propulsion upon the presence of air, a large number of experiments were performed in which the chamber, Fig. 1, was held in a support, Fig. 3, and fired in a 3-in. pipe, P, on a large tank, Fig. 4, exhausted to a low pressure. These experiments demonstrated that the presence of the air was not necessary for reaction and that *the recoil is produced by reaction from the high-velocity gases* that are ejected. The operation of the jet *in vacuo* need not appear mysterious if one thinks of the ejected gases as a charge of fine shot moving with a very high velocity. Obviously the chamber will react, or "kick," when this charge is fired,

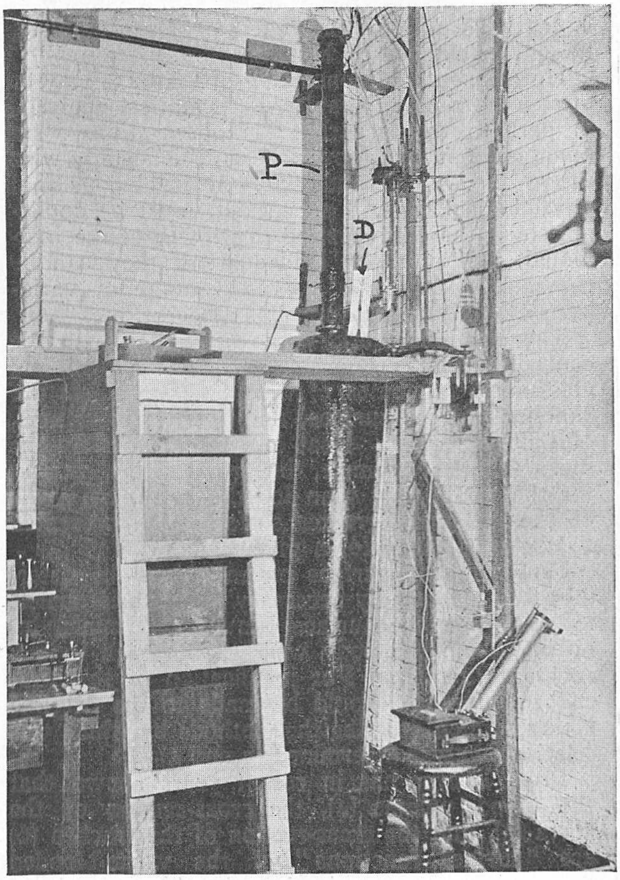

FIG. 5.—Tank in which the gases struck a coil of wire-fencing.

exactly as a shot-gun "kicks" when firing a charge of ordinary shot.

The gases were prevented from rebounding from the bottom of the tank, Fig. 4, by the form of the tank, the gases moving in a circular path until stopped by friction. Another tank, Fig. 5, was also used, in which rebound was prevented by the gases striking a large coil of ½-in. mesh wire-fencing. The results with both tanks agreed down to the lowest pressure employed, 0·5 mm. of mercury, which is probably the pressure that exists at a height of thirty miles.

The figures given in the Smithsonian publication regarding the initial masses necessary to propel 1 lb. to various heights, such as 12·3 lb. for 430 miles, and 438 lb. for an "infinite" altitude (for the most favourable conditions, *in so far as they are set forth in that publication*), do not assume a larger velocity of ejection of the gases than has been obtained experimentally, but do assume a greater lightness than has so far been obtained. No attempt has, however, been made to reduce any part of the apparatus to the minimum weight possible, and it is believed that with further research such lightness as is assumed is realisable.

At the present time, the work that is being done is the developing of a rocket, of small size, for employing a large number of cartridges, or charges, and this is being done on the remainder of the original grant from the Smithsonian Institution.

Application of the Method.

The most important of the immediate applications of the method is in the providing of a simple and, when sufficiently developed, inexpensive means of obtaining meteorological data at the 10-kilometre level. It is well recognised that this is the most important level for studying pressure, temperature, humidity, and wind velocity; and any means of sending recording instruments rapidly into this region, and of obtaining data soon after the ascent has been made, is certain to be of value in weather forecasting.

At greater elevations the study of temperature, pressure, wind velocity, and composition of the atmosphere is of scientific importance, and also the study of the aurora, during the day as well as at night, and the radiations from the sun that are otherwise absorbed by the atmosphere.

A further application of much general interest is the possibility of sending a mass beyond the predominating gravitational field of the earth. Concerning the possibility of demonstrating this point by hitting the moon with a rocket, it can be said, apart from the questions of aiming and of correcting the flight, that the ignition of but a few pounds of flash powder should be visible in a powerful telescope, provided, of course, that the conditions of ignition were substantially the same as those in certain experiments described in a recent Smithsonian publication, in which 1/20 of a grain fired *in vacuo* was observed at a distance of 2¼ miles.

Regarding these questions, as well as others which naturally follow, the writer believes that detailed discussion, before one has checked up matters completely by experiment, is unwise, for this merely precipitates a flood of useless argument, to which reply, in some form, must be made. The ideal method, which unfortunately is not always possible, is to solve a problem completely, as was done with the tests of the jet *in vacuo*, and then to state the results.

New Aspects in the Assessment of Physical Fitness.

By DR. F. G. HOBSON, Department of Pathology, University of Oxford.

A Physician in a great city seems to be the mere plaything of Fortune; his degree of reputation is for the most part casual; they that employ him know not his excellence; they that reject him know not his deficience.—SAMUEL JOHNSON.

THESE words might, with truth, have been written of Dr. John Hutchinson, one time physician to the Brompton Hospital for Diseases of the Chest. His earlier years devoted to the study of engineering, he later turned to medicine, and carried with him into his profession that enthusiasm for the accurate expression of scientific data which must have been engendered by his early training. In 1846 he published a paper "On the Capacity of the Lungs and on the Respiratory Functions" (1)[1], in which he showed that he possessed the inspiration which is ever the mark of true genius, combined with the ability for accurate observation and the patient collection of data. He made the earliest investigations into the physiological effects of "forced breathing"; by means of a mercurial manometer he examined "expiratory force"; but interest lies for the special ends of the present subject in the extensive series of observations which he made upon the "vital capacity"[2] of more than 3000 persons covering a wide range of body size, occupation, and mode of life.

Dr. Hutchinson claimed that he had shown that "vital capacity" increases in simple arithmetical progression with increasing height, and believed that he had disproved any relationship between "vital capacity" and body weight, trunk length, or circumference of the chest. The fact that his conclusions might be open to criticism, and that the fundamental principles underlying his investigation might yet have eluded his grasp, was present in his mind, and he concluded his treatise with the following remarkable sentences, which could well be taken as a model by any scientific worker:—

> The matter of this communication is founded upon a vast number of facts—immutable truths which are infinitely beyond my comprehension. The deductions which I have ventured to draw therefrom I wish to advance with modesty, because time, with its mutations, may so unfold science as to crush these deductions and demonstrate them as unsound.
>
> Nevertheless, the facts themselves can never alter nor deviate in their bearing upon respiration, one of the most important functions of the animal economy.

This prediction has, with the passage of time, been fulfilled.

Prof. G. Dreyer, of Oxford University, has made an extensive re-investigation of the whole subject, drawing upon Hutchinson's data as well as upon his own records. In a brilliant analysis of this considerable body of observations, he has conclusively proved the existence of physiological laws which escaped the mind of the pioneer Hutchinson. On practically every point do these laws refute the conclusions reached by Hutchinson.

Prof. Dreyer (2) has shown that definite relationships do exist between "vital capacity" and body surface, body weight, trunk length, and the circumference of the chest, while no true relationship can be traced when "vital capacity" is regarded as a simple function of the standing height, as claimed by Hutchinson.

Hutchinson's misconception of the facts may be attributed in part to faulty mathematical analysis, in part to the fact that his observations were made upon subjects covering an insufficiently wide range of weight and size. It is obvious that physiological laws, if such exist, must be applicable over the entire period of growth of the individual, and must be inadequate if they can be established only over a limited range of variations of sex, age, stature, body weight, etc.

The scientific world is now familiar with the conception that certain physical, physiological, and anatomical attributes of the living organism are functions of the surface, and not of the volume, of that organism. Heat loss offers possibly the most familiar example, being relatively greater for the small body than for the large, by virtue of the relatively greater surface area presented by the small body for a given volume.

How can the surface of an animal be determined? It is simply necessary in this brief article to state that the surface can be determined indirectly from the body weight, of which it is a constant function. For justification of this procedure reference should be made to the original articles which describe the methods by which this relationship was determined (3 and 4).

Prof. Dreyer has in recent years shown that the blood volume (4), the cross-section of the aorta (5), and the cross-section of the trachea (6) are "surface functions" of the warm-blooded mammals, and not simply related to the body weight, as has often been maintained. It comes, therefore, as no surprise when he finds that "vital capacity" is also a "surface function," since this must represent, in one direction, the limit of the capacity possessed by the organism for oxygenating its blood and discharging the waste products of its metabolism, and consequently be a physiological expression of one most important aspect of respiration. It follows that this measurement gives us an index of the "vitality" of the organism, *i.e.* its ability to meet the various strains and stresses of its life.

If the "vital capacity" is a "surface function," there is the further difficulty to be faced: What

(*Continued on p.* 829.)

[1] The figures in brackets refer to the Bibliography at the end of the article.

[2] The term "vital capacity" is used to indicate the maximum amount of air the individual is able to expel from his lungs, by voluntary effort, after the deepest possible inspiration.

SALTERS' INSTITUTE OF INDUSTRIAL CHEMISTRY.

The Committee will shortly proceed to allocate a limited number of Grants in Aid to persons employed in chemical works situated in or near London who desire to extend their knowledge of chemistry. Applications, giving full particulars of age, nature of employment and manner in which the grant would be used, should be made before Sept. 15 to the DIRECTOR of the Institute, Salters' Hall, St. Swithin's Lane, E.C.4.

MINISTRY OF AGRICULTURE AND FISHERIES.

Applications are invited for the temporary post of ASSISTANT BACTERIOLOGIST in the FISHERIES DEPARTMENT. The salary, inclusive of bonus, will be at the rate of £400 to £500 per annum (according to qualifications) plus travelling and subsistence expenses. Candidates should have graduated in a British, Irish, or Colonial University with a general training in science, and should possess special knowledge of Bacteriology. Preference will be given to men who have seen active service in the war.

Application forms can be obtained from the GENERAL SECRETARY, Ministry of Agriculture and Fisheries, 4 Whitehall Place, S.W. 1, and must be returned not later than Sept. 7.

PLYMOUTH EDUCATION AUTHORITY.

PLYMOUTH TECHNICAL SCHOOL.

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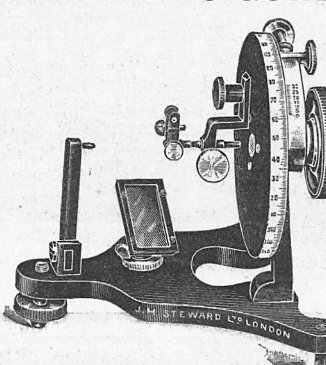

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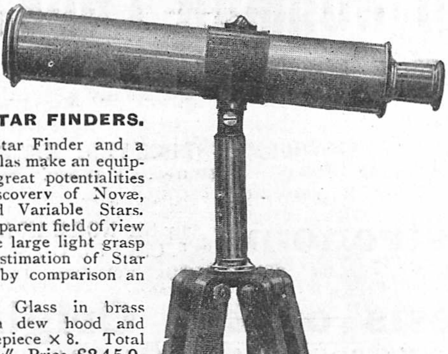

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Oceanography and the Sea-Fisheries.*

By WILLIAM A. HERDMAN, C.B.E., D.Sc., Sc.D., LL.D., F.R.S.,

Professor of Oceanography in the University of Liverpool, President.

IT has been customary, when occasion required, for the president to offer a brief tribute to the memory of distinguished members of the Association lost to science during the preceding year. These, for the most part, have been men of advanced years and high reputation who had completed their life-work and served well in their day the Association and the sciences which it represents. Such are our late general treasurer, Prof. Perry, and our past-president, Sir Norman Lockyer, of whom the retiring president has just spoken. We have this year no other such losses to record; but it seems fitting on the present occasion to pause for a moment and devote a grateful thought to that glorious band of fine young men of high promise in science who, in the years since our Australian meeting in 1914, gave, it may be, in brief days and months of sacrifice, greater service to humanity and the advance of civilisation than would have been possible in years of normal time and work. A few names stand out already known and highly honoured—Moseley, Jenkinson, Geoffrey Smith, Keith Lucas, Gregory, and more recently Leonard Doncaster—all grievous losses; but there are also others, younger members of our Association, who had not yet had opportunity for showing accomplished work, but who equally gave up all for a great ideal. I prefer to offer a collective rather than an individual tribute. Other young men of science will arise and carry on their work, but the gap in our ranks remains. Let their successors remember that it serves as a reminder of a great example and of high endeavour worthy of our gratitude and of permanent record in the annals of science.

At the last Cardiff meeting of the British Association in 1891 you had as your president the eminent astronomer Sir William Huggins, who discoursed upon the then recent discoveries of the spectroscope in relation to the chemical nature, density, temperature, pressure, and even the motions of the stars. From the sky to the sea is a long drop, but the sciences of both have this in common: that they deal with fundamental principles and with vast numbers. More than three hundred years ago Spenser in the "Faerie Queene" compared "the seas abundant progeny" with "the starres on hy," and recent investigations show that a litre of sea-water may contain more than a hundred times as many living organisms as there are stars visible to the eye on a clear night.

During the past quarter of a century great advances have been made in the science of the sea, and the aspects and prospects of sea-fisheries research have undergone changes which encourage the hope that a combination of the work now carried on by hydrographers and biologists in most civilised countries on fundamental problems of the ocean may result in a more rational exploitation and administration of the fishing industries

And yet even at your former Cardiff meeting thirty years ago there were at least three papers of oceanographic interest—one by Prof. Osborne Reynolds on the action of waves and currents, another by Dr. H. R. Mill on seasonal variation in the temperature of lochs and estuaries, and the third by our honorary local secretary for the present meeting, Dr. Evans Hoyle, on a deep-sea tow-net capable of being opened and closed under water by the electric current.

It was a notable meeting in several other respects, of which I shall merely mention two. In Section A Sir Oliver Lodge gave the historic address in which he expounded the urgent need, in the interests of both science and the industries, of a national institution for the promotion of physical research on a large scale. Lodge's pregnant idea put forward at this Cardiff meeting, supported and still further elaborated by Sir Douglas Galton as president of the Association at Ipswich, has since borne notable fruit in the establishment and rapid development of the National Physical Laboratory. The other outstanding event of that meeting is that you then appointed a committee of eminent geologists and naturalists to consider a project for boring through a coral reef, and that led during following years to the successive expeditions to the atoll of Funafuti, in the Central Pacific, the results of which, reported upon eventually by the Royal Society, were of great interest alike to geologists, biologists, and oceanographers.

Dr. Huggins, on taking the chair in 1891, remarked that it was more than thirty years since the Association had honoured astronomy in the selection of its president. It might be said that the case of oceanography is harder, as the Association has never had an oceanographer as president; and the Association might well reply, "Because until very recent years there has been no oceanographer to have." If astronomy is the oldest of the sciences, oceanography is probably the youngest. Depending as it does upon the methods and results of other sciences, it was not until our knowledge of physics, chemistry, and biology was relatively far advanced that it became possible to apply that knowledge to the investigation and explanation of the phenomena of the ocean. No one man has done more to apply such knowledge derived from various other subjects and to organise the results as a definite branch of science than the late Sir John Murray, who may therefore be regarded as the founder of modern oceanography.

It is to me a matter of regret that Sir John Murray was never president of the British Association. I am revealing no secret when I tell you that he might have been. On more than one occasion he was invited by the council to accept nomination, and he declined for reasons that were good and commanded our respect. He felt that the necessary duties of this post would interfere with what he regarded as his primary life-work — oceanographical explorations already planned, and the last of which he actually carried out in the North Atlantic in 1912, when above seventy years of age, in the Norwegian steamer *Michael Sars* along with his friend Dr. Johan Hjort.

Anyone considering the subject-matter of this new science must be struck by its wide range, overlapping as it does the borderlands of several other sciences and making use of their methods and facts in the solution of its problems. It is not only world-wide in its scope, but it also extends beyond our globe, and includes astronomical data in their relation to tidal and certain other oceanographical phenomena. No man in his work, or even thought, can attempt to cover the whole ground, although Sir John Murray, in his remarkably comprehensive "Summary" volumes of the *Challenger* Expedition and other writings, went far towards doing so. He, in his combination of physicist, chemist, geologist, and biologist, was the nearest approach we have had to an all-round oceanographer. The International Research Council probably acted wisely at the recent Brussels Confer-

* Presidental address delivered at the Cardiff meeting of the British Association on August 24.

ence in recommending the institution of two International Sections in our subject, one of physical and the other of biological oceanography, although the two overlap and are so interdependent that no investigator on one side can afford to neglect the other.[1]

On the present occasion I must restrict myself almost wholly to the latter division of the subject, and be content, after brief reference to the founders and pioneers of our science, to outline a few of those investigations and problems which have appeared to me to be of fundamental importance, of economic value, or of general interest.

Although the name "oceanography" was only given to this branch of science by Sir John Murray in 1880, and although, according to that veteran oceanographer Mr. J. Y. Buchanan, the last surviving member of the civilian staff of the *Challenger*, the science of oceanography was born at sea on February 15, 1873,[2] when at the first official dredging station of the expedition, to the westward of Teneriffe, at 1525 fathoms, everything that came up in the dredge was new, and led to fundamental discoveries as to the deposits forming on the floor of the ocean, still it may be claimed that the foundations of the science were laid by various explorers of the ocean at much earlier dates. Aristotle, who took all knowledge for his province, was an early oceanographer on the shores of Asia Minor. When Pytheas passed between the Pillars of Hercules into the unknown Atlantic and penetrated to British seas in the fourth century B.C., and brought back reports of Ultima Thule and of a sea to the north thick and sluggish like a jellyfish, he may have been recording an early planktonic observation. But passing over all such and many other early records of phenomena of the sea, we come to surer ground in claiming as founders of oceanography Count Marsili, an early investigator of the Mediterranean, and that truly scientific navigator Capt. James Cook, who sailed to the South Pacific on a Transit of Venus expedition in 1769, with Sir Joseph Banks as naturalist, and by afterwards circumnavigating the South Sea about latitude 60° finally disproved the existence of a great southern continent; and Sir James Clark Ross, who, with Sir Joseph Hooker as naturalist, first dredged the Antarctic in 1840.

The use of the naturalist's dredge (introduced by O. F. Müller, the Dane, in 1799) for exploring the sea-bottom was brought into prominence almost simultaneously in several countries of North-West Europe—by Henri Milne-Edwards in France in 1830, by Michael Sars in Norway in 1835, and by our own Edward Forbes about 1832.

The last-mentioned genial and many-sided genius was a notable figure in several sections of the British Association from about 1836 onwards, and may fairly be claimed as a pioneer of oceanography. In 1839 he and his friend the anatomist, John Goodsir, were dredging in the Shetland seas, with results which Forbes made known to the meeting of the British Association at Birmingham that summer, with such good effect that a "Dredging Committee"[3] of the Association was formed to continue the good work. Valuable reports on the discoveries of that committee appear in our volumes at intervals during the following twenty-five years.

It has happened over and over again in history that the British Association, by means of one of its research committees, has led the way in some important new research or development of science, and shown the Government or an industry what wants doing and how it can be done. We may fairly claim that the British Association has inspired and fostered that exploration of British seas which through marine biological investigations and deep-sea expeditions has led on to modern oceanography. Edward Forbes and the British Association Dredging Committee, Wyville Thomson, Carpenter, Gwyn Jeffreys, Norman, and other naturalists of the pre-*Challenger* days—all these men in the quarter-century from 1840 onwards worked under research committees of the British Association, bringing their results before successive meetings; and some of our older volumes enshrine classic reports on dredging by Forbes, McAndrew, Norman, Brady, Alder, and other notable naturalists of that day. These local researches paved the way for the *Challenger* and other national deep-sea expeditions. Here, as in other cases, it required private enterprise to precede and stimulate Government action.

It is probable that Forbes and his fellow-workers on this "Dredging Committee" in their marine explorations did not fully realise that they were opening up a most comprehensive and important department of knowledge. But it is also true that in all his expeditions—in the British seas from the Channel Islands to the Shetlands, in Norway, and in the Mediterranean as far as the Ægean Sea—his broad outlook on the problems of Nature was that of the modern oceanographer, and he was the spiritual ancestor of men like Sir Wyville Thomson, of the *Challenger* Expedition, and Sir John Murray, whose accidental death a few years ago, whilst still in the midst of active work, was a grievous loss to this new and rapidly advancing science of the sea.

Forbes in these marine investigations worked at border-line problems, dealing, for example, with the relations of geology to zoology and the effect of the past history of the land and sea upon the distribution of plants and animals at the present day, and in these respects he was an early oceanographer. For the essence of that new subject is that it also investigates border-line problems, and is based upon and makes use of all the older fundamental sciences—physics, chemistry, and biology—and shows, for example, how variations in the great ocean-currents may account for the movements and abundance of the migratory fishes, and how periodic changes in the physico-chemical characters of the sea, such as variations in the hydrogen-ion and hydroxyl-ion concentration, are correlated with the distribution at the different seasons of the all-important microscopic organisms that render our oceanic waters as prolific a source of food as the pastures of the land.

Another pioneer of the nineteenth century who, I sometimes think, has not yet received sufficient credit for his foresight and initiative is Sir Wyville Thomson, whose name ought to go down through the ages as the leader of the scientific staff on the famous *Challenger* Deep-Sea Exploring Expedition. It is due chiefly to him and to his friend, Dr. W. B.

1 The following classification of the primary divisions of the subject may possibly be found acceptable:—

Physiography
- Oceanography
  - Hydrography (Physics, etc.)
  - Metabolism (Biochemistry)
  - Bionomics (Biology)
  - Tidology (Mathematics)
- Geography

2 Others might put the date later. Significant publications are Sir John Murray's Summary Volumes of the *Challenger* (1895), the inauguration of the Musée Océanographique at Monaco in 1910, the foundation of the Institut Océanographique at Paris in 1906 (see the Prince of Monaco's letter to the Minister of Public Instruction), and Sir John Murray's little book "The Ocean" (1913), where the superiority of the term "oceanography" to "thalassography" (used by Alexander Agassiz) is discussed.

