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Technical Education and Industry.

IF any apology were needed for our return to the third volume published by the Committee on Industry and Trade,[1] we would refer our readers to the articles and reports dealing with education and industry which have appeared in our columns during the last two years or so. If those articles and reports be carefully scrutinised, it will be seen that we have attempted, very deliberately, to show not only the necessity, but also the origins, directions, and even deflexions of the rapidly growing tendencies towards a scientific view of education in relation to the structure of modern society. We venture to suggest, too, that our interpretation of the term 'scientific education' has been wide and liberal enough to satisfy the most suspicious guardian of the delectably elusive qualities which are covered by the word 'culture.' Perhaps at another time we shall demonstrate the possibility of realising some of the classical ideals which are still inherent in the life of a community developing under an apparently grey and formless industrialism. In the meantime, the attitude of the present volume towards technical education has a special attraction from the point of view of its significance to the educational movements we have been observing.

Whatever may be our notions of the contributions which are made towards the solution of the problems before the Committee, we believe that its attitude towards the relationship of technical education to industry will do much to strengthen that relationship, and so aid, not only in the industrial reconstruction which lies ahead, but also in the general intellectual progress towards a less anomalous civilisation than exists at present.

It would be easy, perhaps, to criticise the chapter on technical education on certain grounds, the chief of which might be that it is based upon memoranda supplied by government education departments, and that it presents the usual shortcomings of memoranda from such sources, namely, a certain timidity and a platitudinous repetition of possible improvements. But it must not be forgotten that what is platitudinous to the expert may be illuminating and inspiring to the layman; and this volume is primarily for business men rather than for educationists. The charge of timidity, too, loses much of its power when we read the Committee's warning that the volume "is not concerned

[1] Committee on Industry and Trade. Factors in Industrial and Commercial Efficiency: being Part I. of a Survey of Industries. With an Introduction by the Committee. Pp. v+544. (London: H.M. Stationery Office, 1927.) 5s. net.

with recommendations. Its aim is to assemble and analyse facts and tendencies, and by so doing to narrow the range of economic controversy and prepare the way for the intelligent study of the problems by which British industry is confronted."

Three necessities are, however, made clear: expansion of the scope and number of technical classes; the better adjustment of their relationship with industry; and the constant need to adjust the relations of general and technical education.

Further, if the Committee does not profess to give detailed recommendations, its survey of the present relationship of technical education to particular industries, and its suggestions as to possible improvements, will be greatly helpful to any national industrial organisation, group of employers, or individual employers. Clearly the Committee is doubtful whether full co-operation can be reached by local advisory committees alone. It realises that as yet there has been little serious study on the side of industry of the possibilities of a considered policy of technical school training for young employees; and it is certain that substantial improvements could be suggested if each industry would survey, from its own point of view, the existing facilities, see what gaps need filling and what developments are desirable, take an active interest in the schools and give effective assistance to their conduct. That assistance could take many forms. Lectureships could be founded or subsidised where the public provision is inadequate; grants to part-time teachers to help them to gain wider experience or to improve qualifications; scholarships to promising students; consideration of the methods of filling the more responsible posts; consideration of the number of men needed annually, and the kind of qualifications they should possess; allowance of 'time-off' during working hours to students who have shown diligence and ability to profit by instruction in technical schools.

Three other serious weaknesses of the present system are indicated. The connexions between universities and technical schools are accidental rather than systematic, even though some technical institutions are of university rank and function as technical universities. Premises, too, are unsatisfactory, and work is sometimes conducted "under conditions which are tolerated rather than approved." Finally, the training of teachers presents a difficult problem. Obviously men of experience and skill in trades and processes they teach are essential. But more than such experience and skill is necessary if the highest results are to be attained. Vacation courses have proved extremely valuable; but these, in themselves, are not sufficient. By what other means can this vital problem be settled?

The Committee's view of its problems is shown excellently in some passages which are worthy of reproduction:

"The vitality of modern industry, like that of an organism, is measured by its power of response to external stimulus and of self-adaptation to modern environment. Mobility (in this sense of the term) does not imply incessant and purposeless movement or change. . . . But it does imply the power of spontaneous reaction to changes in economic conditions and of internal modifications and rearrangement to meet such changes. . . . It applies to modes of preparation for industry and the right adjustment between the functions of school education and workshop training which demand continual modification and re-adaptation both to fit the changing needs of modern large-scale industry and to counteract some of the dangers of excessive sub-division of employments."

Following this line of thought, the Committee does not fail to observe that in our age of flux and transformation, no plan of educational development can be justified which does not maintain unimpaired initiative, flexibility of temperament, powers of adaptation and capacity for co-operation among all the partners in production and distribution. Such a view ought to show very clearly to those who may be fearful, that mere vocational instruction is by no means what the Committee understands by the term 'technical education.'

It would, after all, be too much to expect from a single committee—and particularly from a committee with such wide terms of reference—a solution of the delicate, far-reaching, and many-sided problems presented by an attempt to examine the relationship of technical education to industry. It must not be forgotten that other bodies are also making their contributions to these problems; and if we indicate only some of the activities which we have been observing, it will be sufficient to justify the remark we made above concerning "rapidly growing tendencies."

The Board of Education's Consultative Committee has presented its report on the education of the adolescent; a Committee on Education and Industry (under Mr. D. O. Malcolm) has presented the first part of its report, and is preparing the second part; a Ministry of Labour Inquiry into the general question of apprenticeship is not yet completed; the League of Nations recently held a conference on conciliation in industry, and will shortly continue that conference at Geneva;

finally, the committee brought into being by the many learned and professional institutions and teaching associations under the chairmanship of the late Lord Emmott, is now in the stages of compiling its report on the relationship of technical to other forms of education and to industry. When such activities are reviewed the importance of the present volume may be rightly judged, especially when it is recalled that the President of the Board of Education informed a deputation of the Emmott Committee, last May, that not until he had before him the reports of at least four of these bodies could he begin to formulate the changes which may be immediately necessary.

The contribution of the present volume, too, falls further into its place when we note that it divides its educational problem into three main parts: industrial output is not a mere question of volume, but depends essentially on quality; under modern industrial conditions the relative range and potency of apprenticeship have tended to diminish; school education before entering, and concurrently with, employment has increased in importance.

There is not yet any consensus of opinion, however, as to the mutual relations and limits of workshop training and school education, looked upon as complementary factors. In making its surveys of technical education and apprenticeship, the Committee hoped to be "of assistance in arriving at clearer views on this vitally important question." That the volume achieves that object is beyond all doubt.

Politics as a Science.

The Science and Method of Politics. By Prof. G. E. G. Catlin. Pp. xii + 360. (London: Kegan Paul and Co., Ltd.; New York: Alfred A. Knopf, 1927.) 12*s*. 6*d*. net.

THIS is an able and interesting volume, in which there is at once great learning and considerable power of speculation. Prof. Catlin has an important thesis to maintain, and his urbanity of manner will not conceal from the reader that he is prepared to maintain his ground against all comers. The field, indeed, is already, as if in advance of conflict, strewn with the illustrious dead; at least I seem to discern there the scalps of Plato and Aristotle, Kant and Hegel, exposed as a warning to prospective combatants.

In a sense, Prof. Catlin's book is difficult to review; for it is to be followed by a book already in preparation in which the thesis he here lays down is to be applied to our problems. Obviously, therefore, we shall not fully know what the method he advocates can do until he himself has applied it; and conclusions upon his analysis must be provisional until he has given us the full opportunity to see it at work. But as I understand his views, his purpose is to construct a science of politics which shall seek to do for man in society what the early economists did for the phenomena they survey. It will be abstract and deductive; it will have its axioms and postulates; and the test of its validity will lie in the verifiability of its predictions. Such a science, he argues, must free itself from the shackles which the historian and the philosopher have sought to impose upon it. For values it will have no concern. It will be concerned only with the observed behaviour of men. Assuming that there is a political man with the appetite for power, it will seek to construct the laws of his behaviour in adjusting means to purpose. With right or wrong it will have no more concern than the chemist with the moral qualities of hydrogen. It will be quantitative in character in that, upon the basis of its assumptions, it will seek from observation the largest possible number of examples from which to draw its conclusions. Having made abstraction of ethics, it will be able to approach the facts without a *parti pris*; and, instead of offering futile sacrifices upon the altar of teleology, it will be able to say (p. 199) that the "social situation only admits of certain appropriate measures." For studying what men do, it will be able to tell us what they will do; between the two Prof. Catlin injects a formidable *therefore*; and as this science of politics is refreshed by the constant accumulation of facts about the behaviour of men in their desire for power, as, also, such sister sciences as psychology contribute their due quota of knowledge, we may hope for the discovery of truths which will have value and influence of the same magnitude as those to which the economists have given birth.

There is an air of promising certitude about these propositions, which have at least the merit of interesting audacity; though I observe with a little surprise that Machiavelli is appealed as their benevolent compurgator. For if ever a man had a definite end in view (which, as a passionate Italian patriot, he would have regarded as ethical), if ever, also, a man selected his facts to suit the thesis his experience dictated as best suited to his end, that man was Machiavelli. Perhaps the best thing one can do is to indicate, though with appreciation, some of the doubts to which Prof. Catlin's argument gives rise. The victories of

economic science as built in terms of 'economic man' seem to me less outstanding than he claims, and its main successes have been won in spite of, rather than because of, its original and rigorous abstraction. The chief influence of the late Prof. Marshall, for example, was mainly due to the ingenuity with which he transformed the classic economics into something approaching the complexity of the facts; in no other way, moreover, could the economists answer the challenge of Marx, whose own 'economic man' led, by the technique of his construction, to quite different conclusions.

Prof. Catlin, moreover, has a simple faith in facts as such, which, in the social sciences, at least, I do not find it easy to share. They are not born free and equal. The expert interpretation of a social environment is coloured by the personal equation of the observer in a way that is momentously different from an expert interpretation of a physical or chemical environment. What Mr. Justice Holmes has called the 'inarticulate major premiss' of the judiciary is, as a rule, the main clue to their decisions; and yet the best of judges usually believe that they are finding the law in an unbiassed and scientific way. Nor is this all. The maxim 'as men behave, so they will behave,' is, statistically, probably true in a static world; the trouble with this world is that the environment changes at a pace so rapid that the forms of behaviour in one place or period are no clue to those forms in another. I agree that most social situations admit only of certain appropriate measures. But the difficulty here (and I cannot find that Prof. Catlin deals with it) is that the measures have to be chosen in terms of an end deemed right or wrong. We are, in fact, at once outside the realm of scientific politics; for here we are dealing with argument that has reference to ethical value which Prof. Catlin deems irrelevant. I would venture here to add that if the 'political man' were what he describes him to be, in any sense that can be called significant, he represents so small a proportion of mankind that prediction built upon his behaviour would be no clue to the general habits of men. I wish, indeed, that Prof. Catlin had given us some examples of the political 'laws' that his science would establish. Provisionally, at least, he still leaves me with the impression that Burke's 'little mirror of circumstances' would be vital in the battle.

Perhaps I may put my difficulty in terms of an analogy. The Common Law for long proceeded upon the assumption (akin in character to that of Prof. Catlin) that where there was no remedy there could be no wrong; and in order that it might be adequate and effective it was necessary to invent the remedies of Equity, which proceeded upon the assumption (akin to that of political philosophy) that wrongs as such were entitled to redress. My own conviction is that Prof. Catlin's science of politics would need a similar supplement. What seems to me really valid (and brilliantly demonstrated) in his book is its plea for the systematic collection of facts and the deliberate undertaking of experiment. We need, in fact, an inductive study of politics, based on quantitative tabulation, instead of deductions moulded from our private desires. To have shown with wit and point and learning how much might be expected from such a development is the very considerable service Prof. Catlin has rendered us.

HAROLD J. LASKI.

Synthetic Organic Chemistry.

(1) *The Synthesis of Benzene Derivatives.* By Stanley C. Bate. Pp. 229. (London: Ernest Benn, Ltd., 1926.) 21*s.* net.

(2) *The Use of Solvents in Synthetic Organic Chemistry.* By Prof. Donald W. MacArdle. Pp. vii+217. (London: Chapman and Hall, Ltd., 1926.) 15*s.* net.

(3) *Organic Syntheses: an Annual Publication of Satisfactory Methods for the Preparation of Organic Chemicals.* Editor-in-Chief: Carl Shipp Marvel. Vol. 5. Pp. vii+110. (New York: John Wiley and Sons, Inc.; London: Chapman and Hall, Ltd., 1925.) 7*s.* 6*d.* net.

THE ever-growing output of research that marks the progress of chemical science is reflected in the increasing size of the chemical journals; and the task of the researcher whose text-books these form becomes more onerous each year. The work is lightened by the publication of the Chemical Society's Annual Reports, and by the appearance from time to time of monographs dealing with the more important theoretical aspects of the problems under investigation, but the wealth of information 'tied up' in the experimental work of the original papers is not so easily rendered accessible. This difficulty has been partially solved by the compilation of such comprehensive treatises as Houben-Weyl's "Die Methoden der organischen Chemie," or Meyer's "Analyse und Konstitutionsermittlung organischer Verbindungen," and the first two of the three books under review are frank attempts on the part of the authors to provide for English-

speaking chemists similar correlated information on definite problems connected with laboratory practice.

(1) Mr. Bate seeks to give in a short and concise form the various methods available for the synthesis of organic compounds that may be of utility both to senior students and research chemists, and the present pioneer volume is concerned with the synthesis of derivatives of benzene. The subject is discussed in twelve chapters, each dealing, usually, with one type of reaction. Thus in the chapter on nitro compounds, the nitration of different types of compounds by means of nitric acid is described; then follows a description of other methods of nitration; of the conversion of amines into nitro compounds; of anomalous cases occurring in nitration; and finally, the effect on certain groups of the presence of the nitro group in the molecule is discussed. The text contains full references to the original papers and patents up to April 1925, as in very few cases is sufficient detail supplied to make the reader independent of the original memoir. The reviewer suggests that in a future edition the names of the investigators be given as well as the references, in order to facilitate cross reference to abstract journals; and also, that the present scanty index be considerably extended.

The general arrangement of the book is excellent, the printing clear, and the text remarkably free from errors, but in a few cases confusion arises from the use of italics at the beginning of a paragraph for the introduction of a new main section, whilst a sub-section is placed under headlines in heavy type. Not a few formulæ are faulty owing to the misuse of the dot and bracket; and the printing of such expressions as "to react the substance," and "the substance to be amidated," and "oxy" for "hydroxy," are not pleasing to the English ear. These minor blemishes do not detract from the value of a book of such excellence that it should form a unique and most useful addition to the reference library of the organic chemistry departments of all university and technical institutions.

(2) Prof. MacArdle's book is the first part of a treatise on the operative technique of synthetic organic chemistry, similar in a general way to the first sections of the well-known German works of Lassar-Cohn and of Weyl. The first chapter is devoted to "General Considerations," and treats of solution, methods of bringing about solution, choice of solvent, interliquefaction, crystallisation, solvent of crystallisation, and mixed crystals. In the following seven chapters the uses of the various types of solvents are discussed, the question of the purifying of the substance being treated critically and the fullest practical details being supplied. These chapters are rich in references to special cases in which the solvent in question has proved of unique value, and also of instances when anomalous reactions have occurred which limit the use of the solvent. The remaining two chapters are devoted to a consideration of "Special Means to Induce Crystallisation" and to "Salting Out"; a full bibliography and two exhaustive indexes are appended.

The arrangement of the book and the presentation of the subject leave nothing to be desired; for, in addition to its eminently practical value, the book is a readable one and holds the interest of the reader from the first page to the last.

The statement on page 138 that the dangers attending the use of dimethyl sulphate have been very much exaggerated cannot be generally endorsed, for in the experience of the reviewer more than one case of serious and prolonged indisposition has resulted from the use of this substance without special precautions being taken to remove all vapours in an effective draught.

(3) The last of the three books with which this review is concerned differs widely in scope and purpose from the others. It is the fifth volume of "An Annual Publication of Satisfactory Methods for the Preparation of Organic Chemicals"; and indeed so eminently satisfactory are the methods described therein that the issue of the yearly volume marks a red-letter day in the organic laboratory. Since the publication of the first volume, when the editors invited the co-operation of other organic chemists, the response has become wider each year, and in this volume twenty-four of the thirty-three preparations have been submitted by eighteen contributors. M. A. W.

The American Mongolian Expedition.

On the Trail of Ancient Man: a Narrative of the Field Work of the Central Asiatic Expeditions. By Dr. Roy Chapman Andrews. With an Introduction and a Chapter by Henry Fairfield Osborn. Pp. xxiv + 375 + 61 plates. (New York and London: G. P. Putnam's Sons, 1926.) 25*s.* net.

NORTH-EASTERN Asia has entered the field as one of the competitors with south-western Asia as the home of man. The discovery of some fossil vertebrates that are common to Europe and western America but are absent from eastern America led Prof. H. F. Osborn in 1900 to predict that these animals had developed in

northern Asia and thence migrated eastward into Europe and westward into America. The ocean they crossed was therefore the Pacific and not the Atlantic. Faith in this theory led Dr. R. C. Andrews to organise an expedition to search for the remains of these animals in the steppes which they must have crossed during their migration from inner Asia to the Rocky Mountains. The generosity of American patrons of science provided £50,000 for the purpose, and Dr. Andrews led to Mongolia a series of well-equipped expeditions which there made several sensational discoveries. The most dramatic was the finding of the eggs of Cretaceous dinosaurs. They were found in such abundance in one locality that one Mongolian woman brought in fragments of egg-shells in tin-fuls. The eggs belong to three genera, one of which, Protoceratops, is a primitive form of the Ceratopsidæ. Dr. Andrews describes this locality as a dinosaur incubator, and he attributes its selection as the breeding-ground to the nature of the sand, which would have formed comfortable nests.

Of still greater importance was the discovery, also in the Middle Cretaceous beds, of some mammal skulls. The first found had been sent to New York as a reptile, and recognised by Dr. W. D. Matthew as a primitive mammal. Stimulated by his report of the importance of the discovery, the search was renewed and other specimens found. A preliminary account of the skulls is given in the volume, but a more detailed account has been recently published elsewhere. The expedition also discovered a series of important Eocene mammals. The first of the vertebrate fossils found by the expedition were some bones of the Baluchitherium, an Oligocene mammal, which was discovered by Cooper in northern India. The expedition found later a skull and a skeleton of this mammal, and Dr. R. C. Andrews was led by the discovery to the expectation that, as the human family probably began to diverge from the ordinary primates in the Oligocene, the remains of some primitive ancestors of man should be found in Mongolia.