3 "For researches with the dredge, with a view to the investigation of the marine zoology of Great Britain, the illustration of the geographical distribution of marine animals, and the more accurate determination of the fossils of the Pleistocene period: under the superintendence of Mr. Gray, Mr. Forbes, Mr. Goodsir, Mr. Patterson, Mr. Thompson of Belfast, Mr. Ball of Dublin, Dr. George Johnston, Mr. Smith of Jordan Hill, and Mr. A. Strickland, 60*l*." Report for 1839, p. xxvi.

Carpenter, that the British Government, through the influence of the Royal Society, was induced to place at the disposal of a committee of scientific experts, first the small surveying steamer *Lightning* in 1868, and then the more efficient steamer *Porcupine* in the two succeeding years, for the purpose of exploring the deep water of the Atlantic from the Faroes in the north to Gibraltar and beyond in the south, in the course of which expeditions they got successful hauls from the then unprecedented depth of 2435 fathoms, nearly three statute miles.

It will be remembered that Edward Forbes, from his observations in the Mediterranean (an abnormal sea in some respects), regarded depths of more than 300 fathoms as an azoic zone. It was the work of Wyville Thomson and his colleagues, Carpenter and Gwyn Jeffreys, on these successive dredging expeditions to prove conclusively what was beginning to be suspected by naturalists, that there is no azoic zone in the sea, but that abundant life belonging to many groups of animals extends down to the greatest depths of from four to five thousand fathoms—nearly six statute miles from the surface.

These pioneering expeditions in the *Lightning* and *Porcupine*—the results of which are not even yet fully made known to science—were epoch-making, inasmuch as they not only opened up this new region to the systematic marine biologist, but also gave glimpses of world-wide problems in connection with the physics, the chemistry, and the biology of the sea which are only now being adequately investigated by the modern oceanographer. These results, which aroused intense interest amongst the leading scientific men of the time, were so rapidly surpassed and overshadowed by the still greater achievements of the *Challenger* and other national exploring expeditions that followed in the seventies and eighties of last century, that there is some danger of their real importance being lost sight of; but it ought never to be forgotten that they first demonstrated the abundance of life of a varied nature in depths formerly supposed to be azoic, and, moreover, that some of the new deep-sea animals obtained were related to extinct forms belonging to the Jurassic, Cretaceous, and Tertiary periods.

It is interesting to recall that our Association played its part in promoting the movement that led to the *Challenger* Expedition. Our general committee at the Edinburgh meeting of 1871 recommended that the president and council be authorised to co-operate with the Royal Society in promoting "a circumnavigation expedition, specially fitted out to carry the physical and biological exploration of the deep sea into all the great oceanic areas"; and our council later appointed a committee consisting of Dr. Carpenter, Prof. Huxley, and others to co-operate with the Royal Society in carrying out these objects.

It has been said that the *Challenger* Expedition will rank in history with the voyages of Vasco da Gama, Columbus, Magellan, and Cook. Like these, it added new regions of the globe to our knowledge, and the wide expanses thus opened up for the first time, the floors of the oceans, though less accessible, are vaster than the discoveries of any previous exploration. Has not the time come for a new *Challenger* expedition?

Sir Wyville Thomson, although leader of the expedition, did not live to see the completed results, and Sir John Murray will be remembered in the history of science as the *Challenger* naturalist who brought to a successful issue the investigation of the enormous collections and the publication of the scientific results of that memorable voyage; these two Scots share the honour of having guided the destinies of what is still the greatest oceanographic exploration of all time.

In addition to taking his part in the general work of the expedition, Murray devoted special attention to three subjects of primary importance in the science of the sea, viz.: (1) The plankton or floating life of the oceans, (2) the deposits forming on the seabottoms, and (3) the origin and mode of formation of coral-reefs and islands. It was characteristic of his broad and synthetic outlook on Nature that, in place of working at the speciography and anatomy of some group of organisms, however novel, interesting, and attractive to the naturalist the deep-sea organisms might seem to be, he took up wide-reaching general problems with economic and geological as well as biological applications.

Each of the three main lines of investigation—deposits, plankton, and coral-reefs—which Murray undertook on board the *Challenger* has been most fruitful of results both in his own hands and in those of others. His plankton work has led on to those modern planktonic researches which are closely bound up with the scientific investigation of our sea-fisheries.

His work on the deposits accumulating on the floor of the ocean resulted, after years of study in the laboratory as well as in the field, in collaboration with the Abbé Renard, of the Brussels Museum, afterwards professor at Ghent, in the production of the monumental "Deep-Sea Deposits" volume, one of the *Challenger* reports, which first revealed to the scientific world the detailed nature and distribution of the varied submarine deposits of the globe and their relation to the rocks forming the crust of the earth.

These studies led, moreover, to one of the romances of science which deeply influenced Murray's future life and work. In accumulating material from all parts of the world and all deep-sea exploring expeditions for comparison with the *Challenger* series, some ten years later, Murray found that a sample of rock from Christmas Island, in the Indian Ocean, which had been sent to him by Comdr. (now Admiral) Aldrich, of H.M.S. *Egeria*, was composed of a valuable phosphatic material. This discovery in Murray's hands gave rise to a profitable commercial undertaking, and he was able to show that some years ago the British Treasury had already received in royalties and taxes from the island considerably more than the total cost of the *Challenger* Expedition.

That first British circumnavigating expedition on the *Challenger* was followed by other national expeditions (the American *Tuscarora* and *Albatross*, the French *Travailleur*, the German *Gauss*, *National*, and *Valdivia*, the Italian *Vettor Pisani*, the Dutch *Siboga*, the Danish *Thor*, and others) and by almost equally celebrated and important work by unofficial oceanographers such as Alexander Agassiz, Sir John Murray with Dr. Hjort in the *Michael Sars*, and the Prince of Monaco in his magnificent ocean-going yacht, and by much other good work by many investigators in smaller and humbler vessels. One of these supplementary expeditions I must refer to briefly because of its connection with sea-fisheries. The *Triton*, under Tizard and Murray in 1882, while exploring the cold and warm areas of the Faroe Channel separated by the Wyville Thomson ridge, incidentally discovered the famous Dubh-Artach fishing-grounds, which have been worked by British trawlers ever since.

Notwithstanding all this activity during the last forty years since oceanography became a science, much has still to be investigated in all seas in all branches of the subject. On pursuing any line of investigation one very soon comes up against a wall of the unknown or a maze of controversy. Peculiar difficulties surround the subject. The matters investigated are often remote and almost inaccessible. Unknown factors may enter into every problem. The samples required may be at the other end of a rope or a wire eight to ten miles long, and the oceanographer may have to grope for them literally in the dark and under other difficult conditions which make it uncertain whether his samples when obtained are adequate and representative, and whether they have undergone any change since leaving their natural environment. It is not surprising, then, that in the progress of knowledge mistakes have been made and corrected, and that views have been held on what seemed good scientific grounds which later on were proved to be erroneous. For example, Edward Forbes, in his division of life in the sea into zones, on what then seemed to be sufficiently good observations in the Ægean, but which we now know to be exceptional, placed the limit of life at 300 fathoms, while Wyville Thomson and his fellow-workers on the *Porcupine* and the *Challenger* showed that there is no azoic zone even in the great abysses.

Or, again, take the celebrated myth of Bathybius. In the sixties of last century samples of Atlantic mud, taken when surveying the bottom for the first telegraph cables and preserved in alcohol, were found when examined by Huxley, Haeckel, and others to contain what seemed to be an exceedingly primitive protoplasmic organism, which was supposed on good evidence to be extended widely over the floor of the ocean. The discovery of this Bathybius was said to solve the problem of how the deep-sea animals were nourished in the absence of seaweeds. Here was a widespread protoplasmic meadow upon which other organisms could graze. Belief in Bathybius seemed to be confirmed and established by Wyville Thomson's results in the *Porcupine* Expedition of 1869, but was exploded by the naturalists on the *Challenger* some five years later. Buchanan in his recently published "Accounts Rendered" tells us how he and his colleague Murray were keenly on the look-out for hours at a time on all possible occasions for traces of this organism, and how they finally proved, in the spring of 1875 on the voyage between Hong-Kong and Yokohama, that the all-pervading substance like coagulated mucus was an amorphous precipitate of sulphate of lime thrown down from the sea-water in the mud on the addition of a certain proportion of alcohol. He wrote to this effect from Japan to Prof. Crum Brown, and it is in evidence that after receiving this letter Crum Brown interested his friends in Edinburgh by showing them how to make Bathybius in the chemical laboratory. Huxley at the Sheffield meeting of the British Association in 1879 handsomely admitted that he had been mistaken, and it is said that he characterised Bathybius as "not having fulfilled the promise of its youth." Will any of our present oceanographic beliefs share the fate of Bathybius in the future? Some may, but even if they do they may well have been useful steps in the progress of science. Although, like Bathybius, they may not have fulfilled the promise of their youth, yet we may add they will not have lived in the minds of man in vain.

Many of the phenomena we encounter in oceanographic investigations are so complex, are or may be affected by so many diverse factors, that it is difficult, if indeed possible, to be sure that we are unravelling them aright and see the real causes of what we observe.

Some few things we know approximately, nothing completely. We know that the greatest depths of the ocean, about six miles, are a little greater than the highest mountains on land, and Sir John Murray has calculated that if all the land were washed down into the sea the whole globe would be covered by an ocean averaging about two miles in depth.[4] We know the distribution of temperatures and salinities over a great part of the surface and a good deal of the bottom of the oceans, and some of the more important oceanic currents have been charted and their periodic variations, such as those of the Gulf Stream, are being studied. We know a good deal about the organisms floating or swimming in the surface waters (the epiplankton), and also those brought up by our dredges and trawls from the bottom in many parts of the world, although every expedition still makes large additions to knowledge. The region that is least known to us, both in its physical conditions and in its inhabitants, is the vast zone of intermediate waters lying between the upper few hundred fathoms and the bottom. That is the region that Alexander Agassiz, from his observations with closing tow-nets on the *Blake* Expedition, supposed to be destitute of life, or at least, as modified by his later observations on the *Albatross*, to be relatively destitute compared with the surface and the bottom, in opposition to the contention of Murray and other oceanographers that an abundant meso-plankton was present, and that certain groups of animals, such as the Challengerida and some kinds of Medusæ, were characteristic of these deeper zones. I believe that, as sometimes happens in scientific controversies, both sides were right up to a point, and both could support their views upon observations from particular regions of the ocean in certain circumstances.

But much still remains unknown or only imperfectly known even in matters that have long been studied and where practical applications of great value are obtained—such as the investigation and prediction of tidal phenomena. We are now told that theories require reinvestigation, and that published tables are not sufficiently accurate. To take another practical application of oceanographic work, the ultimate causes of variations in the abundance, in the sizes, in the movements, and in the qualities of the fishes of our coastal industries are still to seek, and, notwithstanding volumes of investigation and a still greater volume of discussion, no man who knows anything of the matter is satisfied with our present knowledge of even the best-known and economically most important of our fishes such as the herring, the cod, the plaice, and the salmon.

Take the case of our common fresh-water eel as an example of how little we know and at the same time of how much has been discovered. All the eels of our streams and lakes of North-West Europe live and feed and grow under our eyes without reproducing their kind; no spawning eel has ever been seen. After living for years in immaturity, at last near the end of their lives the large male and female yellow eels undergo a change in appearance and in nature. They acquire a silvery colour and their eyes enlarge, and in this bridal attire they commence the long journey which ends in maturity, reproduction, and death. From all the fresh waters they migrate in the autumn to the coast, from the inshore seas to the open ocean and still westward and south to the mid-Atlantic, and we know not how much further, for the exact locality and manner of spawning have still to be discovered. The youngest known stages of the Leptocephalus, the larval stage of eels, have been found by the Dane, Dr. Johannes Schmidt, to the west of the Azores, where the water is more than 2000 fathoms in depth. These were about one-third of an inch in length, and were probably not long hatched. I cannot now refer to all the able inves-

[4] It was possibly in such a former world-wide ocean of ionised water that, according to the recent speculations of A. H. Church ("Thalassiophyta," 1919), the first living organisms were evolved, to become later the floating unicellular plants of the primitive plankton.

tigators—Grassi, Hjort, and others—who have discovered and traced the stages of growth of the Leptocephalus and its metamorphosis into the "elvers" or young eels which are carried by the North Atlantic drift back to the coasts of Europe and ascend our rivers in spring in countless myriads; but no man has been more indefatigable and successful in the quest than Dr. Schmidt, who in the various expeditions of the Danish investigation steamer *Thor* from 1904 onwards found successively younger and younger stages, and is during the present summer engaged in a traverse of the Atlantic to the West Indies in the hope of finding the missing link in the chain, the actual spawning fresh-water eel in the intermediate waters somewhere above the abysses of the open ocean.[5]

Again, take the case of an interesting oceanographic observation which, if established, may be found to explain the variations in time and amount of important fisheries. Otto Pettersson in 1910 discovered by his observations in the Gullmar Fjord the presence of periodic submarine waves of deeper salter water in the Kattegat and the fjords of the west coast of Sweden, which draw in with them from the Jutland banks vast shoals of the herrings which congregate there in autumn. The deeper layer consists of "bankwater" of salinity 32 to 34 per thousand, and as this rolls in along the bottom as a series of huge undulations it forces out the overlying fresher water, and so the herrings living in the "bankwater" outside are sucked into the Kattegat and neighbouring fjords and give rise to important local fisheries. Pettersson connects the crests of the submarine waves with the phases of the moon. Two great waves of salter water which reached up to the surface took place in November, 1910, one near the time of full moon and the other about new moon, and the latter was at the time when the shoals of herring appeared inshore and provided a profitable fishery. The coincidence of the oceanic phenomena with the lunar phases is not, however, very exact, and doubts have been expressed as to the connection; yet, if established, and even if found to be due, not to the moon, but to prevalent winds or the influence of ocean currents, this would be a case of the migration of fishes depending upon mechanical causes, while in other cases it is known that migrations are due to spawning needs or for the purpose of feeding, as in the case of the cod and the herring in the west and north of Norway and in the Barents Sea.

Then, turning to a very fundamental matter of purely scientific investigation, we do not know with any certainty what causes the great and all-important seasonal variations in the plankton (or floating minute life of the sea) as seen, for example, in our own home seas, where there is a sudden awakening of microscopic plant-life, the Diatoms, in early spring when the water is at its coldest. In the course of a few days the upper layers of the sea may become so filled with organisms that a small silk net towed for a few minutes may capture hundreds of millions of individuals. And these myriads of microscopic forms, after persisting for a few weeks, may disappear as suddenly as they came, to be followed by swarms of Copepoda and many other kinds of minute animals, and these again may give place in the autumn to a second maximum of Diatoms or of the closely related Peridiniales. Of course, there are theories as to all these more or less periodic changes in the plankton, such as Liebig's "law of the minimum," which limits the production of an organism by the amount of that necessity of existence which is present in least quantity, it may be nitrogen or silicon or phosphorus. According to Raben, it is the accumulation of silicic acid in the sea-water that determines the great increase of Diatoms in spring and again in autumn. Some writers have considered these variations in the plankton to be caused largely by changes in temperature supplemented, according to Ostwald, by the resulting changes in the viscosity of the water; but Murray and others are more probably correct in attributing the spring development of phyto-plankton to the increasing power of the sunlight and its value in photosynthesis.

Let us take next the fact—if it be a fact—that the genial, warm waters of the tropics support a less abundant plankton than the cold polar seas. The statement has been made and supported by some investigators and disputed by others, both on a certain amount of evidence. This is possibly a case like some other scientific controversies where both sides are partly in the right or right under certain conditions. At any rate, there are marked exceptions to the generalisation. The German Plankton Expedition in 1889 showed in its results that much larger hauls of plankton per unit-volume of water were obtained in the temperate North and South Atlantic than in the tropics between, and that the warm Sargasso Sea had a remarkably scanty microflora. Other investigators have since reported more or less similar results. Lohmann found the Mediterranean plankton to be less abundant than that of the Baltic; gatherings brought back from tropical seas are frequently very scanty, and enormous hauls, on the other hand, have been recorded from Arctic and Antarctic seas. There is no doubt about the large gatherings obtained in northern waters. I have myself in a few minutes' haul of a small horizontal net in the north of Norway collected a mass of the large Copepod, *Calanus finmarchicus,* sufficient to be cooked and eaten like potted shrimps by half a dozen of the yacht's company, and I have obtained similar large hauls in the cold Labrador current near Newfoundland. On the other hand, Kofoid and Alexander Agassiz have recorded large hauls of plankton in the Humboldt current off the west coast of America, and during the *Challenger* Expedition some of the largest quantities of plankton were found in the equatorial Pacific. Moreover, it is common knowledge that on occasions vast swarms of some planktonic organism may be seen in tropical waters. The yellow alga, Trichodesmium, which is said to have given its name to the Red Sea, and has been familiarly known as "sea-sawdust" since the days of Cook's first voyage,[6] may cover the entire surface over considerable areas of the Indian and South Atlantic Oceans; and some pelagic animals, such as Salpæ, Medusæ, and Ctenophores, are also commonly present in abundance in the tropics. Then, again, American biologists[7] have pointed out that the warm waters of the West Indies and Florida may be noted for the richness of their floating life for periods of years, while at other times the pelagic organisms become rare and the region is almost a desert sea.

It is probable, on the whole, that the distribution and variations of oceanic currents have more than latitude or temperature alone to do with any observed scantiness of tropical plankton. These mighty rivers of the ocean in places teem with animal- and plant-life, and may sweep abundance of food from one region to another in the open sea.

But even if it be a fact that there is this alleged deficiency in tropical plankton, there is by no means

[5] According to Schmidt's results, the European fresh-water eel, in order to be able to propagate, requires a depth of at least 500 fathoms, a salinity of more than 35·20 per mile, and a temperature of more than 7° C. in the required depth.

[6] See "Journal" of Sir Joseph Banks. This and other swarms were also noticed by Darwin during the voyage of the *Beagle.*

[7] A. Agassiz A. G. Mayer, and H. B. Bigelow.

agreement as to the cause thereof. Brandt first attributed the poverty of the plankton in the tropics to the destruction of nitrates in the sea as a result of the greater intensity of the metabolism of denitrifying bacteria in the warmer water; and various writers since then have more or less agreed that the presence of these denitrifying bacteria, by keeping down to a minimum the nitrogen concentration in tropical waters, may account for the relative scarcity of the phyto-plankton, and, consequently, of the zoo-plankton, that has been observed. But Gran, Nathansohn, Murray, Hjort, and others have shown that such bacteria are rare or absent in the open sea, that their action must be negligible, and that Brandt's hypothesis is untenable. It seems clear, moreover, that the plankton does not vary directly with the temperature of the water. Furthermore, Nathansohn has shown the influence of the vertical circulation in the water upon the nourishment of the phyto-plankton—by rising currents bringing up necessary nutrient materials, and especially carbon dioxide, from the bottom layers; and also possibly by conveying the products of the drainage of tropical lands to more polar seas so as to maintain the more abundant life in the colder water.

Pütter's view is that the increased metabolism in the warmer water causes all the available food materials to be used up rapidly, and so puts a check to the reproduction of the plankton.

According to van't Hoff's law in chemistry, the rate at which a reaction takes place is increased by raising the temperature, and this probably holds good for all biochemical phenomena, and therefore for the metabolism of animals and plants in the sea. This has been verified experimentally in some cases by J. Loeb. The contrast between the plankton of Arctic and Antarctic zones, consisting of large numbers of small crustaceans belonging to comparatively few species, and that of tropical waters, containing a great many more species generally of smaller size and fewer in number of individuals, is to be accounted for, according to Sir John Murray and others, by the rate of metabolism in the organisms. The assemblages captured in cold polar waters are of different ages and stages, young and adults of several generations occurring together in profusion,[8] and it is supposed that the adults "may be ten, twenty, or more years of age." At the low temperature the action of putrefactive bacteria and of enzymes is very slow or in abeyance, and the vital actions of the Crustacea take place more slowly and the individual lives are longer. On the other hand, in the warmer waters of the tropics the action of the bacteria is more rapid, metabolism in general is more active, and the various stages in the life-history are passed through more rapidly, so that the smaller organisms of equatorial seas probably live only for days or weeks in place of years.

This explanation may account also for the much greater quantity of living organisms which has been found so often on the sea-floor in polar waters. It is a curious fact that the development of the polar marine animals is, in general, "direct" without larval pelagic stages, the result being that the young settle down on the floor of the ocean in the neighbourhood of the parent forms, so that there come to be enormous congregations of the same kind of animal within a limited area, and the dredge will in a particular haul come up filled with hundreds, it may be, of an Echinoderm, a Sponge, a Crustacean, a Brachiopod, or an Ascidian; whereas in warmer seas the young pass through a pelagic stage and so become more widely distributed over the floor of the ocean. The *Challenger* Expedition found in the Antarctic certain Echinoderms, for example, which had young in various stages of development attached to some part of the body of the parents, whereas in temperate or tropical regions the same class of animals set free their eggs and the development proceeds in the open water quite independently of, and it may be far distant from, the parent.

Another characteristic result of the difference in temperature is that the secretion of carbonate of lime in the form of shells and skeletons proceeds more rapidly in warm than in cold water. The massive shells of molluscs, the vast deposits of carbonate of lime formed by corals and by calcareous seaweeds, are characteristic of the tropics; whereas in polar seas, while the animals may be large, they are for the most part soft-bodied and destitute of calcareous secretions. The calcareous pelagic Foraminifera are characteristic of tropical and sub-tropical plankton, and few, if any, are found in polar waters. Globigerina ooze, a calcareous deposit, is abundant in equatorial seas, while in the Antarctic the characteristic deposit is siliceous Diatomaceous ooze.

The part played by bacteria in the metabolism of the sea is very important and probably of wide-reaching effect, but we still know very little about it. A most promising young Cambridge biologist, the late Mr. G. Harold Drew, now unfortunately lost to science, had already done notable work at Jamaica and at Tortugas, Florida, on the effects produced by a bacillus which is found in the surface waters of these shallow tropical seas and in the mud at the bottom; and which denitrifies nitrates and nitrites, giving off free nitrogen. He found that this *Bacillus calcis* also caused the precipitation of soluble calcium salts in the form of calcium carbonate ("drewite") on a large scale in the warm shallow waters. Drew's observations tend to show that the great calcareous deposits of Florida and the Bahamas previously known as "coral muds" are not, as was supposed by Murray and others, derived from broken-up corals, shells, nullipores, etc., but are minute particles of carbonate of lime which have been precipitated by the action of these bacteria.[9]

The bearing of these observations upon the formation of oolitic limestones and the fine-grained unfossiliferous Lower Palæozoic limestones of New York State, recently studied in this connection by R. M. Field,[10] must be of peculiar interest to geologists, and forms a notable instance of the annectant character of oceanography, bringing the metabolism of living organisms in the modern sea into relation with palæozoic rocks.