Large numbers of stone implements were found; they represent two periods—Neolithic and Upper Palæolithic. The age of the latter is suggested as Azilian. Some members of the expedition were at first under the impression that the rough stone cores represented a pre-Chellean culture; but ultimately they were convinced by the large series collected and arranged by the archæologist, Mr. Nelson, that the cores were the residue of Upper Palæolithic flaking. Nothing human was obtained by the expedition earlier than the Mousterian, of which implements have already been found in China, in the valley of the Hoang-ho. While the palæontologists were excavating the fossils, the two geologists with the expedition—Prof. Berkey and Mr. F. K. Morris—surveyed the area, worked out its history, and thus made a valuable contribution to Asiatic geology. Amongst other points of interest they find that there is no evidence of glaciation in the district, except in some small corries on the highest hills.

The volume tells the narrative of the expedition. It is graphically and racily written, and gives a delightful picture of a group of men in cordial co-operation and all enthusiastic in their work. Probably in the effort to be popular the author constantly states the age of the beds in years, reporting, for example, that the earlier implements date from 40 thousand, and the later from 15 thousand years ago; such estimates are about as useful as if a historian tried to date an Act of Parliament by reference to the birth of John Smith. The book is well illustrated by photographs showing the expedition at work and the nature of the country, and by ideal pictures of the fossils skipping about in their native haunts. J. W. GREGORY.

Our Bookshelf.

The Year-Book of the Scientific and Learned Societies of Great Britain and Ireland: a Record of the Work done in Science, Literature, and Art during the Session 1925–1926, by numerous Societies and Government Institutions. Compiled from Official Sources. Forty-third Annual Issue. Pp. vii + 399. (London: Charles Griffin and Co., Ltd., 1926.) 18*s*. net.

To those who have used this work of reference, the new issue requires no commendation. For those who have not yet handled it, emphasis may be laid on the words from the title-page: "Compiled from Official Sources." The information provided as to the titles, addresses, officers, and activities of the scientific and learned societies and Government institutions in Great Britain and Ireland has been obtained from officials of the societies concerned, so the volume serves as a directory. In addition, the lists of authors and titles of papers presented before each society during 1925 gives some indication of the amount and direction of progress made in science and the arts. Take, for example, the Royal Society: the total number of papers, 226, shows great activity in the scientific world, while the fact that nearly three-quarters of them were published in Series A of the *Transactions* or *Proceedings* testifies to the fertile field of the mathematical and physical sciences.

The various societies are grouped according to the subjects of their interests, beginning with those dealing with science generally. As regards

classification, there will obviously be differences of opinion; we think, however, that the Röntgen Society would be better in the Physics Section than under Chemistry and Photography, while the Spelæological Society (University of Bristol) is certainly archæological rather than biological. The index, however, soon smooths out little difficulties of this kind. The new address of the British Cast Iron Research Association, at 24 St. Paul's Square, Birmingham, was probably announced too late for insertion. We are still of the opinion that all the research associations in Great Britain now in existence should be included and indexed under 'Research.' Some of the more recently formed scientific bodies have not yet appeared in the volume, but meanwhile we must be grateful for the valuable collection of data with which the publishers of this annual continue to supply us.

Elemente der exakten Erblichkeitslehre: mit Grundzügen der biologischen Variationsstatistik. Von Prof. Dr. W. Johannsen. Dritte deutsche, neubearbeitete Auflage in dreissig Vorlesungen. Pp. xi+736. (Jena: Gustav Fischer, 1926.) 32 gold marks.

This well-known book, which was first published in 1909, has now reached its third edition. It is still divided into thirty 'lectures,' but various additions and alterations have been made. More attention is paid to Sheppard's correction for class variants and to Bravais' formula for reckoning the coefficient of correlation. In the latter formula the value of every variant, and not merely that of the classes, enters into the result, and the method can also be used for alternative as well as quantitative variations. The chapters on selection have been extended and those on Mendelism re-written in the light of the more recent work. The word 'gen' is used throughout for the hereditary unit, and Bateson's term 'allelomorph' has been shortened to 'allele,' with a result which would not be very happy if the word were used in English form. In its present form the work will continue to be of great use to geneticists, since it gives in convenient form the various statistical methods used in genetical investigations. But more than this, it is a discussion from the author's characteristic point of view of large fields in experimental genetics. R. R. G.

Prehistoric Man and the Cambridge Gravels. By the Rev. Frederick Smith. Pp. viii+121+30 plates. (Cambridge: W. Heffer and Sons, Ltd.; London: Simpkin, Marshall and Co., Ltd., 1926.) 7*s.* 6*d.* net.

The Rev. Frederick Smith, the author of a book on the Stone Ages in North Britain and Ireland, has been engaged in archæological research for more than sixty years. He began to collect from the Cambridge gravels when he was a boy, and he returned to his old hunting-ground in 1924. He has collected many thousands of specimens, and the constant recurrence of certain forms has convinced him that his specimens are implements of various kinds—arrowheads, spear heads, hatchets, knives, and flakers, piercers, and saws—and that certain of them were fitted with shafts. In addition he has found sculptures—a baboon, eagle's beak, an oyster shell, and so forth. The date attributed to them is pre-Chellean, Chellean, and Acheulean. Mr. Smith argues that though the early archæologists were ridiculed and rejected, their views were afterwards accepted, and by analogy claims indulgence for his own views. The argument is as dangerous as its converse. Mr. Smith figures a number of the specimens which he maintains are implements, showing them with and without hafts, but his illustrations still fail to convince.

Handbuch der biologischen Arbeitsmethoden. Herausgegeben von Prof. Dr. Emil Abderhalden. Lieferung 199. Abt. 9: *Methoden zur Erforschung der Leistungen des tierischen Organismus*, Teil 4, Heft 2. *Methoden der Erforschung bestimmter Funktionen bei einzelnen Tierarten. Methoden zur Erforschung des Vogelzuges*, von J. Thienemann; *Methoden zur Behandlung der Atemphysiologie der Insekten*, von Albert Koch; *Die Verfahren zur Erforschung der Tierfluges*, von Oskar Prochnow. Pp. 123-294. (Berlin und Wien: Urban und Schwarzenberg, 1926.) 7·50 gold marks.

The first article on the speed and height of the flight of birds is a very brief account of the subject. In the second one, on the respiration of insects (about 80 pages), the function of the spiracles and the movements which ventilate the tracheæ are discussed, and the principal methods for investigating the movements are described and illustrated. Due attention is given to the physical and chemical aspects of the problem, *e.g.* the technique of gas microanalysis. The third article discusses the flight of insects and of birds and the methods which have been employed in the elucidation of the movements and of their mechanics.

Surface Equilibria of Biological and Organic Colloids. By Dr. P. Lecomte du Noüy. (American Chemical Society Monograph Series.) Pp. 212. (New York: The Chemical Catalog Co., Inc., 1926.) 4.50 dollars.

In the measurement of surface tension the 'ring' method has the great advantage of rapidity, so that variations are readily discovered; and in the hands of the author of this volume it has proved a most useful weapon of research. The book deals largely with the work of the author, but although its scope is therefore not so wide as the title might imply, it is full of interest to the biologist and the physicist. An ingenious method of deducing the three dimensions of the sodium oleate molecule (leading to a value for Avogadro's constant in remarkable agreement with that obtained in very different ways), the size of the albumin molecule and the differentiation of normal and immune serum are among the subjects dealt with in this work, which should prove singularly attractive even to those who are not specialists.

P. C. L. T.

Letters to the Editor.

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The Origin of the Earth's Surface Structure.

IN the *Journal and Proceedings of the Asiatic Society of Bengal* (vol. 8, No. 9; 1912) there is a paper by Dr. L. L. Fermor entitled "Preliminary Note on the Origin of Meteorites."

In approaching his subject Dr. Fermor deals with the effects of pressure in determining the mineral constitution of rocks. He refers especially to the case of eclogite, wherein the development of garnet, and occasionally of diamond, is remarkable. The first represents the allocation of the normal elements present in a gabbroid magma in such a manner as to give rise to the development of minerals possessing the maximum density; the second, the same effect in the relatively rare case of carbon being present. He instances the well-known occurrence of both diamond and garnet in certain eclogites of South Africa. Dr. Fermor concludes that there must be what he calls an infra-plutonic zone deep in the earth's surface materials, and probably extending far downwards, composed of rocks of eclogitic type and, probably, at such a temperature as maintains them in a plastic-solid state. He explains the occasional appearance of this infra-plutonic rock at the surface as due to special conditions whereby cooling forestalls the effects of reduction of pressure during the ascension of the rock; which in this way attains a region of negligible pressure while preserving a mineral structure proper to very great depths. The well-known kelyphite rims, sometimes surrounding the garnets of eclogites, indicate a partial break-down into mineral structures of lesser density.

The recent results arrived at by Dr. Harold Jeffreys (NATURE, Sept. 25, 1926), based upon the velocity of transmission of compressional seismic waves, point to the existence of a zone of the density of basaltic glass underlying the granitic continents; the basaltic zone being succeeded downwards by one which Dr. Jeffreys suggests may be dunite. The granitic layer may possess an average thickness of from 20 km. to 30 km. The basaltic zone may have a thickness of about 20 km. The underlying layer may extend to a depth of 1500 km.

Daly has contended for the existence of a general basaltic layer extending beneath the continents and oceans. Other eminent petrologists have held this view. We desire here, in the first place, to cite some recently added evidence in its favour. Washington's discovery of the chemical resemblance of the plateau basalts ejected at various times and at different points of the earth's surface, might in itself be regarded as conclusive. The resemblance, however, seemed to fail respecting the radioactivity of the rocks; the Oregonian basalt showing a much higher radioactivity than the Deccan and Hebridean (*Phil. Mag.*, Nov. 1924). However, we pointed out at the time that the authenticity of our 'Oregonian' material was not perfectly assured. Thanks to the courtesy of Prof. Daly, Prof. Landes, and Prof. W. P. Smith, we have been able to examine specimens of Oregonian basalt of undoubted authenticity, and even a fragment from the specimen chemically investigated by Washington. The average radium and thorium contents of Oregonian rocks from twelve localities come out as closely alike with those already determined for the Deccan and Hebridean areas. Those who are inclined to limit radioactivity to local conditions will find it difficult to explain away the chemical and radioactive similarity of these enormous and widely sundered outpourings.

Coming now to the third terrestrial layer—the high-density medium underlying the basaltic—it appears that there is no necessity, so far as seismic evidence is concerned, to suppose this layer to differ from the basaltic save in the matter of its mineral structure. The gabbros and the eclogites are magmatically the same. We have found that an eclogite possessing the density 3·415 yielded upon fusion a glass which when cold possessed a density of 2·746, which agrees with the results obtained by Day, Sosman, and Hostetter (*Am. Jour. Sci.*, 37, 1914) for the density of basaltic glass. The density of eclogite—the piezocrystalline form of the magma—would agree with the seismic evidence. It ranges from 3·2 to 3·5. That of dunite is 3·3. We see, then, that seismic evidence is not opposed to the simplifying assumption that the sub-continental materials as revealed in the plateau basalts may extend downwards to a depth approximating to 1500 km. In short, the assumption of the eclogitic character of the third terrestrial layer involves little more than the acceptance of Dr. Fermor's inference that the pressure conditions which convert carbon into diamond in eclogites is also responsible for the high-density mineral structure of these rocks.

However, there is something more to be said. We have found recently that the eclogites possess on the average barely one-half the radium and thorium contents of the plateau basalts. An explanation, we believe, can be offered for this apparently contradictory result; an explanation which, if it is correct, seems to throw light on the origin of terrestrial surface structure and surface history.

Yet the explanation we would suggest is very elementary and simple. We assume that the outer material of the primeval earth was originally compounded of all those siliceous aggregates afterwards differentiated into the layers we have been discussing; and that it was not throughout uniform in chemical composition. There was heterogeneity on, probably, a very varied scale; in some places coarse, in others fine: and this heterogeneity of distribution and association affected the stable chemical elements as well as those that are radioactive. These assumptions seem to be the most general we can make as well as the most probable.

Let us consider first the effects of heterogeneity in the distribution of radioactive elements. This would carry with it thermal heterogeneity. Some parts would melt before others, and when their surroundings were melted would retain a higher temperature and lower density. These parts would gravitate upwards. Again, some parts of lesser radioactivity would retain for longer periods the solid state. In the depths this condition would be especially effective, for here the pressure confers upon the medium the maximum density, as we have seen. Thus the temperature and pressure conditions conspire to preserve to, or confer upon, the medium a high density; and accordingly it gravitates downwards when the fusion of its surroundings permits. Hence it would come about that such gabbroid magma as was poor in radioactive elements—poor in uranium, in thorium, and in potassium—would retain the solid state longest and sink into the depths. It is a fact that eclogite is poorer than the plateau basalts in all three radioactive elements. Respecting potassium, the mean content of K_2O in the five plateau basalts analysed by Washington is 0·89 per cent. The mean

K_2O content of seventeen eclogites cited by Rosenbusch is 0·70 per cent., and of eleven cited by Mlle. Brière (*Bull. Soc. Française de Min.*, 43, 1920) it is 0·37 per cent. They are, in fact, at once the poorest in the heat-producing elements and the densest rocks known.

There would, also, exist a lack of homogeneity respecting the distribution of the non-radioactive elements. Some parts would be richer in silica, alumina, etc.; others in metallic oxides, etc.; such parts would for ever seek to ascend or to descend. Or, in times of thermal loss, certain well-known factors concerned in magmatic differentiation would operate in the same directions.

The final results should be precisely what we find; a highly siliceous and aluminous surface layer rich in radioactive elements and—what seismic evidence reveals—in the depths, rocks of maximum density and, as we now find, of minimum radioactivity. Should these inevitable final conditions be disturbed by the circulation attending a great revolution, they would gradually be re-established during the long later period of thermal loss. We perceive, in short, that heterogeneity in the circumstances is not stable, but must result in radioactive and gravitational stratification. Reversing our line of argument, we might justify our assumption of initial heterogeneity in recognition of the revealed surface structure of the earth.

If these views are correct, it would appear that radioactivity mainly has been responsible for the stratification of the earth's outer materials. It has determined the origin of the radioactively rich and gravitationally light continental layer, of the isostatic layer of intermediate radioactivity and density, and of that more deep-seated layer which only at long intervals takes part in the great events of surface history: the major revolutions ("The Halley Lecture," 1924, pp. 31 *et seq.*, and A. Holmes, *Geol. Mag.*, July 1926). In short, it would appear to have fashioned those structural conditions which have been responsible for geological history and for the development of life upon the globe.

Further evidence of stratification in the earth's great basaltic layer is revealed in the petrology of the oceanic islands. The island basalt—which we must regard as representing the same lava as composes the ocean floor or prevails immediately beneath it—is richer in all the radioactive elements, and at the same time lower in density, than are the plateau basalts. These island lavas reveal, in fact, the final differentiation of the substratum where it attains the surface of the globe; a differentiation referable to physical causes similar to those we have referred to above.

As bearing on all our views of earth-history we would point out that the low radioactivity of eclogite directly affects estimates of geological time based upon the period required to bring about a major revolution. The length of previous estimates will require to be doubled.

J. JOLY.
J. H. J. POOLE.

Trinity College, Dublin.

Experiments on highly penetrating Radiation from the Earth.

MEASUREMENTS of penetrating radiation of the earth executed at Piatigorsk (in the Caucasus) by means of a portable electrometer covered with lead 1 cm. thick have shown that, though the same apparatus was used, the intensity fluctuated according to the stations of observation where the measurements were made. The fluctuations of intensity were especially marked in places rich in radium, where differences of so much as 100 per cent. were observed between stations separated by a few metres only.

Measurements made at the same observing stations during a period of three years have shown the intensity to be constant and independent of meteorological conditions, and of fluctuations of emanations contained in the atmosphere, within the limits of sensibility of the apparatus.

Measurements of the prevalence of radioactive elements in the upper layers of the soil have shown its constancy, which indicates that the fluctuations were caused by deeper strata only.

The application of four hoods fitting one into the other, each 2 cm. thick and covering the apparatus from above and laterally, and likewise of four flat lead screens covering it from beneath, has shown the influence of the hoods to be very slight, while that of the screens was quite important, indicating that the electrometer was acted upon chiefly from below.

The thickness of lead protecting the apparatus from above, laterally, and from below, having been varied from 0 to 8 cm., the computation of coefficients of absorption was rendered possible. It appeared that the coefficients of absorption by screens varied from 0·45 to 0·06 for 1 cm. Values approaching the lower limit were frequently encountered at different stations. In most cases the value of the coefficient of absorption diminished with an increase of thickness of the lead screens; that is to say, a complex of radiations was being dealt with, some of them possessing a much greater radiating capacity than the γ-rays of radium C. The radiations are directed from below, and their source lies apparently in radio-elements diffused in upper strata of the soil.

The full report of this work will be published in the *Bulletin of the Institute of Practical Geophysics*, Leningrad.

L. N. BOGOIAVLENSKY.
A. A. LOMAKIN.

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Weights and Measures,
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Leningrad.

Spectrographic Observations of the Second Green Line of the Auroral Spectrum.

I THINK that all those who have worked on the spectrum of the aurora will congratulate Prof. Vegard on the notable success he has achieved in photographing so distinctly the line or band about λ5238 as recorded in his letter in NATURE of Mar. 5, p. 349. The technical difficulties which he had to overcome were formidable.

The present letter is not written in an unsympathetic spirit, but it seems worth while to point out that an interpretation alternative to that of Prof. Vegard is possible. He identifies the band with one which he has observed in the phosphorescent spectrum of frozen nitrogen. But there is a band in about the same position in the negative band spectrum of gaseous nitrogen. Ångström and Thalen (quoted by Kayser in "Spectroscopie") gave the wave-length as λ5227·5. The stronger bands of the same series come out with great intensity on Prof. Vegard's photograph as on other photographs of the auroral spectrum: so that it is probable, indeed nearly certain, that a long enough exposure would bring out this band.

If, as would appear from Prof. Vegard's letter, precise wave-length comparisons are not feasible, the criterion of intensity distribution remains. I hope Prof. Vegard may think it worth while to photograph this negative nitrogen band with the same instrument, for direct comparison with the auroral spectrum. It is not unlikely that this would help a decision.