The work of marine biologists on the plankton has been in the main *qualitative*, the identification of species, the observation of structure, and the tracing of life-histories. The oceanographer adds to that the *quantitative* aspect when he attempts to estimate numbers and masses per unit-volume of water or of area. Let me lay before you a few thoughts in regard to some such attempts, mainly for the purpose of showing the difficulties of the investigation. Modern quantitative methods owe their origin to the ingenious and laborious work of Victor Hensen, followed by Brandt, Apstein, Lohmann, and others of the Kiel school of quantitative planktologists. We may take their well-known estimations of fish-eggs in the North Sea as an example of the method.

The floating eggs and embryos of our more important food-fishes may occur in quantities in the plankton during certain months in spring, and Hensen and

8 Whether, however, the low temperature may not also retard reproduction is worthy of consideration.

9 Journ. Mar. Biol. Assoc., October, 1911.

10 Carnegie Institution of Washington. "Year Book for 1919," p. 197.

Apstein have made some notable calculations based on the occurrence of these in certain hauls taken at intervals across the North Sea, which led them to the conclusion that, taking six of our most abundant fish, such as the cod and some of the flat-fish, the eggs present were probably produced by about 1,200,000,000 spawners, enabling them to calculate that the total fish population of the North Sea (of these six species) at that time (the spring of 1895) amounted to about 10,000,000,000. Further calculations led them to the result that the fishermen's catch of these fishes amounted to about one-quarter of the total population. Now all this is not only of scientific interest, but also of great practical importance if we could be sure that the samples upon which the calculations are based were adequate and representative, but it will be noted that these samples represent only 1 square metre in 3,465,968,354. Hensen's statement, repeated in various works in slightly differing words, is to the effect that, using a net of which the constants are known hauled vertically through a column of water from a certain depth to the surface, he can calculate the volume of water filtered by the net and so estimate the quantity of plankton under each square metre of the surface; and his whole results depend upon the assumption, which he considers justified, that the plankton is evenly distributed over large areas of water which are under similar conditions. In these calculations in regard to the fish-eggs he takes the whole of the North Sea as being an area under similar conditions, but we have known since the days of P. T. Cleve and from the observations of Hensen's own colleagues that this is not the case, and they have published chart-diagrams showing that at least three different kinds of water under different conditions are found in the North Sea, and that at least five different planktonic areas may be encountered in making a traverse from Germany to the British Isles. If the argument be used that wherever the plankton is found to vary there the conditions cannot be uniform, then few areas of the ocean of any considerable size remain as cases suitable for population-computation from random samples. It may be doubted whether even the Sargasso Sea, which is an area of more than usually uniform character, has a sufficiently evenly distributed plankton to be treated by Hensen's method of estimation of the population.

In the German Plankton Expedition of 1889 Schütt reports that in the Sargasso Sea, with its relatively high temperature, the twenty-four catches obtained were uniformly small in quantity. His analysis of the volumes of these catches shows that the average was 3·33 c.c., but the individual catches ranged from 1·5 c.c. to 6·5 c.c., and the divergence from the average may be as great as +3·2 c.c.; and, after deducting 20 per cent. of the divergence as due to errors of the experiment, Schütt estimates the mean variation of the plankton at about 16 per cent. above or below. This does not seem to me to indicate the uniformity that might be expected in this "halistatic" area occupying the centre of the North Atlantic Gulf Stream circulation. Hensen also made almost simultaneous hauls with the same net in quick succession to test the amount of variation, and found that the average error was about 13 per cent.

As so much depends in all work at sea upon the weather, the conditions under which the ship is working, and the care taken in the experiment, with the view of getting further evidence under known conditions I carried out similar experiments at Port Erin on four occasions during last April and on a further occasion a month later, choosing favourable weather and conditions of tide and wind so as to be able to maintain an approximate position. On each of four days in April the Nansen net, with No. 20 silk, was hauled six times from the same depth (on two occasions 8 fathoms and on two occasions 20 fathoms), the hauls being taken in rapid succession and the catches emptied from the net into bottles of 5 per cent. formaline, in which they remained until examined microscopically.

The results were of interest, for although they showed considerable uniformity in the amount of the catch—for example, six successive hauls from 8 fathoms being all of them 0·2 c.c., and four out of five from 20 fathoms being 0·6 c.c.—the volume was made up rather differently in the successive hauls. The same organisms occur for the most part in each haul, and the chief groups of organisms are present in much the same proportion. For example, in a series where the Copepoda average about 100, the Dinoflagellates average about 300 and the Diatoms about 8000, but the percentage deviation of individual hauls from the average may be as much as *plus* or *minus* 50. The numbers for each organism (about 40) in each of the twenty-six hauls have been worked out, and the details will be published elsewhere, but the conclusion I come to is that if on each occasion one haul only in place of six had been taken, and if one had used that haul to estimate the abundance of any one organism in that sea-area, one might have been about 50 per cent. wrong in either direction.

Successive improvements and additions to Hensen's methods in collecting plankton have been made by Lohmann, Apstein, Gran, and others, such as pumping up water of different layers through a hose-pipe and filtering it through felt, filter-paper, and other materials which retain much of the micro-plankton that escapes through the meshes of the finest silk. Use has even been made of the extraordinarily minute and beautifully regular natural filter spun by the pelagic animal Appendicularia for the capture of its own food. This grid-like trap, when dissected out and examined under the microscope, reveals a surprising assemblage of the smallest protozoa and protophyta, less than 30 micro-millimetres in diameter, which would all pass easily through the meshes of our finest silk nets.

The latest refinement in capturing the minutest-known organisms of the plankton (excepting the bacteria) is a culture method devised by Dr. E. J. Allen, director of the Plymouth Laboratory.[11] By diluting half a cubic centimetre of the sea-water with a considerable amount (1500 c.c.) of sterilised water treated with a nutrient solution, and distributing that over a large number (70) of small flasks in which after an interval of some days the number of different kinds of organisms which had developed in each flask was counted, he calculates that the sea contains 464,000 of such organisms per litre; and he gives reasons why his cultivations must be regarded as minimum results, and states that the total per litre may well be something like a million. Thus every new method devised seems to multiply many times the probable total population of the sea. As further results of the quantitative method, it may be recorded that Brandt found about 200 Diatoms per drop of water in Kiel Bay, and Hensen estimated that there are several hundred millions of Diatoms under each square metre of the North Sea or the Baltic. It has been calculated that there is approximately one Copepod in each cubic inch of Baltic water, that the annual consumption of these Copepoda by herring is about a thousand billion, and that in the sixteen square miles of a certain Baltic fishery there is Copepod food for more than 530,000,000 herring of an average weight of 60 grams.

[11] Journ. Mar. Biol. Assoc., vol. xii., p. 1, July, 1919.

There are many other problems of the plankton in addition to quantitative estimates—probably some that we have not yet recognised—and various interesting conclusions may be drawn from recent planktonic observations. Here is a case of the introduction and rapid spread of a form new to British seas.

Biddulphia sinensis is an exotic Diatom which, according to Ostenfeld, made its appearance at the mouth of the Elbe in 1903, and spread during successive years in several directions. It appeared suddenly in our plankton gatherings at Port Erin in November, 1909, and has been present in abundance each year since. Ostenfeld in 1908, when tracing its spread in the North Sea, found that the migration to the north along the coast of Denmark to Norway corresponded with the rate of flow of the Jutland current to the Skager Rak, viz. about 17 cm. per second—a case of plankton distribution throwing light on hydrography—and he predicted that it would soon be found in the English Channel. Dr. Marie Lebour, who recently examined the store of plankton gatherings at the Plymouth Laboratory, finds that, as a matter of fact, this form did appear in abundance in the collections of October, 1909, within a month of the time when, according to our records, it reached Port Erin. Whether or not this is an Indo-Pacific species brought accidentally by a ship from the Far East, or whether it is possibly a new mutation which appeared suddenly in our seas, there is no doubt that it was not present in our Irish Sea plankton gatherings previous to 1909, but has been abundant since that year, and has completely adopted the habits of its English relations, appearing with *B. mobiliensis* in late autumn, persisting during the winter, reaching a maximum in spring, and dying out before summer.

The Nauplius and Cypris stages of Balanus in the plankton form an interesting study. The adult barnacles are present in enormous abundance on the rocks round the coast, and they reproduce in winter at the beginning of the year. The newly emitted young are sometimes so abundant as to make the water in the shore-pools and in the sea close to the shore appear muddy. The Nauplii first appeared at Port Erin in 1907 in the bay gatherings on February 22 (in 1908 on February 13), and increased with ups and downs to their maximum on April 15, and then decreased until their disappearance on April 26. None were taken at any other time of the year. The Cypris stage follows on after the Nauplius. It was first taken in the bay on April 6, rose to its maximum on the same day with the Nauplii, and was last caught on May 24. Throughout the Cypris curve keeps below that of the Nauplius, the maxima being 1740 and 10,500 respectively. Probably the difference between the two curves represents the death-rate of Balanus during the Nauplius stage. That conclusion I think we are justified in drawing, but I would not venture to use the result of any haul, or the average of a number of hauls, to multiply by the number of square yards in a zone round our coast in order to obtain an estimate of the number of young barnacles or of the old barnacles that produced them; the irregularities are too great.

To my mind it seems clear that there must be three factors making for irregularity in the distribution of a plankton organism:

(1) The sequence of stages in its life-history, such as the Nauplius and Cypris stages of Balanus.

(2) The results of interaction with other organisms, as when a swarm of Calanus is pursued and devoured by a shoal of herring.

(3) Abnormalities in time or abundance due to the physical environment, as in favourable or unfavourable seasons.

And these factors must be at work in the open ocean as well as in coastal waters.

In many oceanographical inquiries there is a double object. There is the scientific interest and there is the practical utility—the interest, for example, of tracing a particular swarm of a Copepod like Calanus, and of making out why it is where it is at a particular time, tracing it back to its place of origin, finding that it has come with a particular body of water, and perhaps that it is feeding upon a particular assemblage of Diatoms; endeavouring to give a scientific explanation of every stage in its progress. Then there is the utility—the demonstration that the migration of the Calanus has determined the presence of a shoal of herring or mackerel that are feeding upon it, and so have been brought within the range of the fisherman and have constituted a commercial fishery.

We have evidence that pelagic fish which congregate in shoals, such as herring and mackerel, feed upon the Crustacea of the plankton, and especially upon Copepoda. A few years ago when the summer herring fishery off the south end of the Isle of Man was unusually near the land, the fishermen found large red patches in the sea where the fish were specially abundant. Some of the red stuff brought ashore by the men was examined at the Port Erin Laboratory, and found to be swarms of the Copepod, *Temora longicornis*; and the stomachs of the herring caught at the same time were engorged with the same organism. It is not possible to doubt that during these weeks of the herring fishery in the Irish Sea the fish were feeding mainly upon this species of Copepod. Some ten years ago Dr. E. J. Allen and Mr. G. E. Bullen published[12] some interesting work from the Plymouth Marine Laboratory demonstrating the connection between mackerel and Copepoda and sunshine in the English Channel; and Farran[13] states that in the spring fishery on the West of Ireland the food of the mackerel is mainly composed of Calanus.

Then again, at the height of the summer mackerel fishery in the Hebrides in 1913, we found[14] the fish feeding upon the large Copepod, *Calanus finmarchicus*, which was caught in the tow-net at the rate of about 6000 in a five minutes' haul, and 6000 was also the average number found in the stomachs of the fish caught at the same time.

These were cases where the fish were feeding upon the organism that was present in swarms—a monotonic plankton—but in other cases the fish are clearly selective in their diet. If the sardine of the French coast can pick out from the micro-plankton the minute Peridiniales in preference to the equally minute Diatoms which are present in the sea at the same time, there seems no reason why the herring and the mackerel should not be able to select particular species of Copepoda or other large organisms from the macroplankton, and we have evidence that they do. Nearly thirty years ago the late Mr. Isaac Thompson, a constant supporter of the Zoological Section of this Association and one of the honorary local secretaries for the last Liverpool meeting, showed me in 1893 that young plaice at Port Erin were selecting one particular Copepod, a species of Jonesiella, out of many others caught in our tow-nets at the time. H. Blegvad[15] showed in 1916 that young food-fishes, and also small shore-fishes, pick out certain species of Copepoda (such as Harpacticoids) and catch them individually—either lying in wait or searching for them. A couple

[12] Journ. Mar. Biol. Assoc., vol. viii. (1909), pp. 394-406.
[13] Conseil Internat. Bull. Trimestr., 1902-8, "Planktonique," p. 89.
[14] "Spolia Runiana," iii., Linn. Soc. Journ., Zoology, vol. xxxiv., p. 95. 1918.
[15] Rep. Danish Biol. Stat., vol. xxiv., 1916.

of years later[16] Dr. Marie Lebour published a detailed account of her work at Plymouth on the food of young fishes, proving that certain fish undoubtedly do prefer certain planktonic food.

These Crustacea of the plankton feed upon smaller and simpler organisms—the Diatoms, the Peridinians, and the Flagellates—and the fish themselves in their youngest post-larval stages are nourished by the same minute forms of the plankton. Thus it appears that our sea-fisheries ultimately depend upon the living plankton, which no doubt, in its turn, is affected by hydrographic conditions. A correlation seems to be established between the Cornish pilchard fisheries and periodic variations in the physical characters (probably the salinity) of the water of the English Channel between Plymouth and Jersey.[17] Apparently a diminished intensity in the Atlantic current corresponds with a diminished fishery in the following summer. Possibly the connection in these cases is through an organism of the plankton.

It is only a comparatively small number of different kinds of organisms—both plants and animals—that make up the bulk of the plankton that is of real importance to fish. One can select about half a dozen species of Copepoda which constitute the greater part of the summer zoo-plankton suitable as food for larval or adult fishes, and about the same number of generic types of Diatoms which similarly make up the bulk of the available spring phyto-plankton year after year. This fact gives great economic importance to the attempt to determine with as much precision as possible the times and conditions of occurrence of these dominant factors of the plankton in an average year. An obvious further extension of this investigation is an inquiry into the degree of coincidence between the times of appearance in the sea of the plankton organisms and of the young fish, and the possible effect of any marked absence of correlation in time and quantity.

Just before the war the International Council for the Exploration of the Sea[18] arrived at the conclusion that fishery investigations indicated the probability that the great periodic fluctuations in the fisheries are connected with the fish-larvæ being developed in great quantities only in certain years. Consequently they advised that plankton work should be directed primarily to the question whether these fluctuations depend upon differences in the plankton production in different years. It was then proposed to begin systematic investigation of the fish-larvæ and the plankton in spring and to determine more definitely the food of the larval fish at various stages.

About the same time Dr. Hjort[19] made the interesting suggestion that possibly the great fluctuations in the number of young fish observed from year to year may not depend wholly upon the number of eggs produced, but also upon the relation in time between the hatching of these eggs and the appearance in the water of the enormous quantity of Diatoms and other plant plankton upon which the larval fish, after the absorption of their yolk, depend for food. He points out that if even a brief interval occurs between the time when the larvæ first require extraneous nourishment and that when such food is available, it is highly probable that an enormous mortality would result. In that case even a rich spawning season might yield but a poor result in fish in the commercial fisheries of successive years for some time to come. So that, in fact, the numbers of a year-class may depend not so much upon a favourable spawning season as upon a coincidence between the hatching of the larvæ and the presence of abundance of phyto-plankton available as food.[20]

The curve for the spring maximum of Diatoms corresponds in a general way with the curve representing the occurrence of pelagic fish-eggs in our seas. But is the correspondence sufficiently exact and constant to meet the needs of the case? The phyto-plankton may still be relatively small in amount during February and part of March in some years, and it is not easy to determine exactly when, in the open sea, the fish-eggs have hatched out in quantity and the larvæ have absorbed their food-yolk and started feeding on Diatoms.

If, however, we take the case of one important fish —the plaice—we can get some data from our hatching experiments at the Port Erin Biological Station, which have now been carried on for a period of seventeen years. An examination of the hatchery records for these years in comparison with the plankton records of the neighbouring sea, which have been kept systematically for the fourteen years from 1907 to 1920 inclusive, shows that in most of these years the Diatoms were present in abundance in the sea a few days at least before the fish-larvæ from the hatchery were set free, and that it was only in four years (1908, 1909, 1913, and 1914) that there was apparently some risk of the larvæ finding no phyto-plankton food or very little. The evidence so far seems to show that if fish-larvæ are set free in the sea so late as March 20 they are fairly sure of finding suitable food[21]; but if they are hatched so early as February they run some chance of being starved.

But this does not exhaust the risks to the future fishery. C. G. Joh. Petersen and Boysen-Jensen in their valuation of the Limfjord[22] have shown that in the case not only of some fish, but also of the larger invertebrates on which they feed, there are marked fluctuations in the number of young produced in different seasons, and that it is only at intervals of years that a really large stock of young is added to the population.

The prospects of a year's fishery may, therefore, depend primarily upon the rate of spawning of the fish, affected, no doubt, by hydrographic and other environmental conditions; secondarily, upon the presence of a sufficient supply of phyto-plankton in the surface-layers of the sea at the time when the fish-larvæ are hatched, and that, in its turn, depends upon photosynthesis and physico-chemical changes in the water; and, finally, upon the reproduction of the stock of molluscs or worms at the bottom which constitute the fish-food at later stages of growth and development.

The question has been raised in recent years: Is there enough plankton in the sea to provide sufficient nourishment for the larger animals, and especially for those fixed forms, such as sponges, that are supposed to feed by drawing currents of plankton-laden water through the body? In a series of remarkable papers from 1907 onwards Pütter and his followers put forward the views: (1) that the carbon requirements of such animals could not be met by the amount of plankton in the volume of water that could be passed through the body in a given time, and (2) that sea-water contained a large amount of dissolved organic carbon compounds which constitute the chief, if not the only, food of a large number of marine animals. These views have given rise to

16 Journ. Mar. Biol. Assoc., May, 1918.
17 See E. C. Jee, "Hydrography of the English Channel," 1904–17.
18 Rapports et Proc. Verb., vol. xix., December, 1913.
19 *Ibid.*, vol. xx., 1914, p. 204.

20 For the purpose of this argument we may include in "phyto-plankton" the various groups of Flagellata and other minute organisms which may be present with the Diatoms.
21 All dates and statements as to occurrence refer to the Irish Sea round the south end of the Isle of Man. For further details see Report Lancs Sea-Fish. Lab. for 1919.
22 Report of Danish Biol. Station for 1919.

much controversy, and have been useful in stimulating further research, but I believe it is now admitted that Pütter's samples of water from the Bay of Naples and at Kiel were probably polluted, that his figures were erroneous, and that his conclusions must be rejected, or at least greatly modified. His estimates of the plankton were minimum ones, while it seems probable that his figures for the organic carbon present represent a variable amount of organic matter arising from one of the reagents used in the analyses.[23] The later experimental work of Henze, of Raben, and of Moore shows that the organic carbon dissolved in sea-water is an exceedingly minute quantity, well within the limits of experimental error. Moore puts it at the most at one-millionth part, or 1 mgm. in a litre At the Dundee meeting of the Association in 1912 a discussion on this subject took place, at which Pütter still adhered to a modified form of his hypothesis of the inadequacy of the plankton and the nutrition of lower marine animals by the direct absorption of dissolved organic matter. Further work at Port Erin since has shown that, while the plankton supply as found generally distributed would prove sufficient for the nutrition of such sedentary animals as Sponges and Ascidians, which require to filter only about fifteen times their own volume of water per hour, it is quite inadequate for active animals such as crustaceans and fishes. These latter are, however, able to seek out and capture their food, and are not dependent on what they may filter or absorb from the sea-water. This result accords well with recorded observations on the irregularity in the distribution of the plankton and with the variations in the occurrence of the migratory fishes which may be regarded as following and feeding upon the swarms of planktonic organisms.

This, then, like most of the subjects I am dealing with, is still a matter of controversy, still not completely understood. Our need, then, is research, more research, and *still more research*.

Our knowledge of the relations between plankton productivity and variation and the physico-chemical environment is still in its infancy, but gives promise of great results in the hands of the biochemist and the physical chemist.

Recent papers by Sørensen, Palitzsch, Witting, Moore, and others have made clear that the amount of hydrogen-ion concentration as indicated by the relative degree of alkalinity and acidity in the sea-water may undergo local and periodic variations, and that these have an effect upon the living organisms in the water and can be correlated with their presence and abundance. To take an example from our own seas, Prof. Benjamin Moore and his assistants in their work at the Port Erin Biological Station in successive years from 1912 onwards have shown [24] that the sea around the Isle of Man is a good deal more alkaline in spring (say April) than it is in summer (say July). The alkalinity, which gets low in summer, increases somewhat in autumn, and then decreases rapidly, to disappear during the winter; and then once more, after several months of a minimum, begins to come into evidence again in March, and rapidly rises to its maximum in April or May. This periodic change in alkalinity will be seen to correspond roughly with the changes in the living microscopic contents of the sea represented by the phyto-plankton annual curve, and the connection between the two will be seen when we realise that the alkalinity of the sea is due to the relative absence of carbon dioxide. In early spring, then, the developing myriads of Diatoms in their metabolic processes gradually use up the store of carbon dioxide accumulated during the winter or derived from the bicarbonates of calcium and magnesium, and so increase the alkalinity of the water until the maximum of alkalinity, due to the fixation of the carbon and the reduction in amount of carbon dioxide, corresponds with the crest of the phyto-plankton curve in, say, April. Moore has calculated that the annual turnover in the form of carbon which is used up or converted from the inorganic into an organic form probably amounts to something of the order of 20,000–30,000 tons of carbon per cubic mile of sea-water, or, say, over an area of the Irish Sea measuring 16 square miles and a depth of 50 fathoms; and this probably means a production each season of about two tons of dry organic matter, corresponding to at least ten tons of moist vegetation, per acre—which suggests that we may still be very far from getting from our seas anything like the amount of possible food-matters that are produced annually.

Testing the alkalinity of the sea-water may therefore be said merely to be ascertaining and measuring the results of the photosynthetic activity of the great phyto-plankton rise in spring due to the daily increase of sunlight.

The marine biologists of the Carnegie Institution, Washington, have made a recent contribution to the subject in certain observations on the alkalinity of the sea (as determined by hydrogen-ion concentration), during which they found in tropical mid-Pacific a sudden change to acidity in a current running eastwards. Now in the Atlantic the Gulf Stream and tropical Atlantic waters generally are much more alkaline than the colder coastal water running south from the Gulf of St. Lawrence—that is, the colder Arctic water has more carbon dioxide. This suggests that the Pacific easterly set may be due to deeper water, containing more carbon dioxide (=acidity), coming to the surface at that point. The alkalinity of the sea-water can be determined rapidly by mixing the sample with a few drops of an indicator and observing the change in colour; and this method of detecting ocean currents by observing the hydrogen-ion concentration of the water might be useful to navigators as showing the time of entrance to a known current.