RAYLEIGH.

Terling Place, Chelmsford,
Mar. 23.

Is Darwinism Dead?

IN NATURE of Feb. 19, Sir Arthur Keith brought against me two specific accusations: (1) That I denied in my book "A Companion" (p. 12) the possibility of birds descending from reptiles; (2) that I had given a false reference to Vialleton's high authority. There was a clear issue: (1) Had I said this? (2) Had I misrepresented my authority?

On Mar. 8 I wrote you a brief letter showing that Sir Arthur Keith was ignorant of the great work of Vialleton to which I had alluded, and giving four detailed references. This letter you did not print. In its place you issued, on Mar. 19, a 'comment,' in which you substituted other issues, and repeated as your own the first of Sir Arthur's blunders.

I am therefore compelled to send you this further letter in order that readers of NATURE may be acquainted both with the real issue and its upshot.

(1) I made no affirmation upon the descent of birds. What I did say was that a very great authority (Vialleton) had given strong arguments against the reptilian origin of birds with the natural effect of such an authority so reasoning.

(2) So far from giving a false reference, I had worked upon Vialleton's latest and famous work, and in my letter I gave four page references (585, 588, 590, 592) to that work: of which apparently Sir Arthur had no knowledge, or he could not have blundered as he did.

Your comment leaves your readers under a directly wrong impression upon both points. You re-affirm the error of the first; you make no mention of my specific references in the letter, but only say vaguely that I have caught my critic "referring to the wrong book."

My accuracy, and Sir Arthur Keith's lack of that quality on this issue, can be verified as plain matters of fact by any one who will consult the texts in question.

H. BELLOC.

Reform Club,
Pall Mall, S.W.1, Mar. 28.

MR. BELLOC is under a triple misapprehension. He believes he gave 'references' in his "Companion"; he did not. He left his readers to guess which Vialleton he had in mind; I guessed the right one, and quoted a pertinent passage from Prof. L. Vialleton's best-known work. If Mr. Belloc had been well advised he would have accepted that quotation without comment, for it is less discordant with modern knowledge than the passages of the later compilation to which Mr. Belloc has directed my attention.

In the second place, Mr. Belloc is under a misapprehension as regards Prof. L. Vialleton's range of original work; that writer has never claimed to be an 'authority' on the evolutionary history of birds, nor is he so regarded by zoologists or palæontologists of any country. I am sure Prof. Vialleton will smile when he learns of the claims which Mr. Belloc now makes for him.

Mr. Belloc's third misapprehension relates to the present state of our knowledge regarding the evolution of birds. The evidence drawn from embryology, geology, and anatomy leaves the expert student in no doubt as to their origin; they arose from a reptilian ancestry.

ARTHUR KEITH.

Royal College of Surgeons, W.C.2.

[NO useful scientific purpose would be served by further correspondence upon the points at issue.—ED. NATURE.]

The Atomic Weight of Silver.

THE following few lines give a necessary elucidation to my critical note and to the answer given by Messrs. H. B. Baker and H. L. Riley (NATURE, Mar. 5, p. 348). My principal first theoretical argument is based on the *interdependence* of the atomic weights of the elements silver, nitrogen, and chlorine, resulting from the classical life-work of Richards and his school, in which I have the greatest confidence. If the atomic weight of silver = 107·876, then nitrogen = 14·006 ± 0·0011, and chlorine = 35·456 ± 0·002, most probably 35·458. If we accept Baker and Riley's value, silver = 107·864, then nitrogen would become 13·999, a value exceedingly improbable, especially having regard to the fact that Baxter found recently (*Proc. Amer. Acad.*, **12**, 12, p. 699, Dec. 1926) by an extremely careful physico-chemical research the value N = 14·006(7), which confirms the higher atomic weight of silver, namely, 107·876. This important argument was not referred to by Messrs. Baker and Riley.

My second, no less important, practical argument was based on the assumption that Messrs. Baker and Riley have lost exceedingly small quantities of silver vapour on fusing the metal in hydrogen, so that the atomic weight found by them is slightly lower than the true one. They did their best to convince themselves that no *visible* condensation of metallic silver could be observed in their tubes, and they say that they have begun a new series of experiments to investigate the volatility and condensability of silver. I beg to remark that some experiments on a large scale in this direction were published by J. S. Stas so long ago as 1865 ("Œuvres complètes," T. I, p. 457), who was my first "atomic weight teacher" in 1875 (but who would read such 'antiquated' papers to-day?). He describes the distillation of 50 gm. of his purest silver in the flame of the oxy-hydrogen blowpipe and says: "Je dois avouer toute fois que, dans les opérations que je viens de décrire, la moitié *au moins* de l'argent employé a été perdue. En effet, il a été entraîné à l'état de vapeur bleue pâle avec le courant de *gaz tonnant*, quoiqu'il fût cependant modéré, et sans excès trop grand d'oxygène; il a été répandu dans l'air ambiant dont il a troublé la transparence, et auquel il a communiqué une saveur métallique très sensible."

From this important observation it follows that when silver once passes into the state of vapour it is not easily condensed in a solid state, but forms only a colloidal dispersion as a fog. Large quantities of silver heated in tubes give a condensation of the metal, but when a small quantity was heated and fused, the silver vapour—the weight of which was, in the said experiments, of the order of 0·0001 gm. and which would occupy in the solid state 0·00001 cm.^{3}—may have passed out of the apparatus.

Messrs. Baker and Riley say that they controlled the weight of the fused silver obtained by repeatedly melting and weighing it to constant weight. But the question arises: What was the weight of the silver obtained in a fine state of division immediately after decomposition of its oxide by heat and before fusion? Such silver has a very great surface, and during fusion a small loss by evaporation may have taken place. After fusion, its surface has become very small and, last but not least, it was "coated with a very thin film of dross consisting of silica." To these circumstances the fact is very probably due that no appreciable loss of weight of the silver was observed after repeated fusion.

BOHUSLAV BRAUNER.

Bohemian University, Prague, Mar. 10.

Convection of Heat in Fluid Flow through Tubes.

THE convection of heat to or from the walls of a circular tube conveying fluid in turbulent motion has been studied by a long line of investigators, among whom may be mentioned Joule, Reynolds, Stanton, Nüsselt, Soennecken, Jordan, Stender, Heinrich, and Stückle. From dimensional considerations Rayleigh (NATURE, Mar. 18, 1915, p. 66) deduced a formula which, written in non-dimensional form, is equivalent to

$$\frac{ad}{k} = \phi\left(\frac{Vd}{\nu}, \frac{k}{s\mu}\right), \quad . \quad . \quad . \quad (1)$$

where a = coefficient of transmission of heat.
d = diameter of tube.
V = mean velocity of flow.
k = conductivity of fluid.
μ = viscosity of fluid.
ν = kinematic viscosity of fluid = μ/ρ.
h = diffusivity of fluid = $k/s\rho$.
s = specific heat of fluid.
ρ = density of fluid.

For gases Stanton (Tech. Report Adv. Committee for Aeronautics, 1912–13) gave a formula reducible to

$$\frac{ad}{k} = \text{const.} \left(\frac{Vd}{\nu}\right)^n, \quad . \quad . \quad . \quad (2)$$

in which $n = 0{\cdot}75$ approximately for smooth tubes.

Nüsselt (*Z. V. d. I.*, 1909) proposed a formula for gases reducible to his later form :

$$\frac{ad}{k} = \text{const.} \left(\frac{Vd}{h}\right)^n, \quad . \quad . \quad . \quad (3)$$

which is equivalent to (2) ($n = 0{\cdot}78$).

Formulæ for water of the form :

$$a \text{ proportional to } V^n, \quad . \quad . \quad . \quad (4)$$

have been proposed by Stanton (*Phil. Trans. Roy. Soc.*, 1897), Soennecken (*Forsch.* Heft 108/109), Stender ("Wärmeubergang an strömendes Wasser," Springer, 1924), and others. These formulæ do not make explicit mention of the conductivity. Stender finds that the index 'n' depends on an equivalent mean temperature τ° C. $= 0{\cdot}9Tm + 0{\cdot}1Tw$, where Tm = mean water temperature and Tw wall temperature. Experiments with oil have been carried out by Heinrich and Stückle, but not fully analysed (*Forsch. Arb.* Heft 271).

The object of the present note is to suggest a general formula applicable to all fluids, liquid or gaseous, under conditions of turbulent flow in circular tubes, namely :

$$\frac{ad}{k} = 0{\cdot}0260\left(\frac{Vd}{\nu}\right)^{f\left(\frac{k}{\mu s}\right)}, \quad . \quad . \quad . \quad (5)$$

in which $f(k/\mu s)$ is given approximately by the following values :

$h/\nu = k/\mu s$	0·01	0·10	0·40	1·30
$f(h/\nu) = f(k/\mu s)$	0·97	0·895	0·835	0·785

which lie well on a smooth graph.

This formula agrees well with the experiments of Heinrich and Stückle for oil, those of Stanton, Soennecken and Stender for water ($\tau = 10°$ C. to $\tau = 70°$ C.). It also agrees as well with the results of Jordan, Nüsselt, Pannel, and others for air, as these agree amongst themselves.

A crucial test of the value of formula (5) would be given by experiments with mercury for which the value of $k/\mu s$ lies outside the range of the experiments referred to above.

A complete formula should take account of the ratio of length to diameter of tube, or else the ratio of initial to final excess temperatures, but (5) is put forward as a step towards the correlation of the results of diverse experiments in which the ratio of length to diameter of tube exceeds about 20.

H. F. P. PURDAY.

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Belfast.

The Polishing of Surfaces.

MAY I describe one or two surface-polishing experiments ?

1. The first is more easily described than performed. Prepare a polished biprism having a supplementary angle of 4 or 5 seconds. Continue the polishing of one surface. The debris removed will be carried over the edge and deposited in the minute wedged space between the other surface and the tool. When this space is filled, a continuous perfectly polished surface will be produced and only an appearance of interference on the lee side will betray the original biprism character of the specimen. But under the microscope, and by the judicious use of a steel needle, it will be found that the debris is really only compacted ; it can gradually be broken away and removed. The underlying surface upon which the debris has been deposited retains its original optical polish.

This seems to indicate that, once a group of molecules has been torn from the embrace of its associates, it is practically impossible under polishing conditions to force it back within the region of molecular cohesion.

2. A thermometer embedded in the polishing tool as nearly as possible in contact with the surface will record a rise of temperature of disappointingly small amount. If polishing is due to actual fusion of the 'hill-tops,' it might be expected in practice that, in view of the multitude of the 'hill-tops' acted upon simultaneously, a considerable rise in temperature might be anticipated. This particular theory seems to be based on the assumption that the small amount of energy involved is transmitted into the glass through an extremely minute area. That the area is never extremely small can be observed by carrying out the operation of polishing under the microscope, the action being viewed through the specimen. Within a second or two the area can be extended from about 2 per cent. to 5 per cent. ; in about four minutes the area is about 95 per cent. These results are for a hard pitch polisher. It is remarkable how quickly the pool-like areas spring into view, and an observer will certainly be impressed with the perfection of these areas ; there is no appearance of any intermediate stage suggestive of progressive abrasion.

When the whole area is optically polished, can it be contended that the energy is sufficient to maintain in a state of thermol fusion the whole extent of the surface, however thin the layer may be ? It is necessary to assume that the load is at any one moment carried by a small number of very minute elements, but the test plate applied to an optically polished surface does not disclose any irregularities sufficiently great to penetrate the film of whatever it may be that exists between the surfaces.

JAMES WEIR FRENCH.

Anniesland, Glasgow, Mar. 19.

The Nodes at the Reduction Division in Bivalents of Hyacinthus.

IN the grasshoppers and some other animals, nodes have been demonstrated in the bivalents, at the late prophase, by Sutton, McClung, Robertson, Wenrich, Janssens, etc. One of the Orthoptera, *Chortophaga* sp., has eleven bivalents and one univalent (X chromo-

some) at the late prophase of the maturation divisions in the spermatocytes. These are well shown in iron-acetocarmine preparations. The writer found that the six largest bivalents showed 23 cases with one node to 19 with two nodes. The smallest five bivalents had only one node each. At each node it was obvious, as had been previously demonstrated by others, that one chromatid from each homologue seemed to pass to the other side, while the other chromatid remained on the same side.

In *Hyacinthus orientalis*, where there are eight bivalents at the reduction metaphase, the four largest showed one or two nodes, while the four small ones had only one node. Out of 116 examples of the four largest bivalents, 62 had one node and 54 had two

FIG. 1.—Bivalent chromosomes in Hyacinthus.

nodes. Examination of these nodes showed that one chromatid appeared to pass obliquely across to the other side, while the other chromatid remained on the same side. Also, as in Chortophaga, the planes of the V or ring-shaped portions on different sides of a node were more or less at right angles.

The best working hypothesis for these cases seems to be segmental interchange between the chromosomes (crossing-over between genes). Crossing-over is known to occur in some monocotyledons, such as Zea. In chromosome I of Drosophila, if we calculate the number of nodes which should be seen in the prophases of the maturation divisions of the ova, to correspond with the determined proportions of no, single, and double crossing-over determined by breeding experiments, we find that the results are not far from those given by Chortophaga and Hyacinthus.

Fig. 1 shows three bivalents of Hyacinthus, the central one having two nodes and the other two one node.

JOHN BELLING.

Carnegie Institution of Washington,
Department of Genetics,
Cold Spring Harbor,
Long Island, N.Y.

Magnetic Double Refraction.

THE action of a strong magnetic field in causing a liquid to become birefringent for light rays transverse to the field was first observed by Cotton and Mouton in nitrobenzene, and was later detected and measured by the same authors in many other carbon compounds of the aromatic series and in some inorganic liquids (*Annales de Physique*, 28, 209-243; 1913). In a recent paper (C. V. Raman and K. S. Krishnan, *Proc. Roy. Soc.*, A, Jan. 1927) it has been shown that the large value of the Cotton-Mouton constant in aromatic compounds indicates that the benzene ring, which is known from observations on light-scattering to be optically anisotropic, has also a very pronounced magnetic anisotropy. Observations on light-scattering in carbon compounds of the aliphatic series indicate that the molecules of these substances are optically anisotropic to an extent which, though smaller than in the aromatic series, is yet very marked (K. S. Krishnan, *Phil. Mag.*, 50, 697; 1925). It accordingly seemed very probable that the compounds of the aliphatic series should also exhibit magnetic anisotropy and give a measurable double-refraction in strong magnetic fields.

As Cotton and Mouton did not in their papers report any observable magnetic double refraction in carbon compounds of the aliphatic series except in some isolated cases, we decided to make a systematic re-examination of the subject. A large electromagnet capable of giving 25,000 gauss in a column of liquid 32 cm. long was available to us. By securing the most favourable optical conditions and taking careful precautions to eliminate any disturbance from the Faraday effect or suspended colloidal particles, we have succeeded in definitely establishing the existence of magnetic birefringence in every one of the liquids examined, the list including many hydrocarbons, alcohols, ethers, and esters belonging to the aliphatic series. New pole-pieces are now in course of construction for our electromagnet, with which we hope to reach a field of 40,000 gauss in a liquid column of the same length and to make an extended series of quantitative measurements of magnetic birefringence. There is good reason to believe that such measurements will prove of value in elucidating problems of molecular structure.

C. V. RAMAN.
J. RAMA KRISHNA RAO.

210 Bowbazar Street,
Calcutta, Feb. 15.

An Important Virus Disease of *Lilium longiflorum* and its Varieties.

IN the course of work on the diseases of lilies I have shown by means of controlled experiments that an important disease occurring on *Lilium longiflorum* Thunberg and its well-known varieties of commerce, 'Lilium giganteum' (*L. longiflorum* var. *takesima* Duchartre), 'Lilium formosum' (*L. longiflorum* var. *insulare* Hort. apud Mallett), and 'Lilium Harrisii' (*L. longiflorum* var. *eximium* Baker), belongs to the group of filterable virus diseases and is transmitted by the aphid *Aphis lilii* Takahashi (very close to *A. gossypii* Glov.). The identification of the insect was made by Dr. F. V. Theobald.

The symptoms are a marked downward curling and slightly chlorotic appearance of the leaves. Affected bulbs produce only a flattened rosette, hence the name 'yellow flat' given to the disease.

The disease occurs commonly among bulbs of oriental origin. Rigid government inspection has reduced its incidence in the Bermuda lily fields of 'Lilium Harrisii' to a practically negligible quantity.

Details will be published in due course.

LAWRENCE OGILVIE.
(Plant Pathologist.)

Department of Agriculture,
Bermuda, Feb. 18.

Salaries of University Lecturers.

PROF. H. E. ARMSTRONG'S recent reference in NATURE (Mar. 19, p. 432) to the salary attached to a lectureship in organic chemistry in the University of Sydney may create misapprehension unless it is pointed out that the general scale for lecturers in all subjects at Sydney is £350, rising by yearly increments of £40 to a maximum of £700 per annum. There is little doubt that the conditions for lecturers at Sydney are distinctly more favourable than those prevailing in many, if not most, of the universities of Great Britain.

JOHN READ.

The University,
St. Andrews.

Lister's Contribution to Preventive Medicine.

By Dr. C. J. Martin, F.R.S.

LISTER was one of the greatest discoverers in the realm of preventive medicine. His direct contribution equalled in usefulness that ever made by one man; for the antiseptic system of treating wounds relieved mankind from most of the danger and suffering attendant upon surgical operations and permitted the art of surgery to advance to unimagined achievements. His indirect contribution was great and far reaching, but is less easy of assessment.

The obliteration of wound infection which followed the successful practice of antisepsis was an enormous stimulus to research into the causation of infectious diseases generally. These researches received every encouragement from Lister, because he, like Pasteur, was convinced that infectious diseases would be found to depend upon the invasion of the body by the lower world of microbes. From 1851, when he was a house surgeon at University College Hospital, his attention had been focussed upon the causation of inflammation, suppuration, fever, and constitutional disturbance, which at that time almost invariably followed surgical operations. That suppuration was not inevitable was clear, because sometimes wounds healed without it, the edges uniting firmly together in a comparatively short time without any bodily illness. After many fruitless attempts to comprehend the process and causation of suppuration, Lister concluded that it would be wise to attack the problem from the beginning and to study the phenomena of inflammation occasioned in the simplest way. To this end he applied hot water and various chemical irritants to a minute portion of the web of a frog's foot and watched under the microscope the effect upon the blood-vessels and surrounding tissues.