Oceanography has many practical applications, chiefly, but by no means wholly, on the biological side. The great fishing industries of the world deal with living organisms, of which all the vital activities and the inter-relations with the environment are matters of scientific investigation. Aquiculture is as susceptible of scientific treatment as agriculture can be; and the fisherman, who has been in the past too much the nomad and the hunter—if not, indeed, the devastating raider—must become in the future the settled farmer of the sea if his harvest is to be less precarious. Perhaps the nearest approach to cultivation of a marine product, and of the fisherman reaping what he has actually sown, is seen in the case of the oyster and mussel industries on the west coast of France, in Holland, America, and, to a less extent, on our own coast. Much has been done by scientific men for these and other similar coastal fisheries since the days when Prof. Coste in France in 1859 introduced oysters from the Scottish oyster-beds to start the great industry at Arcachon and elsewhere. Now we buy back the descendants of our own oysters from the French ostreiculturists to replenish our depleted beds.

It is no small matter to have introduced a new and important food-fish to the markets of the world. The remarkable deep-water "tile-fish," new to science and

[23] See Moore, etc., *Bio-Chem. Journ.*, vol. vi., p. 266, 1912.
[24] "Photosynthetic Phenomena in Sea-water," Trans. Liverpool Biol. Soc., vol. xxix., p. 233, 1915.

described as *Lopholatilus chamaeleonticeps*, was discovered in 1879 by one of the United States fishing schooners to the south of Nantucket, near the 100-fathom line. Several thousand pounds' weight was caught, and the matter was duly investigated by the United States Fish Commission. For a couple of years after that the fish was brought to market in quantity, and then something unusual happened at the bottom of the sea, and in 1882 millions of dead tile-fish were found floating on the surface over an area of thousands of square miles. The schooner *Navarino* sailed for two days and a night through at least 150 miles of sea thickly covered, so far as the eye could reach, with dead fish, estimated at 256,000 to the square mile. The Fish Commission sent a vessel to fish systematically over the grounds known as the "Gulf Stream slope," where the tile-fish had been so abundant during the two previous years, but she did not catch a single fish, and the associated subtropical invertebrate fauna was also practically obliterated.

This wholesale destruction was attributed by the American oceanographers to a sudden change in the temperature of the water at the bottom, due in all probability to a withdrawal southwards of the warm Gulf Stream water and a flooding of the area by the cold Labrador current.

I am indebted to Dr. C. H. Townsend, director of the celebrated New York Aquarium, for the latest information in regard to the reappearance in quantity of this valuable fish upon the old fishing-grounds of Nantucket and Long Island, at about 100 miles from the coast to the east and south-east of New York. It is believed that the tile-fish is now abundant enough to maintain an important fishery, which will add an excellent food-fish to the markets of the United States. It is easily caught with lines at all seasons of the year, and reaches a length of more than 3 ft. and a weight of 40–50 lb. During July, 1915, the product of the fishery was about 2,500,000 lb. weight, valued at 55,000 dollars, and in the first few months of 1917 the catch was 4,500,000 lb., for which the fishermen received 247,000 dollars.

We can scarcely hope in European seas to add new food-fishes to our markets, but much may be done through the co-operation of scientific investigators of the ocean with the administrative departments to bring about a more rational conservation and exploitation of the national fisheries.

Earlier in this address I referred to the pioneer work of the distinguished Manx naturalist, Prof. Edward Forbes. There are many of his writings and of his lectures to which I have no space to refer which have points of oceanographic interest. Take this, for example, in reference to our national sea-fisheries. We find him in 1847 writing to a friend: "On Friday night I lectured at the Royal Institution. The subject was the bearing of submarine researches and distribution matters on the fishery question. I pitched into Government mismanagement pretty strong, and made a fair case of it. It seems to me that at a time when half the country is starving we are utterly neglecting or grossly mismanaging great sources of wealth and food. . . . Were I a rich man I would make the subject a hobby for the good of the country and for the better proving that the true interests of Government are those linked with and inseparable from Science." We must still cordially approve of these last words, while recognising that our Government Department of Fisheries is now being organised on better lines, is itself carrying on scientific work of national importance, and is, I am happy to think, in complete sympathy with the work of independent scientific investigators of the sea and desirous of closer co-operation with university laboratories and biological stations.

During recent years one of the most important and most frequently discussed of applications of fisheries investigation has been the productivity of the trawling grounds, and especially those of the North Sea. It has been generally agreed that the enormous increase of fishing power during the last forty years or so has reduced the number of large plaice, so that the average size of that fish caught in our home waters has become smaller, although the total number of plaice landed had continued to increase up to the year of the outbreak of war. Since then, from 1914 to 1919, there has of necessity been what may be described as the most gigantic experiment ever seen in the closing of extensive fishing-grounds. It is still too early to say with any certainty exactly what the results of that experiment have been, although some indications of an increase of the fish population in certain areas have been recorded. For example, the Danes, A. C. Johansen and Kirstine Smith, find that large plaice landed in Denmark are now more abundant, and they attribute this to a reversal of the pre-war tendency, due to less intensive fishing. But Dr. James Johnstone has pointed out that there is some evidence of a natural periodicity in abundance of such fish, and that the results noticed may represent phases in a cyclic change. If the periodicity noted in Liverpool Bay[25] holds good for other grounds, it will be necessary in any comparison of pre-war and post-war statistics to take this natural variation in abundance into very careful consideration.

In the application of oceanographic investigations to sea-fisheries problems one ultimate aim, whether frankly admitted or not, must be to obtain some kind of a rough approximation to a census or valuation of the sea—of the fishes that form the food of man, of the lower animals of the sea-bottom on which many of the fishes feed, and of the planktonic contents of the upper waters which form the ultimate organised food of the sea—and many attempts have been made in different ways to attain the desired end.

Our knowledge of the number of animals living in different regions of the sea is for the most part relative only. We know that one haul of the dredge is larger than another, or that one locality seems richer than another, but we have very little information as to the actual numbers of any kind of animal per square foot or per acre in the sea. Hensen, as we have seen, attempted to estimate the number of food-fishes in the North Sea from the number of their eggs caught in a comparatively small series of hauls of the tow-net, but the data were probably quite insufficient and the conclusions may be erroneous. It is an interesting speculation to which we cannot attach any economic importance. Heincke says of it: "This method appears theoretically feasible, but presents in practice so many serious difficulties that no positive results of real value have as yet been obtained."

All biologists must agree that to determine even approximately the number of individuals of any particular species living in a known area is a contribution to knowledge which may be of great economic value in the case of the edible fishes, but it may be doubted whether Hensen's methods, even with greatly increased data, will ever give us the required information. Petersen's method, of setting free marked plaice and then assuming that the proportion of these recaught is to the total number marked as the fishermen's catch in the same district is to the total population, will hold good only in circumscribed areas where there is practically no migration and the fish

[25] See Johnstone, Report Lancs Sea-Fish. Lab. for 1917, p. 60; and Daniel, Report for 1919, p. 51.

are fairly evenly distributed. This method gives us what has been called "the fishing coefficient," and this has been estimated for the North Sea to have a probable value of about 0·33 for those sizes of fish which are caught by the trawl. Heincke,[26] from an actual examination of samples of the stock on the ground obtained by experimental trawling ("the catch coefficient"), supplemented by the market returns of the various countries, estimates the adult plaice at about 1,500,000,000, of which about 500,000,000 are caught or destroyed by the fishermen annually.

It is difficult to imagine any further method which will enable us to estimate any such case as, say, the number of plaice in the North Sea, where the individuals are so far beyond our direct observation and are liable to change their positions at any moment. But a beginning can be made on more accessible ground with more sedentary animals, and Dr. C. G. Joh. Petersen, of the Danish Biological Station, has for some years been pursuing the subject in a series of interesting reports on "The Evaluation of the Sea."[27] He uses a bottom-sampler or grab, which can be lowered down open and then closed on the bottom so as to bring up a sample square foot or square metre (or in deep water one-tenth of a square metre) of the sand or mud and its inhabitants. With this apparatus, modified in size and weight for different depths and bottoms, Petersen and his fellow-workers have made a very thorough examination of the Danish waters, and especially of the Kattegat and the Limfjord, have described a series of "animal communities" characteristic of different zones and regions of shallow water, and have arrived at certain numerical results as to the quantity of animals in the Kattegat expressed in tons—such as 5000 tons of plaice requiring as food 50,000 tons of "useful animals" (mollusca and polychæt worms), and 25,000 tons of starfish using up 200,000 tons of useful animals which might otherwise serve as food for fishes, and the dependence of all these animals directly or indirectly upon the great Beds of Zostera, which make up 24,000,000 tons in the Kattegat. Such estimates are obviously of great biological interest, and, even if only rough approximations, are a valuable contribution to our understanding of the metabolism of the sea and of the possibility of increasing the yield of local fisheries.

But on studying these Danish results in the light of what we know of our own marine fauna, although none of our seas have been examined in the same detail by the bottom-sampler method, it seems probable that the animal communities as defined by Petersen are not exactly applicable on our coasts, and that the estimates of relative and absolute abundance may be very different in different seas under different conditions. The work will have to be done in each great area, such as the North Sea, the English Channel, and the Irish Sea, independently. This is a necessary investigation, both biological and physical, which lies before the oceanographers of the future, upon the results of which the future preservation and further cultivation of our national sea-fisheries may depend.

It has been shown by Johnstone and others that the common edible animals of the shore may exist in such abundance that an area of the sea may be more productive of food for man than a similar area of pasture or crops on land. A Lancashire mussel-bed has been shown to have as many as 16,000 young mussels per square foot, and it is estimated that in the shallow waters of Liverpool Bay there are from 20 to 200 animals of sizes varying from an amphipod to a plaice on each square metre of the bottom.[28]

From these and similar data which can be readily obtained it is not difficult to calculate totals by estimating the number of square yards in areas of similar character between tide-marks or in shallow water. And from weighings of samples some approximation to the number of tons of available food may be computed. But one must not go too far. Let all the figures be based upon actual observation. Imagination is necessary in science, but in calculating a population of even a very limited area it is best to believe only what one can see and measure.

Countings and weighings, however, do not give us all the information we need. It is something to know even approximately the number of millions of animals on a mile of shore and the number of millions of tons of possible food in a sea area, but that is not sufficient. All food-fishes are not equally nourishing to man, and all plankton and bottom invertebrata are not equally nourishing to a fish. At this point the biologist requires the assistance of the physiologist and the biochemist. We want to know next the value of our food-matters in proteids, carbohydrates, and fats, and the resulting Calories. Dr. Johnstone, of the oceanography department of the University of Liverpool, has already shown us how markedly a fat summer herring differs in essential constitution from the ordinary white fish, such as the cod, which is almost destitute of fat.

Prof. Brandt at Kiel, Prof. Benjamin Moore at Port Erin, and others have similarly shown that plankton gatherings may vary greatly in their nutrient value according as they are composed mainly of Diatoms, of Dinoflagellates, or of Copepoda. And, no doubt, the animals of the "benthos," the common invertebrates of our shores, will show similar differences in analysis.[29] It is obvious that some contain more solid flesh, others more water in their tissues, others more calcareous matter in the exoskeleton, and that therefore, weight for weight, we may be sure that some are more nutritious than others; and this is probably at least one cause of that preference we see in some of our bottom-feeding fish for certain kinds of food, such as polychæt worms, in which there is relatively little waste, and thin-shelled lamellibranch molluscs, such as young mussels, which have a highly nutrient body in a comparatively thin and brittle shell.

My object in referring to these still incomplete investigations is to direct attention to what seems a natural and useful extension of faunistic work for the purpose of obtaining some approximation to a quantitative estimate of the more important animals of our shores and shallow water and their relative values as either the immediate or the ultimate food of marketable fishes.

Each such fish has its "food-chain" or series of alternative chains, leading back from the food of man to the invertebrates upon which it preys, and then to the food of these, and so down to the smallest and simplest organisms in the sea, and each such chain must have all its links fully worked out as to seasonal and quantitative occurrence back to the Diatoms and Flagellates, which depend upon physical conditions, and take us beyond the range of biology, but not beyond that of oceanography. The Diatoms and the Flagellates are probably more important than the more obvious seaweeds not only as food, but also in

26 F. Heincke, Cons. Per. Internat. Explor. de la Mer, "Investigations on the Plaice," Copenhagen, 1913.

27 See Reports of the Danish Biological Station, and especially the Report for 1918, "The Sea Bottom and its Production of Fish Food.

28 "Conditions of Life in the Sea," Cambridge University Press, 1908.

29 Moore and others have made analyses of the protein, fat, etc., in the soft parts of Sponge, Ascidian, Aplysia, Fusus, Echinus, and Cancer at Port Erin, and find considerable differences—the protein ranging, for example, from 8 to 51 per cent., and the fat from 2 to 14 per cent. (see *Bio-Chemical Journ.*, vol. vi., p. 291).

supplying to the water the oxygen necessary for the respiration of living protoplasm. Our object must be to estimate the rate of production and rate of destruction of all organic substances in the sea.

To attain to an approximate census and valuation of the sea—remote though it may seem—is a great aim, but it is not sufficient. We want not only to observe and to count natural objects, but also to understand them. We require to know not merely what an organism is—in the fullest detail of structure and development and affinities—where it occurs —again in full detail—and in what abundance in different circumstances, but also *how* it lives and what all its relations are to both its physical and its biological environment, and that is where the physiologist, and especially the biochemist, can help us. In the best interests of biological progress the day of the naturalist who merely collects, the day of the anatomist and histologist who merely describe, is over, and the future is with the observer and the experimenter animated by a divine curiosity to enter into the life of the organism and understand how it lives and moves and has its being. "Happy indeed is he who has been able to discover the causes of things."

Cardiff is a seaport, and a great seaport, and the Bristol Channel is a notable sea-fisheries centre of growing importance. The explorers and merchant venturers of the south-west of England are celebrated in history. What are you doing now in Cardiff to advance our knowledge of the ocean? You have here an important university centre and a great modern national museum, and either or both of these homes of research might do well to establish an oceanographical department, which would be an added glory to your city and of practical utility to the country. This is the obvious centre in Wales for a sea-fisheries institute for both research and education. Many important local movements have arisen from British Association meetings, and if such a notable scientific development were to result from the Cardiff meeting of 1920, all who value the advance of knowledge and the application of knowledge to industry would applaud your enlightened action.

In a wider sense, it is not to the people of Cardiff alone that I appeal, but to the whole population of these islands, a maritime people who owe everything to the sea. I urge them to become better informed in regard to our national sea-fisheries and to take a more enlightened interest in the basal principles that underlie a rational regulation and exploitation of these important industries. National efficiency depends to a very great extent upon the degree in which scientific results and methods are appreciated by the people and scientific investigation is promoted by the Government and other administrative authorities. The principles and discoveries of science apply to aquiculture no less than to agriculture. To increase the harvest of the sea the fisheries must be continuously investigated, and such cultivation as is possible must be applied, and all this is clearly a natural application of the biological and hydrographical work now united under the science of oceanography.

Summaries of Addresses of Presidents of Sections of the British Association.

Mathematical and Physical Science.

PROF. EDDINGTON's presidential address to Section A deals with the investigation of the internal conditions of the stars. Most of the naked-eye stars have densities so low that they may be treated as spheres of perfect gas (giant stars). In familiar hot bodies the energy existing in the æther (radiant heat) is extremely small compared with that associated with the matter (molecular motions); conditions might exist in which this disproportion was reversed; but the stars are of just such a mass that the two kinds of energy are roughly equal. It is thought that this balance cannot be a coincidence, but determines why the masses of the stars are always close to a particular value. From astronomical data as to the masses and radiation of the stars it is possible to determine the opacity of stellar material to the radiation traversing it. The opacity turns out to be very high and of the same order of magnitude as that found for X-rays in the laboratory. (At the high temperatures in the stars the radiation consists mainly of soft X-rays.) A rather surprising result is that the opacity varies very little with the temperature of the star or wave-length of the radiation. The discussion leads to many astronomical results which appear to be generally confirmed by observation; in particular, it fixes within fairly narrow limits the period of a mechanical pulsation of any star, and this agrees in all known Cepheid variables with the observed period of light-pulsation. The question of the source of a star's heat is raised in an acute form by these investigations. It appears that the energy of gravitational contraction is quite inadequate. The recent experimental results of Aston and Rutherford seem to throw some new light on the often-discussed question whether sub-atomic energy can be made available in the stars. The address concludes with some observations on the legitimate place of speculation in scientific research.

Chemistry.

MR. C. T. Heycock deals in his presidential address to Section B with the manner in which our present rather detailed knowledge of metallic alloys has been acquired, starting from the sparse information which was available thirty or forty years ago, and sketches briefly the present position of the subject. He considers chiefly the non-ferrous alloys, not because any essential difference in type exists between these and ferrous alloys, but because the whole field presented by the chemistry of the metals and their alloys is too vast to be covered in an address of reasonable length. Though Réaumur in 1722 employed the microscope to examine the fractured surfaces of white and grey cast-iron and steel, and Widmanstatten in 1808 polished and etched sections from meteorites, the founder of modern metallography is undoubtedly H. C. Sorby, whose methods of polishing and etching alloys and of vertical illumination are used to-day by all who work at this subject. The first important clue to what occurs on cooling a fused mixture of metals was given by Guthrie's experiments on cryohydrates, and these researches, with those of Sorby, undertaken as they were for the sake of investigating natural phenomena, are remarkable examples of how purely scientific experiment can lead to most important practical results. Raoult's work on the depression of the freezing point of solvents due to the addition of dissolved substances led to the establishment by van't Hoff of a general theory applicable to all solutions. Later experiments established the similarity between the behaviour of metallic solutions or alloys and that of aqueous and other solutions of organic compounds in organic solvents; and in 1897 Neville and Heycock determined the complete freezing-point curve of the copper-tin alloys, confirming and extending the work of Roberts-Austen, Stansfield, and Le Chatelier. These were probably the first of the binary alloys on which an attempt was made to determine the changes which take place in passing from one pure constituent to the other; and without a working theory of solution the interpretation of the results would have been impossible. Many difficulties are encountered in the examination of binary alloys, but they are enormously increased in the investigation of ternary alloys, and with quaternary alloys they seem almost insurmountable; in the case of steels containing always six, and usually more, constituents, information can be obtained at present by purely empirical methods only.

Geology.

In discussing the relations of palæontology to other branches of biology in his presidential address to Section C, Dr. F. A. Bather emphasises the influence of the time-concept, which gives palæontology a fourth dimension and necessitates a new method of classification. The known facts of succession, while upsetting some rash speculations, do not, unaided, prove descent. Recapitulation, however, does furnish the desired proof. The "line-upon-line" method of research is the only sure one, and this has brought out a continuous transition in development, and definite directions leading to a seriation of forms. But this appearance of seriation, though it may be sometimes due to determinate variation, in no way implies determination; and still less do the facts warrant the belief in predetermination so generally held by palæontologists. After rebutting the various arguments for predestination, counter-adaptive degeneration, and momentum in evolution, Dr. Bather shows how light is thrown on the supposed instances by the study of adaptive form and of habitat. The varying rate of evolution, the recurrent cycles of structure, and the birth and death of races, all are dependent on the secular changes of environment. To correlate the succession of living forms with those changes is the task of the palæontologist. When completed, our geological systems will express truly the rhythm of evolution. But if there is no inevitable law of progress for any living creature, neither is there a law of decadence; and man, by controlling his environment and adapting his race through conscious selection, has but to aim at a high mark in order to prolong and hasten his ascent.

Zoology.

Prof. Stanley Gardiner in his presidential address to Section D asks the consideration of the public to the claims of zoology to support, and of the professional students of the science to the comparative sterility of much of their teaching and research. The chief claim of zoology lies in its broad applicability to human life. Harvey's researches on circulation and embryology apply directly to medicine and human growth. Malaria, typhus, dysentery, trench fever, and now, perhaps, cancer, are understandable only by the studies of the pure zoologist on insects and on the physiology of unicellular organisms. Mendel's work gives hopes of the understanding of the laws governing human heredity and of establishing immunity to many diseases. Economic entomology is founded on the seventeenth-century study of insect life-histories, and now we struggle for knowledge of the enemies or parasites of insects wherewith to destroy them by natural means. Curiosity as to the possibilities of life in the deep sea led to the opening up of great banks, without which our fishing industry would still be a small thing. River-eels migrate thousands of miles to breed, and mackerel migrations are correlated with sunlight; the Swedish herring fisheries depend on cycles of sun-spots and longer cycles of lunar changes.

Great as are such results, they approach the limit of what can be attained from the old zoological studies of anatomy, distribution and development. The future lies in the study of the living protoplasm, its universal association with water, the effects of acidity or alkalinity on reproduction and growth, the possibilities of dissolved food substances and perhaps of vitamines in water, and, finally, reproduction without the help of the male. Yet zoology is in danger, for its results are seldom immediately applicable to industry, and economic specialists are trying to make their students study their specialities without having a sufficiently broad scientific education to be able to consider what life really is. The old naturalists were largely cataloguers, but what they sought was the understanding of life. Then came in succession the anatomists, the embryologists, and the evolutionists, the last clearly seen to-day in that the subject as taught in many schools is merely history. Zoology must emancipate itself from its dry bones, and recognise that its museums and institutions are means only for the study of life itself.

Geography.

In his presidential address to Section E Mr. J. McFarlane discusses the principles upon which the territorial rearrangement of Europe has been based. He considers that the promise of stability is greatest in those cases where geographical and ethnical conditions are most in harmony, and least where undue weight has been given to considerations which are neither geographical nor ethnical. The transfer of Alsace-Lorraine to France must be defended, if at all, on the ground that its inhabitants are more attached to France than to Germany. The loss of territory which Germany has sustained both in the east and in the west is aggravated by the fact that from the regions lost she has in the past obtained much of her coal and iron-ore. Serious as her position is, however, her economic stability is not necessarily threatened. The position of Poland is geographically weak, partly because the surface features are such that the land has no well-marked individuality, and partly because there are no natural boundaries to prevent invasion or to restrain the Poles from wandering beyond the ethnic limits of their State. On the other hand, the population is sufficiently large and the Polish element within it sufficiently strong to justify its independence on ethnical grounds.