Lister's paper on the early stage of inflammation, published in the *Philosophical Transactions* in 1858, is now classical. In it he showed that inflammation was a reaction of the tissues to a noxious stimulus from without. The problem was: When a wound became inflamed, what was the noxious stimulus? This question was ever present in his mind, but no answer was forthcoming, until in 1865 a scientific colleague directed his attention to Pasteur's studies on fermentation and putrefaction. The full significance of Pasteur's observations was immediately apparent to Lister, as his mind was prepared by his previous experimental work. Infection of wounds by germs, and the action upon the tissues of the products produced by them, would supply the cause he was looking for. Were all these untoward phenomena due to the putrefaction of the liquids exuded by the injured tissues? This inference was tested by ingenious experiments and its accuracy was proved, to the lasting benefit of mankind. It should be emphasised that Lister's discovery of the *nature* of wound diseases was one of the great steps in the progress of preventive medicine, and antedated by fifteen years the proof that any particular microbe was indeed the cause of disease.

At this time (1865) the enlightened medical world had grasped that Pasteur's discovery that particular fermentations were produced by specific microbes indicated the possible nature of the various *contagia viva* responsible for disease. It was appreciated that diseases bred true, as dogs and cats bred true, and that they did not arrive *de novo*, although their ultimate origin was as mysterious as the origin of species of higher animals or plants. The real nature of the *contagia* was pure guesswork.

The success of Lister's treatment of wounds was a powerful stimulus to the study of the cause of infectious diseases, but, occupied with the development of his antiseptic system of surgery, he could take little part in these researches. Nevertheless, in the intervals of a busy life, he did find time for bacteriological investigations of a fundamental character.

This new realm of scientific discovery yet lacked appropriate methods, and Lister had to forge his tools as required. He carried out these early researches in his back parlour. Their importance and the ingenuity of the methods he devised are dealt with in their proper perspective by Prof. Bulloch in another article in this week's issue of Nature.

For fifteen years Lister was the principal representative and exponent in Great Britain of the new knowledge, bit by bit unfolded, of the relation of micro-organisms to disease. As his preoccupations increased with his renown, his personal contributions to bacteriological research, perforce, diminished, but the good effect of his encouragement increased.

Whenever the application of bacteriological discoveries to the public health was in question, Lister always took a prominent part. He was president of the Bacteriological Section of the International Congress of Hygiene in 1881, when Koch demonstrated his newly discovered methods of cultivation upon solid media and isolation of different bacteria. In 1890, Koch introduced tuberculin for the treatment of tuberculous infections. Lister, who had a profound respect for Koch, arranged for a thorough trial of the method in his wards at King's College Hospital. Unfortunately, the results, though encouraging at first, proved disappointing.

At the second Tuberculosis Congress in 1901, Lister was in the chair when Koch communicated the results of his experiments upon human and bovine tubercle which had led him to the conclusion that human and bovine tuberculosis were two distinct diseases and that there was no danger for human beings from the consumption of milk or meat from tuberculous cattle. Lister very courteously, but nevertheless trenchantly, criticised Koch's conclusions, pointing out that although the evidence adduced by Koch to show that human tuberculosis could not be communicated to bovines seemed convincing, his reasons for supposing the

reciprocal process to be unusual were far less satisfying. In view of Koch's pre-eminence as a bacteriologist and considering the importance of the question, the Congress moved for the appointment of a Royal Commission of inquiry. This suggestion was adopted by the Government. Lister was not a member of the Commission, but he took an active interest in its labours, and when it reported in 1911, it completely justified the criticisms made by him ten years before.

Another enterprise in the interest of preventive medicine which had Lister's sympathy and active support from its inception, was the foundation in England of an institute for the study of the causation and prevention of disease. The origin of the Lister Institute, as it is now called, was as follows. On July 1, 1889, a meeting was held at the Mansion House, London, for the purpose of taking steps to present M. Pasteur with a grateful acknowledgment from Great Britain of his gratuitous kindness in Paris to more than two hundred British patients who had been bitten by rabid animals. The acknowledgment took the form of a donation of £2000 to M. Pasteur for the use of the Institut Pasteur in Paris. At the same time the committee realised the want in the United Kingdom of an institute similar in character and purpose to the Institut Pasteur in Paris, or to the Hygienic Institute in Berlin, and others, established on the Continent for scientific research into the causation and prevention of the various infective diseases of men and animals.

With the idea of meeting this need the British Institute of Preventive Medicine was incorporated on July 25, 1891, and the objects of the Institute were set forth in a Memorandum of Association, namely:

(*a*) To study, investigate, discover, and improve the means of preventing and curing infective diseases of man and animals; and to provide a place where research may be carried on for the purposes aforesaid.

(*b*) To provide instruction and education in preventive medicine to medical officers of health, medical practitioners, veterinary surgeons, and advanced students.

(*c*) To prepare and to supply to those requiring them such special protective and curative materials as have been already found, or shall in future be found, of value in the prevention and treatment of infective diseases.

(*d*) To treat persons suffering with infective diseases or threatened with them, in buildings of the Institute or elsewhere.

(*e*) With a view to effecting these objects, to provide laboratories, to appoint a scientific staff, to institute lectures and demonstrations, to issue publications of the transactions of the Institute, and to found a library.

Lister succeeded the Lord Mayor as chairman of the committee after its first meeting, and was the first chairman of the council of the British Institute of Preventive Medicine. Among his colleagues were Roscoe, Huxley, Ray Lankester, Burdon Sanderson, Horsley, Cheyne, and Sir Andrew Clark. Lister was a regular attendant at the meetings of the council for many years and took the most active part in the management of the Institute. The office of chairman of the council was for a while no sinecure, and the direction of the new Institute was an anxious task. During its early years it had great financial difficulties to contend with, and on more than one occasion its continued existence was almost despaired of. It was only by means of the enthusiasm and careful guidance of its council and the self-sacrifice of the small body of scientific men which composed its staff that it did not succumb to inanition.

It was also unfortunate in changing its birth name more frequently than is good for a young institution. In 1898 it became the Jenner Institute of Preventive Medicine in order to receive the donation of a sum of money collected to perpetuate the memory of Edward Jenner and his work. Afterwards it was found that a trading firm possessed the prior legal claim to this title, and a further change of designation being necessitated, it was decided to associate the Institute in future with the honoured name of its chairman. It thus, in 1903, became the Lister Institute of Preventive Medicine.

In the meantime the financial stresses which threatened the collapse of the Institute had been considerably relieved by substantial donations from the Berridge Trustees, the Grocers' Company, and a number of public-spirited men. The Duke of Westminster having granted, on terms which meant a large personal contribution, a fine site facing the Thames at Chelsea Gardens, the council proceeded to build one-half of the present headquarters of the Institute. These were opened in 1897.

The permanent income of the Institute was not, however, adequate to the requirements and capabilities of the enlarged establishment, until towards the end of 1898 it received, for the encouragement of research into the cause and treatment of disease, a most generous endowment of a quarter of a million sterling from Lord Iveagh. This endowment enabled the governing body to extend greatly the usefulness of the Institute and to increase the —up to that time—very inadequate staff.

The development of serum therapeutics in 1894 attracted general interest in preventive medicine. A few years previously Behring had discovered that by accustoming an animal to small but progressively increasing doses of tetanus poison, the serum of such an animal possessed the property of neutralising considerable quantities of the poison. This discovery was amplified and put to practical use for the treatment of diphtheria by Roux and Ehrlich, and rapidly established itself as the only rational and effective treatment for this disease.

The preparation of antitoxic sera was at once taken up by the Institute. Some temporary premises near London where horses could be accommodated were acquired, and as soon as the value of the remedy was established the council purchased a freehold property near Elstree, Hertfordshire, where a complete equipment for the production of anti-toxic sera and for research into serum therapeutics was installed.

Since then the activities of the Institute have

increased considerably, but two of the objects for which the Institute was founded, the education of medical officers of health and the treatment of patients, have been discontinued. Elementary education in bacteriology was soon afterwards adequately provided for by the medical schools, and the prophylactic treatment for hydrophobia, which was the particular treatment in view, was no longer required owing to the freedom of the British Isles from rabies.

The advantages which the Institute enjoyed from its association with Lister were, in the earlier days of its history, by no means confined to his guidance as chairman of its council. To the scientific staff he was always a colleague. Whatever the nature of the problem they were occupied with, they were sure of his sympathy, and his knowledge and critical insight were ever at the disposal of the humblest worker. During the latter years of his life, although no longer able to take an active part in directing its affairs, he did not cease to take a keen interest in the welfare of the institution he had been largely instrumental in founding, and he manifested his confidence in its continued usefulness by making it joint beneficiary with the Royal Society under his will.

Some Aspects of Lister's Scientific Work.

By Prof. William Bulloch, F.R.S.

My qualifications to write on certain aspects of Lister's scientific work rest on an acquaintance with his published writings. I have studied these critically by themselves and in relation to the writings on the same subjects by his contemporaries. For more than ten years I also had the great privilege of knowing Lord Lister in a manner which, considering the great disparity of our positions, I may say was almost intimate. As bacteriologist to the British Institute of Preventive Medicine I had to visit him as chairman almost weekly, to keep him in touch with the progress of the work in the antitoxin department. Even after I left the service of the Institute he frequently asked me to call upon him in connexion with scientific work in which he was interested. In this way I was a great deal in his company and, among the younger men of that time, probably saw more of him than any one else.