Czecho-Slovakia, in various ways the most interesting country in the reconstructed Europe, is alike geographically and ethnically marked by some features of great strength and by others of great weakness. Bohemia possesses geographical individuality, and Slovakia is at least strategically strong, but Czecho-Slovakia as a whole does not possess geographical unity, and is, in a sense, strategically weak, since Moravia, which unites Bohemia and Slovakia, lies across the great route from the Adriatic to the plains of Northern Europe. Rumania has sacrificed unity of political outlook and ethnic homogeneity by the annexation of Transylvania, while her position on the Hungarian plain is likely sooner or later to involve her in further trouble with the Magyars. Indeed, the treatment of the Hungarian plain is the most unsatisfactory part of the whole Peace settlement. In that great natural region the Magyar element is the strongest, and to divide it as has been done is to induce a position of unstable equilibrium which is likely to lead to trouble in the future.

The troubles of Austria are due to the fact that she has failed to realise that an empire such as hers can be permanently retained only on a basis of common political and economic interest. At present she has no place in the reconstructed Europe, and a complete political re-orientation will be necessary if she is to emerge successfully from her present trials.

The pre-war frontier of Italy in the east is unsatisfactory, because it assigns to Austria the essentially Italian region of the Lower Isonzo. But beyond that region and a position on the neighbouring highlands for strategic purposes, Italy has no claim except what she can establish on ethnic grounds. The so-called "Wilson line" meets her requirements fairly well.

Economic Science and Statistics.

Dr. J. H. Clapham's presidential address to Section F contains a comparison and contrast between the economic condition of Western Europe after the Napoleonic wars and its economic condition to-day. Figures for the total losses of France and for the debt accumulated by Great Britain during the former period go to prove that if warfare in those days lacked intensity, it made up in duration. As in 1918, France was short of men, and her means of communication had suffered; her rapid recovery illustrates the essential difference between the two periods: a hundred years ago few men were demobilised in either France or Germany, and these were readily absorbed in an agricultural community. In 1816 the harvest was bad, and Western Europe approached starvation; the situation was saved only by the excellent harvest of the following year. Economic organisation was primitive, but elastic. A modern parallel is Serbia, which has improved wonderfully since the bountiful harvest of 1919. Germany suffered rather longer owing to the lack of a strong central Government; the States which have risen from the wreckage of the Austro-Hungarian Empire are now in a similar plight. Great Britain was partly industrial, and recovery was delayed by mismanagement of supplies, taxation, and demobilisation. Stocks of Colonial goods had accumulated with which home markets were flooded, and a commercial and industrial crisis followed. A similar situation exists now in the United States; she is a creditor nation with a big export trade, but she will not permit indiscriminate exchange. Modern financial methods are staving off such a crisis as followed the Napoleonic wars. The central problem is: When will the inability of war-damaged countries to pay for the material they require to restart their industries be felt by the nations supplying them? If trade balances are adjusted, the post-war slump will become a slow decline; otherwise, a crisis must occur when international obligations cannot be met. Another feature of the situation in the early part of the nineteenth century was the rapid growth in population observed everywhere. Official figures indicate the possibility of a repetition of this phenomenon.

Engineering.

Prof. C. F. Jenkin in his presidential address to Section G suggests that the time has come for an extensive revision of the theory of the strength of materials as used by engineers. The mathematical theory needs to be extended to cover anisotropic materials, such as timber, and to enable concentrations of stress such as occur at all changes of section to be calculated. Our knowledge of the physical properties of materials requires to be extended so that their suitability for all engineering purposes may be known. The need for the wider theory and for more research into the properties of materials is illustrated by examples of the problems which occurred in aeroplane construction during the war. The first material dealt with by the Air Service was timber. How was the strength of such material to be calculated? It was shown that the components of the tensile stress in three principal directions must not exceed the tensile strengths in those directions. Curves limiting the stress at any angle to the grain have been drawn for spruce, ash, walnut, and mahogany. For plywood, "split-off" veneers were recommended in place of "cut-off" wood. The method used for the determination of Young's modulus for wood neglects the effect of shear, and is therefore inaccurate. As an example of an isotropic substance steel is discussed. Fatigue limit is suggested as a measure of strength; in samples examined it was found to be slightly less than half the ultimate strength. Research is necessary to determine the effects of the speed of testing, rest and heat treatment, and previous testing. For this improved methods are required; Stromeyer's method would be useful if modified for commercial use. Present methods of testing in torsion are unsatisfactory, and knowledge of the internal mechanism of fatigue failure is required. For members of structures subjected to steady loads a proof-load specification which limits the permanent set to $\frac{1}{2}$ per cent. or $\frac{1}{4}$ per cent. is suggested. If fatigue limit is the basis for engine-strength calculation, the distribution of stresses in irregularly shaped parts of the machine must be investigated. Prof. Coker's optical method has been applied to this end, but A. A. Griffith's calculations on the effects of grooves and polishing have not been tested. Wood and steel are the only materials about which trustworthy data have been collected.

Anthropology.

Prof. Karl Pearson in his presidential address to Section H urges the importance of anthropology, "the true study of mankind." Science should be studied, not for itself, but for the sake of man. For this reason there is no use for the collection of measurements of height, span, size of head, etc. The important characteristics are the psycho-physical and psycho-physiological factors, reaction-time, mental age, and pulse-tracing. Body measurement has no connection with "vigorimetry" and psychometry, for no pure "line" in man has been traced. Moreover, present methods are entirely qualitative; they must be made quantitative. Three things are urged as essential to the recognition of anthropology as a useful science. First, folk-psychology as well as individual psychology should be studied as a means to determine race efficiency. For this purpose, the ancestry of man must be investigated in order that we may know which is likely to have the greater influence on his future, Nature or nurture. Secondly, institutes for the study of anthropology ought to be established in at least three of our universities. There the workers would be in touch with allied sciences, they would have a wide field open for measurements, and would be able to teach as well as to research on the subject. In this way men could be fitted for important "extra-State" work as diplomatic agents, traders, etc., in foreign lands. Another section of the work should be devoted to a study of the population at large; the schools, the factories, and the prisons must all be investigated, so that the present wasteful organisation of society may be remedied. When its value to the State has been proved, anthropology can ask for adequate support as its right. The third point urged is the adoption of a new technique. Logical accuracy and mathematical exactness must be introduced; training should start with anthropometry in its broadest sense, advancing later to ethnology, sociology, prehistory, and the evolution of man. Only by devotion to problems of real use can anthropology achieve her true position as "Queen of the Sciences."

Physiology.

Mr. Joseph Barcroft in his presidential address to Section I deals particularly with anoxæmia—by derivation a deficient quantity of oxygen in the blood—which is used to cover a larger field embracing all those conditions in which the supply of oxygen to the tissues is inadequate. The statement has been made that anoxæmia not only stops, but also wrecks, the machine. An inquiry into this statement cannot be made without first specifying whether the anoxæmia is sudden and profound, as in drowning, poisoning with mine-gas, etc., or is of long duration but trivial in degree. In the former case the stoppage of the machine may be almost complete, as in the case of persons rendered unconscious by carbon monoxide, by stoppage of the cerebral circulation, or by attaining an altitude in the air at which the oxygen pressure is too low. In such cases the permanent damage to the machinery is very slight. On the other hand, mild anoxæmia continued over weeks and months, as in sufferers from gas-poisoning, shallow respiration, and deficient ventilation of portions of the lung, is stated by Haldane, Meakins, and Priestley to produce far-reaching effects on the central nervous system. Anoxæmia may be classified as consisting of three categories. They are tabulated as follows, with examples:

ANOXÆMIA.

Types	I. Anoxic	II. Anæmic	III. Stagnant
Characteristics	Too little oxygen pressure and too much reduced hæmoglobin in arterial blood, which is too dark in colour	Too little oxyhæmoglobin, but normal oxygen pressure in arterial blood, which is bright unless discoloured by some abnormal pigment	Arterial blood normal in oxygenation, but blood-flow too slow
Examples	Mountain sickness, pneumonia, etc.	Anæmia CO poisoning Methæmoglobin poisoning	Shock Back pressure

For a given deficiency of oxygen carried to the tissue in unit time the first type is the most serious, and the last least so. The anoxic type is measured by the percentage saturation of the arterial blood; the anæmic by the quantity of oxyhæmoglobin in it; and the stagnant by the "minute volume."

Botany.

Miss E. R. Saunders in her presidential address to Section K deals with the subject of Heredity. In the brief historical introduction attention is directed to the fundamental opposition between the earlier statistical methods of representing the hereditary process and the Mendelian conception which has its foundation in the act of sexual reproduction. Various complex relations which have proved capable of elucidation through the application of Mendelian principles are illustrated, and evidence is adduced in proof of the applicability of these principles to the case of specific hybrids. Certain cases are described where the unit for which the Mendelian factor stands appears to be a particular state of physiological equilibrium, and where lack of conformity of phenotypic appearance to genotypic constitution can be readily induced by a change in environmental conditions. The assumptions and difficulties involved in the explanations offered by the reduplication theory and the chromosome view respectively are discussed, together with the bearing of the evidence to date upon the question whether the same end-result, viz. segregation, may not be effected by a different mechanism, or at a different phase of the life-cycle, in different types. As a practical outcome greater co-operation is pleaded for between cytologists, physiologists, chemists, and breeders in attacking genetical problems.

Educational Science.

Sir Robert Blair in his presidential address to Section L directs attention to two of the wider aspects of present educational activities. The first part of the address is devoted to a general statement of the lines of advance and the success obtained in the application of psychology to the problems of education. The president, however, desires that education should become something more than applied psychology. The science of education "must be built up, not out of the speculations of theorists or from the deductions of psychologists, but by direct, definite, *ad hoc* inquiries concentrated upon the problems of the class-room by teachers themselves. When by their own researches teachers have demonstrated that their art is, in fact, a science, then, and not till then, will the public allow them the moral, social, and economic status which it accords to other professions." The second part of the address consists of an appeal to all voluntary effort to associate itself directly with the work of the local education authority. Sir Robert Blair thinks that our system of education will become national only when such national institutions as the public schools, the endowed grammar schools, and the universities have joined forces with the local education authorities and take a direct share in the solution of their problems. He seeks a form of association which will retain all the advantages of the older traditions.

Agriculture.

Prof. F. W. Keeble's presidential address to Section M is devoted to the subject of intensive cultivation. Commencing with a review of the work done by horticulturists during the war, it passes on to consider the prospects of success of any large development of intensive cultivation which may be undertaken. It insists on the great need for organisation in research, education, and administration, and describes the organisation which the author established during his tenure of the office of Controller of Horticulture in the Ministry of Agriculture. In this connection the important question of the relation of the "expert" and the "administrator" is considered, and the conclusion reached that "if the work of a Government office is to be and remain purely administrative, no creative capacity is required, and it may be left to the sure and safe and able hands of the trained administrator; but if the work is to be creative it must be under the direction of minds turned, as only research can turn them, in the direction of creativeness." The consideration of our imports, of the reduced acreage under fruit, and of the continuous rise in the standard of living throughout the world suggests that the acreage under fruit might be increased by a good many thousand acres without fear of over-production. After illustrating by a series of striking examples the effect which the practice of intensive cultivation has on bringing about the colonisation of the countryside, the address reaches the conclusion that it is the duty of the State to help the intensive cultivator to hold his own against world-competition by perfecting the organisation of horticulture, and, above all, by providing a thorough and practical system of horticultural education. The measure of success which intensive cultivation will achieve will depend ultimately on the quality and kind of education which the cultivators are able to obtain.

PRINTED IN GREAT BRITAIN BY R. CLAY AND SONS, LTD., BRUNSWICK STREET, STAMFORD STREET, S.E. I, AND BUNGAY, SUFFOLK.

(*Continued from p.* 812.)

is to be taken as the normal weight of the animal, if we are to determine its surface from its weight? This fundamental question has hitherto defied solution, but is now brought into the realms of exact science, since the work of Prof. Dreyer and Dr. Ainley Walker (2 and 7) has shown that in animals and man definite relationships exist between the trunk length, chest circumference, and body weight of individuals in health, while no accurate relationship, as has long been realised by those familiar with the subject, can be traced between standing height and body weight.

The value of these measurements is enhanced by the fact that, as anatomical data, they will be practically immune from change in diseases which may be accompanied by a loss of weight, and, further, that as they bear a constant relation to the body weight, so must they bear a constant relation to the surface area of that animal.

The relationships which have definitely been shown to exist between "vital capacity," body weight, trunk length, and the circumference of the chest can be expressed by the following formulæ (8):—

(i) $\frac{W^n}{V.C.}=K_1$, where the power n is approximately $\frac{2}{3}$, though more accurately 0·72;

(ii) $\frac{\lambda^n}{V.C.}=K_2$, where the power n is approximately 2, though more accurately in males 2·26, in females 2·3;

(iii) $\frac{Ch^n}{V.C.}=K_3$, where the power n is approximately 2, though more accurately in males 1·97, in females 2·54;

while the relationships between body weight, trunk length, and circumference of the chest, respectively, can be expressed as follows:—

(iv) $\frac{W^n}{\lambda}=K_4$, where the power n is approximately $\frac{1}{3}$, though more accurately in males 0·319, in females 0·313;

(v) $\frac{W^n}{Ch}=K_5$, where the power n is approximately $\frac{1}{3}$, though more accurately in males 0·365, in females 0·284.

In all the above formulæ W = net body weight in grams, λ = trunk length in centimetres, Ch = circumference of the chest in centimetres, and V.C. = vital capacity in cubic centimetres.

The procedures for taking the above-mentioned measurements, briefly described, are as follows:—

(i) Body weight = net weight, without clothes, in grams.

(ii) Trunk length in centimetres is taken by making the subject sit on a level floor with the knees flexed, the os sacrum, spine, and occiput being in contact with an upright measuring standard.

(iii) Circumference of the chest is taken at the nipple level in males, and just under the breasts in females, the subject being encouraged to talk and breathe naturally while the measurement is being taken.

(iv) The "vital capacity" in cubic centimetres is obtained by taking five consecutive readings with a suitable spirometer. The subject is instructed patiently and carefully how to proceed, and encouraged to make the maximum effort, the highest reading of the five measurements being recorded as the "vital capacity."

The relationships established by Prof. Dreyer, by the examination of individuals in perfect health, provide standards with which an individual or groups of individuals can be compared as regards two fundamental attributes, namely, "physique" and "physical fitness." These two attributes have hitherto been subject to the widest possible individual interpretation, and even in the judgment of one individual are liable to undergo monthly, if not diurnal, variations, dependent upon humour and an infinity of changeable circumstances in observer and observed.

Applying the standards determined for individuals in perfect health, it is found, as might have been expected, that different persons exhibit considerable deviations from these standards, particularly in respect to their "vital capacity," dependent upon their occupation and mode of life. Thus persons living a healthy outdoor life exhibit a greater "vital capacity" than persons following a sedentary occupation, and when this deficiency is *not* due to fundamental bodily defects it can be remedied by properly regulated training and outdoor life.

Critical examination of the available data has enabled Prof. Dreyer to grade the community, for all practical purposes, into three classes, A, B, and C, representing conditions of perfect, medium, and poor physical fitness. A classification on such lines is essential when any degree of accuracy is required in the determination of the aberrations from normal met with in disease. It would obviously be unjustifiable in disease (9) to apply A class standards to the individual who, by reason of his occupation and mode of life, belongs in normal health to C class. The consideration of this aspect of the question, however, need not detain us longer, as being outside the scope of the present article.

It is extremely difficult in so brief an account to do full justice to the immense significance and the great possibilities which lie behind this recent work of Prof. Dreyer's, but sufficient, it is hoped, has been said to show that by systematic measurement of "vital capacity" and the body measures herein discussed, in adults and adolescents, it should be possible to ascertain what detrimental or beneficial effects environment and occupation exert upon the development and health of the individual. Further, it is clear that most important information, from the point of view of national health, should become available in connection with the methods employed to ameliorate the conditions of those who show deficiencies from the standards obtaining in conditions of perfect health.

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The British Association at Cardiff.

THE eighty-eighth annual meeting of the British Association opened at Cardiff on Tuesday morning, in the very unfortunate circumstances of a general strike of tramwaymen and some other sections of the city workmen. It is to be feared that as, unfortunately, paragraphs about this found their way into the Sunday newspapers, this local trouble has had the effect of diminishing the attendance at the meeting. Members and intending members might have rested assured that the city of Cardiff would rise to the occasion. The local secretaries immediately arranged a British Association motor service for the use of members, but it appears that no inconvenience was felt by those who are attending the meeting, and most of the services have now been withdrawn.

It is not possible at the moment of writing to give exact figures of the membership, but it exceeded 1200 on Tuesday morning, so that a fair average meeting was even then certain, in spite of the strike. The weather, always inclined to be wet in this part of the country, and particularly atrocious during the present summer, has taken a turn for the better, and the visitors have had the opportunity of seeing the sun in Cardiff, when the residents had almost forgotten its existence.

The citizens' lecture on "Light and Life," by Prof. J. Lloyd Williams, of University College, Aberystwyth, in the Park Hall, on Monday evening, attracted a large audience, notwithstanding that many of those present had to face a long walk home.

At the inaugural general meeting on Tuesday evening, when Prof. Herdman delivered the illuminating address published in full elsewhere in this issue, the retiring president, Sir Charles Parsons, read a message which the council had sent to the King offering, at this meeting in Wales, the grateful congratulations of the Association for the inspiring work done for the Empire by the Prince of Wales during his Australasian tour. Sir Charles Parsons read also messages of condolence sent to relatives of Prof. J. Perry and Sir Norman Lockyer at the loss sustained by the recent deaths of these two distinguished representatives of British science—one of whom was general treasurer of the Association from 1904 until his death, while the other was president in 1903–4.

At the meeting of the general committee on Tuesday, the report of the council was adopted nominating Sir Edward Thorpe as president of the Association for the meeting next year in Edinburgh, and Sir Charles Parsons as a permanent trustee, in succession to the late Lord Rayleigh.

The whole of the presidential addresses are this year published in volume form under the title "The Advancement of Science, 1920," at the price of 6*s*., or 4*s*. 6*d*. to members at the meeting. The volume makes a valuable record of the progress and position of many departments of science, and of authoritative conclusions concerning them.

Whilst the meeting is not likely to rank as a "record," the members present are very keen, and everything possible to ensure its success is being done by the city authorities and local Press.

The palatial apartments of the City Hall are being used for the reception room and other offices, whilst in the University College and Technical College near by all the sections are provided with excellent accommodation. The Park Hall, in which the president's address, the evening discourses, and the citizens' lectures are delivered, has a seating capacity of well above 2000, and everyone present has an uninterrupted view and hearing.

The numerous sectional and the two general excursions have not been interfered with by the strike, as they rely chiefly on road or railway transport.

R. V. S.

Sir Norman Lockyer's Contributions to Astrophysics.

By PROF. A. FOWLER, F.R.S.

BY the death of Sir Norman Lockyer the science of astrophysics has lost the energising and stimulating influence of the last of the great pioneers whose labours opened the way to so vast an extension of our knowledge of the universe. The science of celestial chemistry and physics had its real beginning in 1859, when Kirchhoff's famous experiment on the reversal of spectral lines furnished the key to the interpretation of the dark lines of the solar spectrum, and thence to the determination of the composition of the sun and stars. During the earlier years the outstanding features in the development of the new science were the brilliant investigations of Huggins on the spectra of stars and nebulæ, and those of Rutherfurd and Secchi on the spectroscopic classification of the stars. Curiously enough, the sun had received but little attention during this period, and Lockyer was practically entering a virgin field when, in 1866, he attached a small spectroscope to the modest 6-in. equatorial of his private observatory, and observed the spectrum of a sun-spot independently of the rest of the solar surface. Simple as it may now seem, this process of "taking the sun to bits," as Sir Norman used to call it, was an advance of fundamental importance. It not only gave an immediate and decisive answer to the question as to the cause of the darkness of sun-spots which was then under vigorous discussion in England and France, but also very soon led to the famous discovery of the method of observing solar prominences without an eclipse, with which Lockyer's name, in conjunction with that of Janssen, will for ever be associated. The story of this epoch-making observation has been told too often to need repetition, but it should not be forgotten that the principle of the method had been clearly recognised by Lockyer two years before he succeeded in obtaining a spectroscope suitable for the purpose in view.

Those who have become familiar with the beautiful solar phenomena presented by this method of observation will best understand the enthusiasm and delight with which Lockyer continued his observations whenever the sun was visible. On the first day of observation—October 20, 1868—he had identified the C and F lines of hydrogen, and a yellow line near D, in the spectra of the prominences, and on November 5 he discovered that the prominences were but local upheavals of an envelope entirely surrounding the photosphere, to which he gave the name of the *chromosphere,* as being the region in which most of the variously coloured effects are seen during total eclipses of the sun. The peculiarities of the bright F line at once suggested to his fertile mind that the spectroscope might disclose the physical state, as well as the chemical composition of the chromosphere and prominences, through the medium of laboratory experiments, and from this beginning the close association of the laboratory with the observatory became the dominant note in his life's work. His first experiments were made in collaboration with his friend Frankland, and it was shown that the widening of the F line at the base of the chromosphere was to be accounted for by an increase of pressure. These experiments further demonstrated that the yellow line of the chromosphere, which had been named D_3, was quite distinct from hydrogen, and the then unknown gas to which it was to be attributed was given the now well-known name of *helium.* Up to the year 1873, however, Lockyer's work was carried on almost entirely in his private observatory, and in the laboratory which he had established in his house at Hampstead. He not only continued his solar observations with conspicuous success, but also commenced his well-known "Researches on Spectrum Analysis in Connection with the Spectrum of the Sun," in which he developed experimental methods which afterwards became common practice.

On his transfer to South Kensington, with which his connection continued for forty years, the facilities at Lockyer's disposal for research were at first very meagre, but additions to equipment and staff were made from time to time, and in the later years the observatories and laboratories were well adapted for their special purposes. Lockyer's dream of becoming director of a permanent astrophysical observatory, comparable with those established by Governments in other countries, however, was never realised, and his work throughout was carried on in temporary buildings, and for the greater part of the time with modest grants in aid from year to year. In 1912, on the transfer of the Solar Physics Observatory to the control of the University of Cambridge, Lockyer, in spite of his weight of years, courageously set about the erection of a new observatory at Sidmouth, and continued his work on stellar spectra almost to the close of his life. It is a lamentable fact that much of his time and energy was almost continually taken up with a struggle to obtain adequate means to carry on his researches.

The contributions to astrophysics made by Lockyer during nearly sixty years of strenuous endeavour in its various fields of investigation form the subject-matter of more than 200 papers and memoirs, and it is only possible here to refer to some of the larger questions in which he was specially interested. His work, both in the laboratory and in the observatory, was largely guided by bold speculations, which he was usually careful to regard as working hypotheses, and from time to time the main points were brought together in appropriate sequence in the form of books, among which are "The Chemistry of the Sun" (1887), "The Meteoritic Hypothesis" (1890), and "Inorganic Evolution" (1900). His observations and his views on their significance were thus made widely known, and the trend of his work could be the more readily followed. It was especially his desire to impress upon chemists and physicists the importance of the sun and stars as a means of investigating the behaviour of matter at high temperatures, and as possibly throwing light upon the nature of atoms and molecules.

Among the researches which have had the most potent influence, and have led to very definite advances, were those which dealt with the changes in the spectrum of the same element under different conditions of experiment. Lockyer was early led by his solar observations to a comparative study of the flame, arc, and spark spectra of some of the metallic elements, and one of his first successes was to show that some of the lines most characteristic of solar prominences, other than those of hydrogen and helium, were produced only under high temperature conditions, while some of those prominently affected in sun-spots were produced at a low temperature. With these and other observations as a basis he put forward, in 1873, his well-known dissociation hypothesis, which became the subject of much discussion. The hypothesis supposed that at successively higher temperatures the "molecular groupings" which existed at lower stages were broken up into finer forms of matter, or possibly into new elements, producing different spectral lines, and on this view it was shown that a multitude of solar observations which had seemed to be wholly inexplicable on the ground of previous laboratory experience became easy of explanation. Thus his view of the construction of the solar atmosphere was that if we could observe a section of it we should see it divided into a number of layers, each with its appropriate spectrum, and the spectrum would be simpler the nearer the layer was to the photosphere. The metallic elements, instead of existing as such in a reversing layer, were considered to be entirely broken up in the vicinity of the photosphere, and their germs distributed throughout the atmosphere, the molecular groupings becoming more complex as they became further removed from the source of heat. The theory doubtless calls for some re-statement in the light of modern views as to the structure of atoms and the origin of spectra, but it was a valuable guide to observation, and Lockyer anticipated the conclusion reached by St. John in recent years, that the complete absorption of any one element in the solar spectrum is the integration of lines special to various levels in the solar atmosphere. Lockyer himself seems to have been convinced that the ultimate products of dissociation were hydrogen and helium; but although this is so closely in accord with recent work on the structure of atomic nuclei, it does not seem probable that the phenomena studied by Lockyer were directly related to those investigated by Rutherford. The writer well remembers numerous attempts to produce the lines of hydrogen or of helium by the passage of powerful condensed discharges between metallic electrodes, all of which, however, were unsuccessful.

Work on the varying spectra of the elements was vigorously resumed by Lockyer in connection with the interpretation of the photographs of the chromospheric spectrum which had been taken under his direction during the solar eclipses of 1893 and 1896, and of a series of photographs of stellar spectra which he had commenced at Kensington about 1890. Several elements were investigated over a long range of spectrum, and numerous additional lines were found to be intensified on passing from the arc to the spark spectrum, or which only appeared in the spark. These were designated "enhanced lines," and the work at once led to the definite assignment of origins to many chromospheric and stellar lines which had previously resisted explanation. But this was not all; the enhanced lines were shown to belong to a special class which were only fully developed at high temperatures, so that they gave valuable evidence of physical conditions in the atmospheres of the sun and stars as well as of their chemical constitutions. It would scarcely be too much to claim that this further work on enhanced lines introduced a new principle into astronomical spectroscopy, inasmuch as it justified the chemical identification of celestial spectra which could not be completely reproduced in the laboratory. The only assumption it was necessary to make was that the series of changes indicated in the flame, arc, and spark would be continued if still more powerful means of excitation were available, so that at sufficiently high temperatures the enhanced lines would be the sole survivors. In accordance with his views on dissociation, and for convenience of reference, the enhanced lines were designated "proto-metallic" lines, and attributed to "proto-metals," which were regarded as simplified forms of the vapours which yielded the arc lines.

Apart from any special views as to the cause of their appearance, however, the discovery of enhanced lines has proved to be of the first importance in astrophysical inquiries, and the tables of such lines which were compiled at South Kensington have been much utilised by astronomers throughout the world. Among other applications, as Lockyer was the first to show, the interpretation of the spectra of new stars in their early stages is almost entirely dependent upon a knowledge of the enhanced lines of iron, titanium, and other elements. In collaboration with his assistants, Lockyer showed later that enhanced lines were also developed under the action of strong electrical discharges in non-metallic elements, including silicon, carbon, sulphur, and nitrogen, and the lines observed in these experiments have also led to important celestial identifications. There can be little doubt that the continuation of these investigations, as in Fowler's experiments on helium and oxygen, and Merton's further work on carbon, will yield results of high value in the interpretation of the spectra of stars at the highest stages of temperature, and possibly also of the nebulæ.

Another of the chief subjects which attracted Lockyer during a great part of his life was the classification of stellar spectra, and the order of celestial evolution which might be inferred. He was at first mainly dependent upon stellar observations made by others, but he soon saw the necessity for first-hand data, and, following Pickering's remarkable success with the objective prism, he adopted this form of instrument in most of his work at Kensington, and afterwards at Sidmouth. He early adopted the suggestion made by Tait that in nebulæ and comets the luminosity may be due to solids heated by impact, as well as to heated gas generated by the impacts, and about 1887 developed it into his "meteoritic hypothesis." The fundamental idea is that all self-luminous celestial bodies are composed either of swarms of meteorites, or of masses of meteoritic vapour produced by heat, the heat being developed by condensation due to gravity, and the vapour being finally condensed into a solid globe. The classification of stellar spectra which he based upon this theory has undergone modifications in detail, chiefly in the direction of subdivision and more complete definition of the criteria for the various stellar groups; but the essential idea has remained unchanged throughout. In common with other astronomers, Lockyer adopted the view that the spectroscopic differences between the various classes of stars are mainly due to differences of temperature, but, unlike most of them, he insisted that in place of a single line of evolution from hot (white) to cool (red) stars the progression must be from cool to hot stars and back again to cool stars. That is, in accordance with the theory of condensing swarms of meteorites or masses of gas, the classification made a distinction between stars of increasing temperature and those which are on the down-grade towards the extinction of luminosity.

Some of the earlier evidence for the separation of the stars on the two branches of the "temperature curve" which Lockyer pictured may be of doubtful validity, but the valuable photographic data accumulated later, in combination with laboratory researches, placed his classification on a much firmer basis. It was found, for example, that when stars at any given stage of temperature were brought together by reference to the relative intensities of enhanced and arc lines, they were definitely divisible into two groups, showing that the spectra were dependent in part upon physical conditions other than those imposed by temperature alone. This difference was attributed to differences in the state of condensation, one group being less condensed than the other, and therefore to be considered as being in an earlier stage of evolution, notwithstanding equality of temperature. The Harvard classification, which has been adopted by most astronomers, is along one line of temperature only, and accordingly disregards this difference. It is clearly of great importance, however, that the difference should be taken into account in questions relating to stellar distribution and other matters connected with the structure of the sidereal universe, and it was a source of profound regret to Lockyer that greater attention was not given to it. In the case of the helium stars, however, Lockyer's classification has received substantial corroboration from a discussion by Herassimovitch of their radial velocities and absolute magnitudes, in which the catalogues of Lockyer were utilised. Among the results it was shown that the stars which Lockyer had located on the ascending branch of the temperature curve were brighter than those on the descending branch, and, assuming the average masses to be equal, it would follow that the former were of greater volume and lower density than the latter, in accordance with Lockyer's hypothesis.

The theory of stellar evolution put forward a few years ago by Prof. H. N. Russell resembles that of Lockyer in its main outlines, though based mainly on deductions as to the densities and absolute magnitudes of the stars. The criteria are thus somewhat different in the two cases, but there can be little doubt that in one form or other the recognition of an ascending, as well as of a descending, line of stellar temperatures will take an important place in the astronomy of the future.

The observation of total eclipses of the sun also occupied much of Lockyer's attention. He personally took part in nine eclipse expeditions, and was responsible for several others in which the observations were undertaken by his assistants. On several occasions, when H.M. ships were detailed to assist the expeditions, his exceptional organising ability enabled him effectively to utilise the services of officers and men so as to cover the widest possible range of observations. The outstanding feature of his work in this connection, however, was the introduction and use, first of a visual spectroscope without slit or collimator, and afterwards, when photographic methods could be adopted, of the prismatic camera. With instruments of this type he was able clearly to differentiate between the coronal and chromospheric radiations, and, besides detecting several new coronal lines, he obtained splendid records of the "flash" spectrum. He was thus able to determine the various heights to which the different vapours extended, and he identified a multitude of the bright lines with enhanced lines which he had so diligently investigated in the laboratory.

Lockyer would have been the last to claim that his work was wholly free from errors, but it was almost invariably of a stimulating character, and has played a leading part in the development of the science of astrophysics practically from its very beginning. Much of his work will have an enduring place in the history of the science to which he devoted his great gifts.

Notes.

THE triennial prize competition for the best original contribution to the scientific advance or the technical progress of electricity, known as the Fondation George Montefiore Prize, and administered by a committee of the Association of Electrical Engineers from the Montefiore Technical Institute of Liége, which had lapsed during the war, is now to be revived, and the competition which would have been held in 1917 is now announced for 1921. The prize will amount to 20,000 francs. Competitors must send in their work by April 30, 1921, and all particulars can be obtained from the Secretary, Fondation George Montefiore, rue Saint-Gilles 31, Liége, Belgium. Contributions may be in English or French, and if successful are published in French in the *Bulletin de l'Association des Ingénieurs Electriciens sortis de l'Institut Technique Montefiore.*

NELA RESEARCH LABORATORY was organised in 1908 under the directorship of Dr. Edward P. Hyde as the physical laboratory of the National Electric Lamp Association. The name was changed to Nela Research Laboratory in 1913, when the National Electric Lamp Association became the National Lamp Works of the General Electric Co. For some years the laboratory was devoted exclusively to the development of those sciences on which the art of lighting has its foundation, but in 1914 the functions of the laboratory were extended by the addition of a small section of applied science which had an immediate practical objective. The section of applied science is now being largely extended as a separate laboratory of applied science under the immediate direction of Mr. M. Luckiesh, who becomes director of applied science, and a new building is being constructed to house this branch of the work. Dr. Ernest Fox Nichols, formerly president of Dartmouth College, and more recently professor of physics at Yale University, has accepted an invitation to assume the immediate direction of the laboratory of pure science under the title of director of pure science. The work of this laboratory, which will be continued in the present building, will be somewhat further extended under the new organisation. The laboratory of pure science and the laboratory of applied science will together constitute the Nela Research Laboratories, and will be co-ordinated under the general direction of Dr. Hyde, who becomes director of research.

THE Public Health Department of the Portsmouth Town Council, having evidently investigated thoroughly the scientific evidence submitted to it on the practicability of preventing the infection of venereal disease by the use of a disinfectant immediately after exposure to risk, has recently issued two descriptive leaflets giving the information necessary to carry out the disinfectant process effectually. We understand that about a dozen other Health Departments are taking, or about to take, similar measures. The leaflets, entitled "What Every Man should Know," embody in clear words the ascertained knowledge on this matter which has been acquired by observation and experiment, and contain a succinct and useful summing-up of the multiform evils of venereal disease. The council states that it has come to the conclusion that, in view of the terrible effects of this disease on national and family life, it is its bounden duty to make public a knowledge of the means by which this scourge can be prevented. These leaflets pay due regard to both the social and scientific aspects of the much-discussed subject of prompt self-disinfection after incurring the risk of infection. The Portsmouth Public Health Department deserves to be congratulated on its action in this seriously important matter of sanitation.

"EPIDEMIC stupors" are often referred to in early records (seventeenth and eighteenth centuries) as occurring in times of influenza prevalence, and in this country encephalitis lethargica made its appearance immediately before and during the influenza epidemic of 1918–19. It is of interest, therefore, to record the occurrence of the same disease in Karachi at the end of 1919 during an epidemic of influenza. A full description of the outbreak, consisting of seventeen cases, is given by Capts. Malone and Maitra in the *Indian Journal of Medical Research* (vol. vii., No. 3).

IN the Journal of the Royal Society of Arts (vol. lxviii., No. 3533, August, 1920) we have a report of the Sir George Birdwood memorial lecture on "The Enduring Power of Hinduism" by Sir Valentine Chirol. Sir Valentine admits that he writes "not as a student, but merely as a layman." He has, however, been a diligent student, and his wide knowledge of contemporary politics and his experience of personal visits to many of the most important sites where archæological investigation is being conducted by Sir John Marshall have enabled him to construct a graphic picture of the historical development of India in relation to Hinduism. This lecture is thus of considerable importance, and it is rendered more attractive by the picturesqueness of the author's style. He has not followed so completely the trend of modern studies as to grasp the fact that the survival of Hinduism, in spite of the rise of Buddhism and the cataclysm of the Mohammedan invasion, is due to its amorphous character, its eclectism, and its capacity for adapting itself to novel conditions. But with these reservations the lecture gives an admirable account of the development of Hinduism.

THE character of the prehistoric culture of the people of the Malay Peninsula has as yet received inadequate attention, but much good work is being done in continuation of that summarised in "The Pagan Races" by Messrs. Skeat and Blagden. Thus we find in the Journal of the Federated Malay States Museum (vol. ix., part 1, January, 1920) an excellent account by Mr. I. H. N. Evans of the exploration of a rock shelter in the Batu Kurau Parish, Perak, with a description of the flint-weapon industry. In more recent times the influence of Islam has been predominant, but it has absorbed and assimilated much of the indigenous animistic beliefs. In this connection, in the same issue of the journal, Mr. R. O. Winstedt refers to some curious analogies between the local customs and those of the Brahmans of South

India, which point to the widespread influence of Hinduism in the peninsula prior to the establishment of Islam as the dominant faith.

MR. HENRY BALFOUR has reprinted his interesting presidential address from the Proceedings of the Somersetshire Archæological and Natural History Society (vol. lxv., 1919, pp. xxiii *sqq.*). He claims connection with Somersetshire on the ground that his late colleague, Sir E. B. Tylor, was a Somersetshire man by birth, and that Mr. H. St. G. Gray, now curator of the Taunton Museum, was his own assistant at Oxford. In his address Mr. Balfour crosses the county border to Rushmore and Cranborne Chase, on the border of Wilts and Dorset, the home of a great archæologist and ethnologist, Col. Pitt Rivers. He closes his review of this notable man with the remark that "he has left his own record of diligent and broad-minded research, and the example afforded by his enthusiasm, characteristically tempered with caution, should have the effect both of stimulating and of restraining the work not only of this generation, but of generations to come."

THE Quarterly Summary for July issued by the Royal Botanic Society of London contains notes on some plants of interest in the gardens. The gigantic floating leaves of the *Victoria regia* water-lily are now 7 ft. in diameter, and, as each new leaf at this time of year exceeds its predecessor, it seems likely that they will reach the maximum of 8½ ft. by the end of August. As the sunlight becomes less the new leaves get smaller, until the plant dies down in October. One of the earliest accounts of this remarkable tropical American water-lily was that given by Lindley in the Proceedings of the society in 1839 (vol. i.). The plant was discovered by Robert Schomburgk, the traveller, on the River Bernice, in Guiana, and the detailed description which he sent home was sufficient to enable Lindley to recognise it as a distinct genus of water-lilies, which was, by permission, dedicated to the young Queen. Efforts to grow the plant at Kew were at first unsuccessful, but in 1849 some fifty plants were successfully raised from seed and distributed to various gardens. The fine specimen growing at Kew is one of the most popular attractions of the Royal Gardens. Another interesting plant in the same tank at the Botanic Gardens is the Lotus, *Nelumbium speciosum*, which has flowered profusely this year. Its large salver-shaped leaves and tall pink flowers rising from the water present a striking appearance. The plant was held in esteem by many ancient peoples in the East; in Egypt paintings of it decorate the temples, and it is still associated with temples in India, where the long, fleshy roots are eaten as well as the oval, nut-like seeds. The society has also been making experimental growths of the soya bean, with the view of ascertaining the most suitable variety for cultivation in this country.

AMONG the recently issued reports of the Canadian Arctic Expedition, 1913–18, are two on the Crustacea, which form part of vol. vii. An account of the marine Copepoda is given by Prof. Arthur Willey (in Part K) and of the Cladocera by Dr. Chancey Juday (in Part H). Cladocera have been examined previously from Greenland and from Alaska, but not from the intervening region of Arctic America. Seven fresh-water and two marine species are recorded, all of which are well known and have a wide geographical range. The fresh-water species belong to the genera Daphnia (*pulex* and *longispina*), Bosmina, Eurycercus, Alona, Chydorus, and Polyphemus, and the marine species to Podon and Evadne respectively. The common *Daphnia pulex* is also recorded from Polaris Bay, Greenland, about 82° N. latitude, where it was collected by the United States North Polar Expedition on August 1, 1872. This seems to be the most northerly record for any of the Cladocera. The material of this species from Polaris Bay consists of several hundred specimens, the great majority being females with ephippia. The specimens of *Daphnia pulex* in the various catches of the Canadian Expedition show that the winter eggs in the ephippia probably hatch during the latter half of June; that females bearing parthenogenetic or summer eggs appear about the first week in July; and that males and ephippial females make their appearance in late July and in August. The season is therefore a relatively short one.

A NOTEWORTHY contribution to the study of that fascinating group of insects, the parasitic aculeate Hymenoptera, is made by Prof. W. M. Wheeler in the Proceedings of the American Philosophical Society (vol. lviii., 1919, No. 1). Prof. Wheeler gives a comprehensive summary of the subject, citing and criticising a long array of literature, and discussing the evolution of the parasitic habit. He is disposed to regard the aculeate parasites as originating directly or indirectly from the insects which serve as their hosts. "The object of the parasite is to secure the provisions accumulated by the host for its own progeny. This involves a destruction of the egg or young larva of the host." But a higher specialisation is reached by the social insects which foster the host-brood so that their own young may be reared and fed.

ANATOMICAL details of some morphological importance are elucidated by Prof. G. H. Carpenter and Mr. F. J. S. Pollard in a recent paper (Proc. R. Irish Acad., B, vol. xxxiv., No. 4) on the presence of lateral spiracles in the larvæ of warble-flies (Hypoderma). Six pairs of these vestigial structures, suggesting a primitive peripneustic condition of the respiratory system, are recognisable in the ripe warble-maggot, connected with the outer lateral tracheæ by fine, thread-like, solidified air-tubes.

DR. E. H. PASCOE, of the Geological Survey of India, revived at a meeting of the Geological Society of London in March, 1919, in a new form the question of the relations of the Indus, the Brahmaputra, and the Ganges (Quart. Journ. Geol. Soc., vol. lxxv., p. 138, 1920). He traces back the now divided system to a river, the Indobrahm, the head-waters of which were in, or soon cut back into, the Brahmaputra region of Assam, while the mouth was in the Indus region of the Arabian Sea. This river originated in the beginning of the Siwalik epoch, when the depression at the foot of the Himalayas ceased to be the scene of conflicting lagoon and terrestrial conditions, and became finally silted up. The great river was guided along this depression westward, while a contemporaneous river ran on the Tibetan side of the range, of which the alluvium remains from Pemakoi, north-east of the Bay of Bengal, to Gilgit, north of the great Indus bend. This river joined the Oxus, or reached the Arabian Sea by an independent course. It is urged that the Indobrahm captured the upper waters of the northern river by cutting back into them along its tributaries at successive points in the recesses of the range from which the Indus now runs south-westward. The speakers in the discussion of the paper, including Mr. R. D. Oldham, approved the main geographical contentions, but laid more stress than the author on earth-movements in determining the diversions and the courses of the tributaries through the hills.

SIMULTANEOUSLY with the investigations of Dr. Pascoe, Dr. G. E. Pilgrim, of the Geological Survey of India, put forward his suggestion of a great Pliocene river running on the south side of the Himalayas from Assam to the Indus course. Dr. Pilgrim's paper and maps (Journ. Asiatic Soc. of Bengal, vol. xv., p. 81, 1919) appeared, indeed, before the printing of Dr. Pascoe's work, and, as that author points out, the argument based on the direction from which the tributaries meet their primaries in the mountain-belt originated with Dr. Pilgrim. The two papers should be read together, and they form a great addition to our conceptions of the past geography of India. Dr. Pilgrim gives prominence to earth-movements as promoting the dislocation of the Assam-Punjab or Siwalik River. His maps of Western Asia in Eocene, Miocene, and Pliocene times are highly useful.

THE "Fossils from the Miura Peninsula and its Immediate North" form the subject of an important memoir by Prof. M. Yokoyama (Journ. Coll. Sci., Tokyo Imp. Univ., vol. xxxix., art. 6, pp. 193, 20 pls.). The geological formations of the peninsula are in part undoubtedly Pliocene, and in part either Pliocene or Pleistocene; those of the plain are divisible into an upper, sub-aerial, and a lower marine series several hundred feet in thickness. The sub-aerial series is made up of a brown loam, an altered volcanic ash, wholly devoid of stratification and organic remains. The marine series, which the author names the Musashino formation, is divisible into an upper and a lower series. In the upper, remains of *Elephas namadicus,* Falc. and Caut., are not uncommon, and are perhaps the most important of the fossil contents. The Lower Musashino beds are provisionally divided by the author into six zones. From the whole series, 232 species of Mollusca and 6 of Brachiopoda are recorded, 91 of the former and 2 of the latter being described as new; the whole are well illustrated, but the nomenclature, as, alas! too generally the case in papers of this class, lags behind the times. The number of forms not known to be living is 88, or about 37 per cent. of the whole fauna, and 7 species have not yet been found in Japanese waters. The author therefore classes these Musashino beds as Pliocene of about the same age as the English Red Crag of Newbourne=Austelien of the Netherlands.

THE *Geologische Reichsanstalt* of Vienna, which was able in Imperial times to spread the influence of a great school of geology over Polish, Transylvanian, and Dalmatian lands, has been forced to adopt, from the opening of 1920, the restricted title of *Geologische Staatsanstalt.* Dr. Emil Tietze, the director, retires after long and honourable service, recognising in the "geschickte Diplomatie des Königs Eduard von England" the prime cause of the restriction of his official field. The *Verhandlungen* for 1919 indicate many changes on the staff, some workers whose names are familiar having become aliens through territorial readjustments. We must hope that their common science will maintain the federal spirit shown in the last publications of the *Reichsanstalt.* Many of the papers deal with mountain structure. Dr. F. Heritsch claims that the discovery of tabulate corals in the supposed Mesozoic mantle of the Hohe Tauern disposes of the idea that the mass has been imported by overfolding, and we may be prepared for continued criticism in Austria of the theory of recumbent folds in general. Dr. O. Ampferer, who becomes one of the *Chefgeologen* and also a *Bergrat,* contributes a paper in his lucid and systematic manner on the very considerable influence that deep notches (*Kerben*) cut by erosion may have on tectonic features when a region comes under processes of crust-folding.

CHEMICAL as well as geological workers will welcome a new and enlarged edition of W. F. Hillebrand's "Analysis of Silicate and Carbonate Rocks" (Bull. 700, U.S. Geological Survey, 1919). The accurate methods described are obviously of service in the analysis of potassium silicates and refractories for commercial use, as well as in the refined discrimination of types of natural rock. The importance of the estimation of small quantities of unusual or commonly overlooked constituents is here pointed out. At the same time this may be quite unnecessary in many cases of ordinary practice, and for these a system of "condensed analysis" is charitably described in the concluding pages.

AN interesting example of the applications of zonal palæontology is afforded by Messrs. F. L. Kitchin and J. Pringle, who show (*Geol. Magazine,* vol. lvii., pp. 4, 52, and 100, 1920) that a mass of Gault and Cenomanian strata at Shenley, near Leighton Buzzard, 250 yards long and 150 yards wide, has been inverted on Lower Greensand. The fossils provide the clue, being in inverse succession to those in the undisturbed beds of the neighbourhood. As a boulder pushed by ice, this presents some parallel with the famous block described by Mr. R. G. Carruthers in the heart of Caithness (NATURE, vol. lxxxix., p. 229), in which a quarry has been opened 160 yards in length.

THE occurrence of barytes in the upper parts of lodes containing metallic sulphides is probably well recognised, and postulates an infiltration of barium chloride upwards during the formation of the lode or downwards to meet the sulphates that are in solution. Mr. H. W. Greenwood suggests (Proc. Liverpool Geol. Soc., vol. xii., part 4, p. 355, 1920) that the barytes which is common in the English Triassic strata, and mainly found in the upper beds, was derived from overlying Jurassic strata. The source of an exceptional quantity of barium in the Jurassic seas is not indicated. Might it not have been brought into the Triassic pan-deposits from the denudation of our Armorican lode-formations?

IN a general "Review of the Reptilian Fauna of the Karroo System" (Trans. Geol. Soc. S. Africa, vol. xxii., p. 13, 1920) Mr. S. H. Haughton concludes that the preservation of complete skeletons of Pareiasaurians in the beds south of Prince Albert Road station was determined by a rapid deposition of fine mud or silt. In the discussion on this paper (Proc. *ibid.*, p. xli.) Dr. van Hoepen supported, by his personal observations on the skeletons of various genera, the view of entombment in swampy lakes rather than, as Mr. Watson had suggested, in wind-borne sand. Dr. du Toit stated that he was unwilling to return to the old supposition of a general Karroo lake in Lower Beaufort times, but he pictured a surface "that became periodically inundated and, at certain stages, semi-arid in climate."

THE present summer has so far experienced some disturbing weather anomalies, the abnormal features being chiefly the persistent low temperatures and the frequent heavy rains. Some improvement has been generally experienced during the present month owing to the greater prevalence of anticyclonic conditions. A disturbance, however, traversed the north of Ireland and the southern portion of Scotland on the night of August 17 and the early part of August 18. The storm area followed a track fairly due east, and was preceded and accompanied by a heavy downpour of rain which occasioned considerable damage in Edinburgh and the surrounding neighbourhood. The rainfall at Edinburgh for the twenty-four hours to Wednesday morning was 3·1 in., and in twelve hours the fall amounted to 2 in. At Leith the fall in twenty-four hours was 2·84 in., and at Renfrew 2·80 in. A subsidiary disturbance occasioned heavy rain in the south of England, and at Falmouth the fall was 2·21 in. between 8 a.m. and 7 p.m. on August 18. Very cool northerly winds spread over the country in the rear of these disturbances. On the morning of August 20 frost occurred on the ground in the open in Scotland and in parts of England, whilst in places the thermometer in the screen fell to 36°. At Greenwich the exposed thermometer registered 33° and in the shade 41°, which was only 3° above the lowest figure reached in August since 1841, 38° being recorded in 1864, when the exposed thermometer fell to 27°. At Kew it was the coldest August night since 1891, and at Falmouth it was as cold as any time in August during the last half-century.

AMONG recent pamphlets issued officially by the Meteorological Office under the heading of Professional Notes is one by Mr. J. S. Dines entitled "Methods of Computation for Pilot-balloon Ascents." Without claiming to be exhaustive, this gives some account of, at any rate, the better-known methods of determining wind velocities at different heights. Part i. deals with the most practised single-theodolite ascents, and nine methods are described, including those in general use by the military Meteorological Services of France, Italy, and the United States, partly graphical and partly depending upon a special slide-rule. The ideal method for open-air work discards the graphical method so far as possible. Part ii., dealing with double-theodolite ascents, gives six methods of dealing with these, including, as does part i., the Meteorological Office method, which depends entirely on the slide-rule. Part iii., on balloon-tail, gives two graphical methods besides the Meteorological Office slide-rule plan. Perhaps more interesting than any of these is the appendix dealing with various methods of obtaining velocities at heights when cloud-sheets prevent the observation of pilot-balloons. The smoke from anti-aircraft shells set to explode at a given height can be observed through a comparatively small break in the cloud, and even when the cloud-sheet is quite unbroken the position of bomb-bursts can be determined by sound-ranging from the ground or by observation from an aeroplane.

IT was scarcely likely that proposals so far-reaching in effect and importance as those put forward by the Egyptian Ministry of Public Works for the extensive development of the cultivable area of the valley of the Nile by the construction of a dam and other irrigation works should escape a large measure of hostile criticism, and we have on several occasions alluded to the attacks made by Sir William Willcocks on the validity and trustworthiness of the data on which the scheme is founded. These attacks, it will be recalled, led to the appointment of a Special International Commission of Inquiry, which has had the projects under review. We have now received a copy of a brochure issued by an independent Commission of Native Egyptian Engineers, who take up an attitude of strong and uncompromising opposition to the official proposals on the grounds that there are obvious inconsistencies in the fundamental calculations, and an evident tendency on the part of the Technical Adviser to the Egyptian Government to "adapt" his data to the requirements of the case. The objectors state that they fear that any attempt to cut off or decrease the supply of water and silt to Egypt from the Blue Nile will be fraught with disastrous consequences, and they set out their arguments in a series of sixteen criticisms of the official scheme. An addendum by Dr. Mahgoub Sabitt, professor of medical jurisprudence and toxicology at the Egyptian University, advances reasons for considering the construction of the proposed dam likely to prove detrimental to public health. A protest is also entered against the alleged secrecy in which the proposals were prepared and formulated, and finally a call is made for a mixed committee of native and foreign engineers, "free from all bias," to investigate the matter thoroughly on account of its vital importance to the welfare of the whole country.

THE paper by W. L. Cheney on the measurement of hysteresis values when using high magnetising forces, which has just been published by the U.S. Bureau of Standards (Paper No. 383), will be of interest to all engaged in magnetic research. When employing ordinary methods it is extremely difficult to get the accurate values of the remanent induction and the coercive force owing to what has been called magnetic viscosity. This probably also slightly affects the author's results. His method is a modification of the isthmus method, and consists essentially of a du Bois electromagnet with flat pole-pieces separated by an air-gap and pierced coaxially so that a rod may be inserted. The magnetic force and the induction are measured by suitable coaxial test coils. Magnetic forces up to 2500 gausses were employed. Quenching eutectoid steel (0·85 per cent. carbon) in oil lowered the remanent induction, but considerably increased the coercive force. Experiments were made on the K.S. magnet steel prepared by Prof. Honda, and the high coercive force of 200 gausses was obtained when the specimen had been magnetised with 800 gausses.

AN uncommon piece of work is described in *Engineering* for August 13 in the form of a long wooden jib for a derrick crane designed and constructed for the Admiralty during the war by the Imber Court Engineering Works, Thames Ditton, Surrey. The crane, with a 50-ft. post, had to be capable of raising a 3-ton load up to a platform 100 ft. high. The jib was 135 ft. long from the centre of the bottom pin to the centre of the rope-wheel, and the wooden construction adopted resulted in a jib being produced of one-third the weight and having a higher factor of safety than steel would have given. Including the rope-wheel and end casings, the jib complete weighed only 2 tons 13 cwt. The jib was built up of four corner-posts, each post being made of nine laminations of Oregon pine glued together with waterproof glue. The jib was divided into panels by struts, also of Oregon pine, and each panel had diagonal bracing, both longitudinal and transverse; these bracings were composed of stranded piano-wire. The struts were fixed to the corner-posts by welded steel clamping boxes, to which the diagonal braces were also connected by means of bolts on which the wire was wound. The bolt-heads were formed with teeth, with which two spring pawls engaged, so that turning the bolt tightened the wires and slacking back was prevented by the pawls.

THE concluding volume—the sixth—of the Scientific Papers of the late Lord Rayleigh is to be published by the Cambridge University Press in the spring of next year. It will range over the period 1911–20. Among the other forthcoming publications of the Cambridge University Press is "The Spectrum of Nova Geminorum II.," by F. J. M. Stratton. It will constitute vol. iv., part i., of the Annals of the Solar Physics Observatory, and is promised for the end of the present year.

Our Astronomical Column.

DISCOVERY OF A NOVA IN CYGNUS.—Mr. W. F. Denning, of Bristol, writes that on the evening of August 20 he observed a star previously unknown to him in the northern region of Cygnus. He has made it a practice during the last few years of carefully searching for these objects while he has been watching for meteors. The object when discerned on August 20 was of about $3\frac{1}{2}$ magnitude, and its rough position was in R.A. 19h. 56m. and declination $53\frac{1}{2}°$ N. It formed a little triangle with the stars ψ and d (20) Cygni. On referring to star-charts, etc., Mr. Denning quite failed to identify the object in question, and therefore concluded it to be a new star.

The position of the nova in the Milky Way is in accordance with past experience, for nearly all past novæ have been in the Milky Way or on its borders.

Mr. Denning saw the present object again on August 21 in the openings between swiftly passing clouds, and it appeared of about the same brightness as on the previous night, but only hurried glimpses were obtainable.

On August 22 the brightness was estimated = 2·8 mag., and on August 23, 2·2 mag., so that its light is increasing.

PARALLAX OF THE B-TYPE STAR BOSS 1517.—Mr. J. Voûte recently announced a large parallax and proper motion for this star. Mr. A. J. Roy showed, however, that the true proper motion in R.A. was only one-tenth of Mr. Voûte's value, being $-0{\cdot}023''$; that in declination is $+0{\cdot}129''$. Mr. Voûte has recomputed the parallax with this value, and finds $0{\cdot}048''$, which is in good accord with Kapteyn's hypothetical value $0{\cdot}033''$.

The star is one of the nearest of the B stars, being at about the same distance as Achernar. Its chief interest lies in its surprisingly low absolute magnitude for a B-type star, its apparent visual magnitude being 5·9. According to Mr. R. E. Wilson, of the D. O. Mills Observatory, the radial velocity is +102 km./sec., or +83 corrected for the sun's motion. The position for 1910 is R.A. 6h. 0m. 59·436s., south decl. 32° 10′ 10·91″.

PUBLICATIONS OF THE ASTRONOMICAL LABORATORY AT GRONINGEN, No. 29.—This is a further instalment of Prof. J. C. Kapteyn's valuable researches on the stellar system. He summarises the large amount of new material that has become available since he first took up the subject, and shows that the time is appropriate for a fresh investigation of the secular parallaxes of stars of different magnitudes and spectral classes. The secular parallax is defined as the angle subtended at the star by the unforeshortened annual motion of the sun. Assuming its speed to be $19\frac{1}{2}$ km./sec., then annual parallax = sec. par. × 0·243. The following values are found for the variation of parallax with galactic latitude: From latitude 90° to 40°, parallax = 1·17 of mean; from 40° to 20°, 0·96 of mean; and from 20° to 0°, 0·87 of mean.

Many investigators have found discordant values of the declination of the solar apex as derived from stars of different magnitudes. Prof. Kapteyn is inclined to attribute this to imperfect elimination of magnitude equation in declination from the catalogues employed, since he makes the discordance very small.

Prof. Kapteyn emphasises the importance of separating stars of different spectral type in these investigations. In view of the great range of absolute magnitude according to type, he says that the grouping of all types is like making a single statistical investigation of the whole animal kingdom, from the elephant to the flea, instead of dividing them into species.

The following table gives the mean secular parallaxes for different magnitudes and spectral types, the former being visual on the Harvard scale:

Mag.	B stars	A stars	F stars	G stars	K stars	M stars
1·0	0″·138	0″·253	0″·591	0″·627	0″·362	0″·172
2·0	0·0921	0·170	0·392	0·422	0·241	0·116
3·0	0·0622	0·115	0·267	0·285	0·163	0·0786
4·0	0·0422	0·0780	0·182	0·192	0·110	0·0537
5·0	0·0285	0·0526	0·123	0·129	0·0749	0·0361
6·0	0·0192	0·0355	0·0827	0·0876	0·0506	0·0244
7·0	0·0130	0·0240	0·0560	0·0599	0·0342	0·0163
8·0	0·0087	0·0161	0·0379	0·0403	0·0231	0·0108
9·0	0·0059	0·0109	0·0254	0·0271	0·0156	0·0073

The small values near the end of the final column show that these distant M stars are giants nearly equivalent to the B stars in absolute magnitude. On the other hand, the M stars mentioned on page vii. as being 17½ magnitudes fainter than the B stars are dwarfs.

Universities, Research, and Brain Waste

THIS is the subject of a presidential address by Prof. J. C. Fields to the Royal Canadian Institute, Toronto, on November 8, 1919. It contains a review of the relations which must subsist between universities and research and between research and the progress of the world in civilisation, and it opens up so many aspects of these questions which are debatable that for that very reason it ought to be read extensively. Though, on the whole, Prof. Fields's views are consolatory to us in the Mother Country, they also show how much has yet to be done in England, as in other countries, to prevent or reduce the waste of potential brain power in the generations to come. Conditions are now greatly improved whereby the educational net is able to select out of the masses of population the individuals whose mental qualities deserve and, in the interest of the community, require due cultivation, but for the full benefit we must wait a generation or two.

It is premature to make comparisons between the different races and nations in respect to intellectual qualities, but it seems to be incontestable that the Germans have for generations been distinguished by their respect for learning and intellectual achievement, and this is illustrated by the way in which during the war their highly trained men were preserved from too much risk. The Allies, on the other hand, took no special care to protect and preserve such men as Moseley, who was allowed to sacrifice his life in Gallipoli. Such waste is, as Prof. Fields says, a tragedy of the first order. But there is similar waste going on every day in the neglect to give every boy of promise an open road to the university and the right kind of teaching when he gets there.

It is a question open to discussion whether the opportunity to do research lies only in a university career. The successive great discoverers at the Royal Institution in London, from Davy and Faraday onwards, and men like Joule, who was a brewer, and others unconnected with educational institutions, rise at once to mind. But it certainly is true that in the universities the example, the methods, and the spirit of research should be found associated with the teaching in every faculty and in every department.

Prof. Fields was severe on the constitution and government of the American universities, but while it appears to be true that most of the professors there are overworked and that the standard of attainment among the graduates is inferior to those of the universities of Europe, the work that has been done at Johns Hopkins, Baltimore, and Harvard Universities must not be forgotten. Probably the next generation on both sides of the Atlantic will profit by the interchange of visits by representatives of the higher educational institutions and by the opportunities for exchange of students, both graduate and undergraduate. It is probable also that there is still great ignorance, especially among the masses of the people in all countries, of the fact that the most potent factor in bringing the world out of barbarism to its present better condition of life has been *science*. "Is it not," Prof. Fields says, "of the first importance that every boy and girl should be made aware of this fact?" With that object in view modern history requires to be taught by teachers better qualified than in the past.

The Sun as a Weather Prophet.

SOME forty years ago Prof. Langley, while engaged on his early bolometric work on the sun, grasped the principle that, inasmuch as solar radiation is *the* governing factor in world meteorology, it should ultimately become possible to forecast weather changes, so soon as sufficient information had been obtained in regard to the mechanism of the radiation effect, by continuous observation of the intensity of radiation. Gradual improvement in instruments and methods has enabled his successors to state positively that the so-called "solar constant" is subject to variations of long and short period, and of late years determined attempts have been made, chiefly by the Smithsonian observers, to trace the meteorological changes that may fairly be attributed to these variations. It is clear that there are, from time to time, disturbing factors of apparently terrestrial origin—for instance, the eruption of Mount Katmai, in Alaska, in 1912, brought a promising summer to an abrupt and chilly close in mid-July; but it is becoming more and more probable that the Smithsonian investigation is on the right lines, and will give definite aid to forecasting, at any rate in tropical and sub-tropical regions.

Publication No. 2544 of the Smithsonian Miscellaneous Collections (vol. lxxi., No. 3) is devoted to a full statement of the case as regards Argentina, Chile, and Brazil in connection with regular observations of solar radiation at the new solar observatory at Calama, in Chile. Clear evidence is provided by the temperatures found at Buenos Aires that high values of solar radiation are followed by maximum values of temperature at an interval of nearly eleven days. The interval is not the same for lower maxima of radiation, and the amount of lag appears to be connected with the latitude of outbreaks on the sun, but more remains to be explained than the solar rotation will cover. The lag is also not the same for all stations considered. Twenty such were chosen in the countries mentioned, and differences are noted in the intensities as well as in the intervals, and also between the effect of longer and shorter waves. The observations do not cover every day, so that the correlation is probably not so good as it would be if complete data could be provided. The change due to a variation of 1 per cent. in the solar radiation appears to range between 0·2° C. and 0·8° C. in the tropics; in the temperate zones the effect, though less direct, is greater, even exceeding 2° C. at some stations.

Having thus obtained satisfactory evidence that, with the exception of the diurnal and annual variations due to the rotation and revolution of the earth, all weather changes are caused chiefly by variation of solar radiation, the next step was clearly to bring it into practice for forecasting. This has now been done for Central Argentina with promising results, but the ideal of daily measures of solar radiation is not yet attainable, because more stations are required. Even at Calama, which is nearly cloudless, good observations are not always possible on account of haze.

The concluding paragraph of the report states: "The ideal arrangement for this solar work would be to carry it on in co-operation with the Smithsonian Astrophysical Observatory. If the work at several widely separated observatories could be directed by one capable institution, so that the methods could be uniform and the results comparable, and then if it could be collected and weighted at the central office before cabling to the various weather surfaces of the world, probably a complete and reliable day-to-day record of the solar changes could be obtained which would be of the greatest value to practical meteorology. If the Smithsonian Institution is unable or unwilling to do this work, then it is hoped that observatories will be established by several countries and some direct method of exchange instituted." W. W. B.

Cotton Industry Research.

THE British Cotton Industry Research Association, which was incorporated in June, 1919, has just issued its first annual report. The association is comprised of 1408 individual members representative of all branches of the cotton industry, and its council includes not only members of the great firms engaged in the industry, but also those representing the various associations of operatives.

The association has appointed as its director of research Dr. A. W. Crossley, who took up his duties last Easter. A large mansion some five miles from the Manchester Exchange, standing in 13½ acres of ground, has been bought for the purposes of the association, to which it is proposed to add extensive buildings, for which it is intended to raise a special fund of 250,000*l.*, to accommodate the various departments of chemistry, physics, colloids, botany, and technology, and to appoint as heads of these departments highly qualified men of science. In order to bring to the notice of the members all available information of work done in the past, Dr. J. C. Withers, of London, has been appointed to direct the abstracting and indexing of scientific and technical matters in connection with the Records Bureau, and the council, in co-operation with the Textile Institute, has arranged for the publication of abstracts from English and foreign papers dealing with matters relevant to the textile industries. It is proposed to establish an extensive library of standard scientific works of reference and of scientific and technical journals. A scheme of education falls within the scope of the association, and already certain Oldham and other mills have arranged to provide scholarships in some branch of science for students who are desirous of becoming members of the staff of the association. The plan of research is intended to cover the qualities of the cotton cuticle and the influence thereon of different reagents employed in mercerisation, bleaching, etc.; the effect of reagents on the strength and elasticity of the fibre, yarn, and fabric; the character of the change due to mercerisation; the nature of tendering in the various types of fibre; the variation in the physical properties of sized yarn with change in the colloid properties of the material used; the action of the dyeing process, with critical regard to the established purity of materials; the nature of the dye solution, and the chemical change in the latter during the dyeing process; finally, the devising of methods for obtaining exact information as to the length of staple, the behaviour of fibres under stress and strain, the degree of variation in counts and in the diameter of yarn, relative twist, the degree of resistance of yarn to weaving friction, etc. Arrangements have been made for co-operation with the Empire Cotton-Growing Committee (Board of Trade), and in co-operation therewith the Research Association has made a grant of 250*l.* for 1919–20 to a student of botany at Oxford in aid of botanical research in the subject of cotton-growing. The joint committee has likewise arranged for two other students to take up like work in the ensuing session. The income of the association is derived from a call upon the members to the extent of about 9000*l.* and a Government grant from the Department of Scientific and Industrial Research of 7000*l.* The Department has shown the greatest interest and given all possible help in the furtherance of the objects of the British Cotton Industry Research Association.

Sugar Cultivation in India.

THE existing world-shortage of sugar lends special interest to all experimental work directed towards any advance in the quantity and quality of this essential crop. Sugar-growing and its improvement are attracting an increasing amount of attention in India, the area under sugar-cane having risen from 2,184,801 acres in 1909–10 to 2,808,204 acres in 1917–18, while in addition the date-palm and palmyra-palm occupied 184,412 acres in the latter period ("Agric. Statistics for India," 1917–18, vol. i.). More than half the sugar-cane is grown in the United Provinces, chiefly Agra, and the Punjab accounts for about one-fifth. Palm-sugar, on the other hand, is chiefly associated with Madras, Bengal, and Upper Burma, little being produced elsewhere. The output of sugar for 1918–19 was 2,337,000 tons (Report on Progress of Agriculture in India for 1918–19), but, as this was insufficient to meet home requirements, a large quantity had to be imported. Before the war India was able to produce a surplus of sugar for export, but as this can no longer be done the Government is investigating the possibility of reorganising and developing the sugar industry of the country, and a strong committee has been appointed to determine future policy in this direction. Dr. Barber, who has worked much on the problem, considers that a case has been made out for the foundation of an Imperial Sugar Bureau, of which the "whole duty will be to collect and collate the results obtained in various directions, and thus be in a position to assist the isolated efforts in different parts of the country with sound advice, based on experience gained by a general survey of the work done in India now and in the past and that accomplished in other countries" (Annual Report of the Board of Scientific Advice for India, 1918–19).

Throughout India much work is being done on the improvement of the sugar-cane and on the selection and breeding of varieties suitable for different conditions and localities. At the cane-breeding station at Coimbatore, under the direction of Dr. Barber, a large number of hybrids have been raised and are under observation, some of the seedlings proving very resistant to red rot and smut, two of the most serious diseases of sugar-cane. As a result of this work it has been possible to pass out a number of seedlings for further testing on a large scale in different places. The trial of new varieties is also carried out in Madras and the United Provinces, for the old ones which have hitherto been grown are rapidly losing favour with the cultivators, and it is necessary to find new and improved varieties to replace them. When imported canes are used it is necessary constantly to renew the stock from the country of origin. Soil and climate have a marked effect on the canes, and varieties that are markedly superior in one area often deteriorate rapidly in quality if transferred elsewhere, and, consequently, experience gained from experimental work in one part of the cane-growing tract is often of doubtful value for another area. This fact makes a strong argument for an increase in the number of sugar research stations in order that the most suitable stocks may be determined for the various localities.

Newly broken up land does not give very satisfactory results, but it should be left for at least a year before planting. If a proper rotation of crops is used, an increase of as much as 5 tons of cane per acre can be obtained. Manurial experiments in Assam have shown that the use of phosphatic fertilisers gives an average increase of 2–3 tons per acre, and in Pusa it is found that rape-cake, farmyard manure, and nitrate of soda can all be utilised with profit. In Madras it is estimated that careful manuring will raise the crop from 25 to 30 tons per acre, which is probably the limit for that particular climate.

Apart from the actual selection and cultivation, special attention is being devoted to the handling of the sugar-cane in order to avoid damage and deterioration. Canes are often stored by windrowing, and tests made over a period of several months show that this does not lead to any appreciable decrease in the quality or amount of sugar obtainable from equal weights of the original and the windrowed cane, but that after a certain time has elapsed deterioration sets in. Experiments suggest that this deterioration is not dependent upon the length of storage, but that the falling off of the quality is probably due to a seasonal rather than a biological factor.

Special methods have been devised at Coimbatore (*Agric. Journ.*, India, xv., part ii.) for the transport of cane for short distances and overseas. In the latter case it is advised that the pieces of cane be pickled in Bordeaux mixture for a short time in order to avoid the introduction of disease from one locality to another. Charcoal-dust, teak sawdust, and wood-shavings all make satisfactory packing materials.

Attention is now being directed to the use of the palmyra-palm as a sugar producer (*Agric. Journ.*, India, xv., part i.). Toddy is made in Bihar from the sweet juice of this palm, but as less than 10 per cent. of the trees are tapped it is probable that the manufacture of sugar would pay. The process of tapping needs special care to obtain the best results. The tips of the flowering stalks are cut off after the male and female inflorescences have been squeezed or otherwise injured to irritate them into producing a good flow of sweet sap. The insides of the collecting pots are coated with lime to preserve the juice and prevent fermentation. The crude sugar obtained from this juice contains lime, which is removed by passing a current of carbon dioxide through the sugar solution until all the lime is precipitated, and a cheap white sugar can then be prepared. It is suggested that as the production of sugar from the wild date-palm has so far been satisfactory, it would be well worth while to give the palmyra-palm industry a fair trial.

W. E. BRENCHLEY.

University and Educational Intelligence.

LIVERPOOL.—The title of emeritus professor of engineering has been conferred upon Prof. H. S. Hele-Shaw.

MR. R. S. GLENNIE, of the Battersea Polytechnic, has been appointed chief lecturer in pharmaceutics at the Royal Technical College, Glasgow.

THE Treasury has made to the University College at Swansea a grant of 5000*l.* in a lump sum towards expenses, and also an annual grant of another 5000*l.*

REFERENCE has already been made in these columns to the establishment of a new Department of Aeronautics at the Imperial College at South Kensington. This addition to the work of the college was initiated by the generous action of Sir Basil Zaharoff, who endowed the University of London chair of aviation known as the Zaharoff chair, tenable at the college, to which Sir Richard Glazebrook was appointed with the duty of directing the new department. A comprehensive scheme of instruction and training, mainly post-graduate in character, has been arranged for next session, beginning in October, including special sections in aeronautical engineering, meteorology, and navigation, and with the valuable co-operation of the Air Ministry the services of a distinguished staff of experts have been engaged. Apart from the director with his great experience of this work at the National Physical Laboratory, Sir Napier Shaw will be professor of meteorology and Mr. Leonard Bairstow professor of aerodynamics; Mr. A. J. Sutton Pippard will deal with the structure and strength of aircraft, and Mr. A. T. Evans with aircraft engines. Courses of lectures will also be given dealing respectively with airships and with navigation, while arrangements are in hand for special instruction in air-cooled engines, high-compression engines, dopes, instruments, wireless telegraphy, and similar subjects. Subject to certain necessary restrictions, it has also been arranged that students of the department will carry out part of their practical training in one or other of the Government establishments concerned with aeronautics.

THE Bureau of Education at Washington has just issued a Bulletin (No. 11) giving statistics relating to school systems in the United States for the year 1917–18. The bulletin is concerned with elementary and secondary education only, and is an elaborate document covering 153 pages octavo, accompanied by 62 tables of statistics and by 49 maps and diagrams illustrative of the various aspects and conditions of primary and higher education, other than university and professional, in the several States. From the figures set forth it would appear that the total population of the States has increased from 38·2 millions in 1870 to 105·4 millions in 1918, and that the children of school age between five and eighteen have increased from 12 to 27·2 millions, and the school enrolment from nearly 7 to nearly 21 millions; whilst the pupils in the high schools, who numbered 80,000 in 1871, were about 1,700,000 in 1918. The number of teachers employed was 650,709, being 105,194 men and 545,515 women, whose average salary in 1918 was 635 dollars, as compared with 189 dollars in 1870. The percentage of scholars enrolled of school age between five and eighteen was 75 in 1918 and 57 in 1870, largely due to better teaching and supervision, a more suitable course of study, transportation of pupils, and improved economic and general conditions. The total value of school buildings, sites, and equipment is stated to be of the vast total of nearly 2,000,000,000 dollars. The school dollar income is spent as follows: 3·3 cents on general control, 58·2 on instruction, 15·5 on new buildings and grounds, and 23 miscellaneous. The average length of the school year is stated to be 160 days, though the cities usually provide a school term of nine months. More than 6,000,000 children attend school, on an average, less than five months in each year. Great diversity exists throughout the States, due to climatic conditions, the scattered nature of much of the population, racial differences, and varying educational legislation, which largely accounts for the striking differences which prevail. The bulletin is well worthy the close attention of educational authorities in this country.

Societies and Academies.

LONDON.

Physical Society, June 25.—Sir W. H. Bragg, president, in the chair.—Dr. J. H. **Vincent**: The origin of the elements. The atomic weights are regarded as the weighted mean values of the atomic weights of the isotopes of the elements; but it is assumed that, as a rule, the atomic weight is near that of some one isotope. Figures and tables are drawn up showing how this accounts for the values of a large number of atomic weights, if one also assumes that the weights and positions in the periodic table of any isotope are conditioned by laws similar to those holding in the recognised radio-active families. The elements are all supposed to be derived from parent elements by processes known to occur in actively radiating families, but their radio-activity is not, in general, detectable by the usual means owing to the velocity of expulsion of the particles being low. The possibility of the reversibility of some radio-active processes is regarded favourably. The various difficulties in connection with the views advocated are discussed, and some suggestions for experiments made. Finally, the theory is used to explain the so-called laws of the atomic weights of elements of low atomic weight, and the shape of the curve obtained when the atomic weights are plotted against Moseley's numbers.—W. H. **Wilson** and Miss T. D. **Epps**: The construction of thermo-couples by electro-deposition. The method, which was devised to overcome the difficulty of making satisfactory soldered joints between the elements of thermopiles having a large number of closely packed junctions, consists in using a continuous wire of one of the elements and coating those parts of it which have to form the other element with an electrolytic deposit of another metal. If the conductivity of the latter is considerably greater than that of the former, and a fairly thick sheath is deposited, a thermo-couple is produced which is not appreciably impaired in efficiency by the short-circuiting effect of the core. Constantan wires coated with either copper or silver sheaths were found to be suitable for most purposes.—J. **Guild**: The use of vacuum arcs for interferometry. The paper discusses the relative merits of short and long mercury arcs for this work, and points out that the defect of the former is due to the broadening of the spectrum lines consequent on the high vapour pressure within the lamp. It is shown that by attaching a condensing bulb to the lamp, so as to prevent excessive rise of vapour pressure, the short lamp can be made practically as good as the long one as regards sharpness of lines, while still being of much greater intrinsic brightness.—S. **Butterworth**: The maintenance of a vibrating system by means of a triode valve. This paper gives a mathematical analysis of the arrangement, previously described by Eccles, whereby the vibrations of a tuning-fork are maintained by means of a triode.

PHILADELPHIA.

American Philosophical Society, April 24.—Dr. G. E. Hale, vice-president, in the chair.—Prof. E. W. **Brown**: The problem of the evolution of the solar system.—W. H. **Wright**: Certain aspects of recent spectroscopic observations of the gaseous nebulæ which appear to establish the relationship between them and the stars. The paper summarises in non-technical terms the evidence afforded by a study of the stellar condensations in the planetary or small gaseous nebulæ which are shown to be spectroscopically identical with stars of the Wolf-Rayet group (Pickering's Class O). A brief account is given of some of the present-day conceptions of stellar evolution for the purpose of indicating the somewhat critical nature with respect to these ideas of the relationship indicated.—Prof. E. P. **Adams**: The Einstein theory. The extension of the principle of relativity and the resulting revision of the concepts of space and time led to Einstein's interpretation of gravitation as a property of space itself when modified by the presence of matter.—Dr. L. A. **Bauer**: The results of geophysical observations during the solar eclipse of May 29, 1919, and their bearing upon the Einstein deflection of light. The present paper gives the results of a special study of the cause of the non-radial effects of the light deflections observed by the British expedition at Sobral, Brazil. It is shown that these non-radial effects may be completely accounted for by incomplete elimination of differential refraction effects in the earth's atmosphere. The same cause may apparently also explain why the observed radial deflections of light exceeded, on the average, by about 14 per cent. the amounts predicted on the basis of the Einstein law of gravitation.—Prof. J. B. **Whitehead**: The high-voltage corona in air. The paper describes the nature of the corona and recent studies of the laws governing its appearance in high-voltage circuits. Its influence as a limiting factor in long-distance transmission occurs through deterioration of insulation and a leakage loss of power between the high-voltage lines. The appearance of corona on a clean round wire is very sharply marked, and may be used for the measurement of high alternating voltages to a degree of accuracy not heretofore possible.—Prof. D. C. **Miller**: The velocity of explosive sounds. Most of the experiments were made in connection with 10-in. and 12-in. rifles, though a few were made with 6-in. and 8-in. guns. The amount of powder charge and the value of the internal pressure developed in the gun are taken into account. The sounds were received by means of specially constructed carbon-granule microphones, those for use near the gun being of unusually rugged construction, while others were of a very sensitive type. The records were made by a specially constructed moving-film camera in connection with a string-galvanometer capable of recording from six stations simultaneously, of the type used by the U.S. Army for sound-ranging. Meteorological observations were made by special observers in the distant stations and on the field near the guns at the time of the experiments, and continuous records were made at the Proving Ground Headquarters and at the United States Weather Bureau Station. These observations covered temperature, barometric height, humidity, wind velocity, and wind direction. Measurements were also made of the velocity of the sound at a series of stations located on a line at right angles to the line of fire and on a line at 45° to one side of the line of fire. Heretofore there has been a general impression that explosive sounds travel much farther than do ordinary sounds, the velocity being, perhaps, several times the normal velocity. These experiments show conclusively that the velocity at a distance of 100 ft. from a 10-in. gun is about 1240 ft. per second, or 22 per cent. above normal; at 200 ft. from the gun the velocity is only about 5 per cent. above normal. For all distances above 500 ft. from the gun the velocity of the explosive sound from the largest-sized gun is practically normal.—Dr. H. C. **Hayes**: The U.S. Navy MV-type of hydrophone as an aid and safeguard to navigation.—Dr. A. E. **Kennelly**: The transient process of establishing a steady alternating electric current on a long line from laboratory measurements on an artificial line. It is known that the current and voltage do not build up steadily and continuously, but advance by little jumps which occur at regular short intervals of time, accompanying successive reflections of electromagnetic waves from one end of the line to the other. There is presented in this paper a number of observations which have been secured photographically of the rise of voltage and current on a long artificial electric power transmission line in the laboratory, and have compared the observed rates of growth with those which are indicated by theory with a fairly satisfactory agreement.—N. W. **Akimoff**: The strephoscope.—Prof. R. S. **Dugan**: New features in the eclipsing variable U Cephei. (Prof. W. B. Scott, president, in the chair.)—Prof. E. N. **Harvey**: Animal luminescence and stimulation. The production of light by animals is due to the burning or oxidation of a substance called luciferin in the presence of an enzyme or catalyst called luciferase. Light production by animals differs from light produced by combustion in that the oxidation product of luciferin, oxyluciferin, can be easily reduced to luciferin, which will again oxidise with light production. The reaction is reversible, and appears to be of this nature: luciferin + O $\rightleftharpoons$ oxyluciferin + H_2O. The difference between luciferin and oxyluciferin lies probably in this: that the luciferin possesses two atoms of hydrogen, which is removed to form H_2O when the luciferin is oxidised. The H_2 must be added to re-form luciferin. Not only is it most efficient so far as the radiation (being all light) it produces is concerned, it is also most economical so far as its chemical processes are concerned. The above reactions can be demonstrated in a test-tube with a mixture of oxyluciferin, luciferase, and ammonium sulphide. The ammonium sulphide is probably represented in living cells by reducing enzymes or reductases. If such a test-tube is allowed to stand, oxyluciferin is reduced to luciferin, which will luminesce only at the surface of the fluid in the test-tube in contact with air. When the tube is agitated so as to dissolve more oxygen of the air, the liquid glows throughout. Even a gentle knock or "stimulus" to the tube is sufficient to cause enough oxygen to dissolve to give a momentary flash of light which is strikingly similar to the flash of light given by luminous animals themselves on stimulation. This suggests that when we agitate a luminous animal, or when the luminous gland-cells of a firefly are stimulated through nerves, with the resultant flash of light, in each case the stimulus acts by increasing the permeability of the surface-layer of the cells to oxygen. This then upsets an equilibrium involving the luciferin, luciferase, oxyluciferin, oxygen, and reductase within the cell, with the production of light and the formation of more oxyluciferin. So long as the luminous cell is resting and unstimulated, the tendency is for reduction processes to occur and luciferin to be formed. It must be pointed out that not all sorts of stimulation can be explained in this way, as the stimulation of muscles or nerve-fibres may take place in the complete absence of oxygen.—Prof. G. H. **Parker**: The phosphorescence of Renilla. During the day Renilla cannot be excited to phosphoresce, but at night on stimulation it can be made to glow with a beautiful golden-green light. The light is produced in wave-like ripples that spread out from the spot stimulated and run over the upper surface of the animal. They travel at a relatively slow rate that agrees with that at which the nervous impulses of the animal travel. Hence it is concluded that the phosphorescence of Renilla is under the control of the nerve-net of the animal, which apparently pervades the whole colony.—Prof. W. M. **Wheeler** and I. W. **Bailey**: Feeding habits of Pseudomyrmine ants. Examination of the mouth of the larva reveals a singular hitherto undescribed organ, evidently used for reducing the food-pellet to such a finely divided state that it can, when acted upon by the digestive juices of the stomach, yield a certain amount of nutriment which the worker-ant could not extract from it while it was in the infrabuccal pocket. This larval organ may be called the trophorhinium. In all Pseudomyrmine larvæ, and in many larvæ of the other sub-families, except the Dorylinæ and Cerapachyinæ, the trophorhinium is beautifully developed, although in many ants (Ponerinæ) it must be used for comminuting parts of insects given directly to the larvæ by the workers. In its development the trophorhinium bears a strange resemblance to the stridulatory organs of the petiole and post-petiole of many adult ants.—Dr. A. E. **Ortmann**: Correlation of shape and station in fresh-water mussels. It has been found that for certain species more swollen specimens are found down-stream in the larger rivers and more compressed specimens more up-stream, and that in the intermediate stretches of a river these extremes are connected by gradual transitions.—Prof. H. F. **Osborn**: Evolution principles deduced from a study of the even-toed Ungulates known as Titanotheres.—Prof. W. B. **Scott**: The Astropotheria.—B. F. **Howell**, jun.: The Middle Cambrian beds at Manuels, Newfoundland, and their relations. These beds are of special scientific interest because they contain large numbers of unusually well-preserved fossils, which prove that the creatures that swarmed in the waters then covering much of what is now New England, south-eastern Canada, and south-eastern Newfoundland were of practically the same sort as those living in the seas which at the same period washed over many parts of Scandinavia and the British Isles. North America has probably been joined to Europe in this way several times in the geological past, so that the animals living in the coastal waters could spread from one hemisphere to the other.—Prof. W. H. **Hobbs**: (1) The Michigan meteor of November 26, 1919. (2) The glacial anticyclone and the blizzard in relation to the domed surface of continental glaciers.

ROME.

Reale Accademia dei Lincei, March 7.—A. Róiti, vice-president, in the chair.—Q. **Majorana**: Gravitation, viii.—O. **Chisini**: Analytic representation of the fold of a surface by a series of fractional powers of two variables.—U. **Cisotti**: Integration of the equation of wave-motion in a deep canal, ii. The equation of the free surface is determined.—O. **Onicescu**: Newtonian fields in the neighbourhood of a given vectorial field. An application of Levi-Civita's notion of harmonics in the neighbourhood of an assigned function. The author deduces the lamellar and solenoidal magnetisation which gives rise to a given magnetic field, and applies the result to deal with the existence and unique nature of the magnetisation in soft iron.

—L. **Tonelli**: Researches on primitive functions, iii. —V. **Sabatini**: Leucitic lavas of the volcano of Roccamonfina. This deals mainly with the composition of the spurs, and particularly with the presence of leucite.—B. **Peyronel**: A parasite of the lupin, *Blepharospora terrestris*. In December, 1919, plants of lupin were received infected with this parasite from Pantano and Pratolongo, near the Lake of Regillo. It appears to kill the plants, completely destroying the tubercles of the roots. The question is raised as to whether the parasite is of American origin, but the author considers it probably an indigenous type that has recently become destructive.—T. **Levi-Civita**: Harmonics in the neighbourhood of an assigned function. The problem is reduced to the determination of the Newtonian function having the given function as its density.—R. **Perotti**: Nitrogen of the cyanic group in manures. A contribution to the determination of the mechanism of action of cyanic nitrogen in vegetable nutrition and the conditions for its utilisation.—M. **Ascoli** and A. **Fagiuoli**: Sub-epidermic pharmacodynamic experiences, ii. The action of pituitrin is discussed. The limit of reactivity in normal subjects fluctuates about a dilution of 500. —L. **Cattolica**: Obituary notice of G. Dalla Vedova, professor of geography in the University of Rome.—Sig. **Baglioni**: The life and work of the late Luigi Luciani, professor of pathology at Parma from 1875 to 1880, and afterwards professor of physiology at Siena, Florence, and Rome in succession.

March 21.—F. D'Ovidio, president, in the chair.—Q. **Majorana**: Gravitation, ix. Gravitation may be partly absorbed by matter, and this absorption may give rise to heat. Bodies will then have two kinds of mass, apparent and real, and the real density of the sun will then be three times its apparent or astronomical density. An experimental test is being arranged at Turin for studying the action of 100 quintals of lead on a small central mass.—O. **Chisini**: Contact of curves of diramation for an algebraic function of two variables.—M. **De Angelis**: Crystalline forms of nitrodichloroacetanilide. This substance is dimorphic, modifications α and β both being monoclinic and prismatic, the former with $a:b:c=$ $1\cdot1507:1:1\cdot1348$ and $\beta=66^\circ\ 23'$, the latter with the values $1\cdot5792:1:1\cdot0952$ and $62^\circ\ 23\cdot5'$. The second form is decidedly unstable, and when left in the mother-solution, or even dried, it transforms in time into an aggregate of crystals of the stable phase.—R. **Perotti**: Measure of the ammoniating power of soils. The best conditions for employing the method of solutions are 10 c.c. solution of peptone of 1·5 per cent. in test-tubes, adding 5 c.c. of a mixture formed of 50 grams of earth in 500 grams of water; cultivation for four days in a thermostat at 20°–25° C., and determination of ammonia by distillation on oxide of magnesia.—M. **Ascoli** and A. **Fagiuoli**: Sub-epidermic pharmacodynamic experiences, iii. Certain alkaloids, such as atropine, pilocarpine, muscarine, physostigmine, morphine, eserine, nicotine, cocaine, and scopolamine, which offer a cutaneous reaction of œdematogenous type, are referred to.

Books Received.

The Theory of Electric Cables and Networks. By Dr. A. Russell. Second edition. Pp. x+348. (London: Constable and Co., Ltd.) 24*s*. net.

Wild Creatures of Garden and Hedgerow. By Frances Pitt. Pp. ix+285. (London: Constable and Co., Ltd.) 12*s*. net.

Every Boy's Book of Geology. By Dr. A. E. Trueman and W. P. Westell. Pp. 315. (London: R.T.S.) 6*s*. net.

The Fall of the Birth-Rate. By G. Udny Yule. Pp. 43. (Cambridge: At the University Press.) 4*s*. net.

Kritik der Abstammungslehre. By Prof. J. Reinke. Pp. v+133. (Leipzig: J. A. Barth.) 13 marks.

History of the Theory of Numbers. By Prof. L. E. Dickson. Vol. ii., Diophantine Analysis. Pp. xxv+803. (Washington: Carnegie Institution.)

An Introduction to the Study of Hypnotism: Experimental and Therapeutic. By Dr. H. E. Wingfield. Second edition. Pp. viii+195. (London: Baillière, Tindall, and Cox.) 7*s*. 6*d*. net.

Industrial Colonies and Village Settlements for the Consumptive. By Sir German Woodhead and P. C. Varrier-Jones. Pp. xi+151. (Cambridge: At the University Press.) 10*s*. 6*d*. net.

A Handbook of Physics and Chemistry. By H. E. Corbin and A. M. Stewart. Fifth edition. Pp. viii+496. (London: J. and A. Churchill.) 15*s*. net.

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MACMILLAN & CO., LTD., St. Martin's Street, London, W.C. 2.

Printed in Great Britain by R. CLAY AND SONS, LIMITED, at Brunswick Street, Stamford Street, S.E.1, and published by MACMILLAN AND CO., LIMITED, at St. Martin's Street, London, W.C.2, and THE MACMILLAN CO., 66 Fifth Avenue, New York.—THURSDAY, August 26, 1920.