When I first knew Lord Lister he was sixty-eight, and I last saw him in 1909 when he was eighty-two years of age. Both then and since he impressed me as a great personality. He was deeply interested in all advances of medical knowledge and, although leading a very busy life, he strove to keep abreast of bacteriological literature, which was then pouring forth in an unbroken stream. I read through with him most of the complicated papers of Ehrlich and Bordet on hæmolysis. During the reading he would make many suggestions or criticisms which might clear up doubtful points. Finished with the work in hand, he would recur to his own work of early days and indicate the difficulties he had had and how he had overcome them. In a conversation we had on Oct. 23, 1905, he said to me—I wrote it down at the time: "If my works are read when I am gone, my papers on the pigmentary changes in the frog and on the early stages of inflammation will be the ones most highly thought of." These were not the mumblings of senility, for he was then intellectually clear and alert. I took it to mean that he wished to be considered as a scientist rather than a surgical craftsman.

In estimating Lister's scientific work it is essential to remember that he had no properly equipped laboratory as we understand the term to-day. There were none such, or but few at the time. His laboratory was his study in his private home, and perhaps the best of his scientific work was that done in 11 Rutland Street, Edinburgh, during his first stay in the northern capital. His principal work on antiseptics was done during the Glasgow period, while his bacteriological work was begun and largely completed in his second Edinburgh period when he resided at 9 Charlotte Square.

The hours for Lister's scientific work were early in the morning and far into the night following a harassing day of active surgical work in private practice, or in the wards, operating theatre, and class-rooms of the Edinburgh Infirmary. He performed all his appointed duties in a most conscientious way, and he undertook his experimental work so that he might speak with first-hand knowledge on the themes which he had to teach. Many of the problems he felt impelled to investigate were obscure and complicated, but of the greatest practical importance. Some were not capable of solution then, and others have not yet been definitively cleared up. I refer in particular to his work on the coagulation of the blood and on the early stages of inflammation.

The coagulation of the blood has at all times excited wonderment, and the theories to explain it have been innumerable and are still being brought to light. In Great Britain notable advances were made in the eighteenth century by William Hewson, who unfortunately died of sepsis from a wound before he was thirty-five. In his short life he made, however, many discoveries. He proved that the red corpuscles were biconcave discs; he described their arrangement in masses like piles of money, an observation extended in 1827 by Lord Lister's father in association with Dr. Thomas Hodgkin. Hewson also clearly noted the existence of the white blood corpuscles and performed a large number of experiments on blood coagulation, although he never quite cleared up the mystery of its nature. His successors in the nineteenth century were not more happy. Coagulation of the blood was early studied by Lister. The problem was constantly before him in connexion with intravascular clotting

and the occurrence of putrefaction and secondary hæmorrhage in wounds. The prevailing theory was that of B. W. Richardson, and referred the clotting to the escape of ammonia, which was believed to hold the coagulative elements, normally, in solution.

In a long series of masterly experiments Lister showed that this ammonia theory was untenable. He clearly saw the need of separating the nature of coagulation from the cause, and while baffled with the former he revealed by his experiments that the latter—the cause of coagulation—is really due to the influence exerted on the blood by the contact, even momentarily, of ordinary matter of some kind. He considered that this contact brings about a reaction between the solid and fluid constituents of the blood so that the corpuscles imparted to the *liquor sanguines* the disposition to clot. As regards the cause of blood coagulation, it cannot be said that we have materially advanced during the seventy years since the publication of Lister's paper.

Another basic pathological process which Lister examined was inflammation. The extraordinary changes which we call inflammation have at all times attracted attention, and the theories intended to explain it constitute a large part of the history of medical doctrines. What is the real nature of the process which we call inflammatory and which results from the application of an *irritamentum* to the body? When Lister began his studies on inflammation, great advances on the older doctrines had already taken place. In England particularly, the science of experimental pathology was in process of rapid growth. The older pathological anatomy so ably created by Morgagni was developed well by the French, among whom the names of Bayle, Portal, Laennec, Bretonneau, Chomel, and Cruveilhier will be brought to mind. Students went from Great Britain to study pathological science in France.

At the beginning of the nineteenth century Edinburgh was a great nursery of medical talent, and many of her graduates migrated across the border to attain fame in the arenas of the south. We all remember with pride the names of Charles Bell, Richard Bright, Thomas Addison, Thomas Hodgkin, C. J. B. Williams, Marshall Hall, William Sharpey, and the peculiarly able if eccentric Wharton Jones. Their work was advanced by the experimental work of Augustus Volnay Waller and of the little-known but successful worker William Addison. Lister had both Sharpey and Wharton Jones for his teachers. The margination of the leucocytes in the inflamed vessels was taught by C. J. B. Williams, and W. Addison about 1842 and Waller (1846) rediscovered the process of emigration of the leucocytes, which had been previously described by Dutrochet in 1827. Wharton Jones summed up in most critical fashion all the work down to 1846, and himself gained the Astley Cooper prize in 1850 for his splendid essay on the phenomena of inflammation.

When, therefore, Lister began to work at the pathology of inflammation he was traversing ground already trodden. He realised, however, that much that had been done concerned the later stages of the process, whereas the real essence of inflammation was most likely to be found by the study of the earliest stages. He worked chiefly with the frog's web and the bat's wing, and took elaborate precautions that at first the parts should be in a perfectly normal condition. By the application of irritants he then passed to the study of what was pathological. Among the phenomena which he particularly investigated may be mentioned the aggregation of the red blood corpuscles, their increased adhesiveness, and the structure of the arterioles and capillaries. He found that the capillaries alter in calibre, but referred the variation to something inherent in their elasticity. While admitting the phenomenon of contractility in the capillaries, modern workers have not accepted his explanation. Lister regarded irritants as acting in a twofold manner. The primary effect was a dilatation of the vessels brought about by the influence of the nervous system and not limited to the *locus* of the irritant. The secondary effect, on the other hand, was the direct result of the irritant acting on the tissues in consequence of which the blood becomes altered physically. The red discs become more adhesive, they accumulate in masses and may bring about the condition of stasis.

Strange to say, Lister made no reference to diapedesis of leucocytes, and probably missed it altogether. Waller's discovery of 1846 had left so little impress at the time that when diapedesis was described in detail in 1867 by Cohnheim, it was regarded as something altogether new. Previous to Lister's work, the advanced changes in inflammation had been observed and very fully described by Wharton Jones, but it is to Lister's credit that he examined it from a new viewpoint and discussed its significance more than his predecessors had done. He was, however, surpassed by Cohnheim in his classical work in 1867.

When Lister embarked on his extended researches on wound complications and the cause of suppuration, his experimental inquiries on blood and inflammation were a great help to him. He was groping unaided for the causes of suppuration, but light was beginning to peer through the darkness. This was early in his Glasgow term. In 1865 his attention was directed by a colleague to the work which had been done on fermentation and putrefaction by Pasteur, and this came to him as a revelation. Almost immediately he grasped the significance of the Frenchman's work for surgery. Ten years later (1875) he specifically tells us that the work of Pasteur "long since made me a convert to the germ theory, and it was on the basis of that theory that I founded the antiseptic treatment of wounds in surgery."

Although Lister constantly stated his indebtedness to Pasteur, it is, I think, a vulgar error to regard him as a mere copyist of his great French contemporary. So early as 1861, and before he knew Pasteur's results, he was getting near the truth about suppuration, and later on he advanced

beyond the point where Pasteur had led him. No doubt Pasteur revealed to him in a more concrete form what he had dimly foreseen himself, and from then onwards he was ardent in the pursuit of bacteriology. The time would be the early 'seventies, when the study of microbes had not emerged as a definite science. There were at the time two conflicting views. One of these, supported by Ferdinand Cohn, the botanist of Breslau, held that bacteria, like other plants, had a constancy of form which rendered them capable of division into genera and species. According to the other view, there was no morphological constancy, but rather a pleomorphism, whereby one and the same bacterium could assume different forms. If this were true, attempts to cultivate or to separate them on morphological grounds were doomed to failure.

In his earliest work on the subject in 1873, Lister's observations led him to support the pleomorphic theory, and it will now be admitted that he suffered shipwreck upon it when he stated that Ehrenberg's and Cohn's morphological classification was "entirely untrustworthy." Lister's mistake was one which at the time was made by a great many others and tends to indicate the extraordinary pitfalls which beset the path of the earlier bacteriologists. In his life of Lister, Godlee has published an interesting correspondence which passed between Lister and Pasteur on the subject of change of form among bacteria. Pasteur clearly saw where Lister had erred and advised him to repeat his observations with additional technical precautions. This Lister did, and profiting by his new experience he became one of the foremost bacteriological technicians of his time. So imbued was he with the spirit of high ideals that instead of covering up his tracks he handsomely withdrew his error. "Next to the promulgation of truth," he said, "the best thing I can conceive that a man can do is the recantation of a published error." This sentiment was almost identical with that given to us nearly two thousand years ago by Celsus, who, however, added that such a confession is suited only to a great genius whose splendour is such as to survive the sacrifice, especially in the performance of a task which is to be handed down for the benefit of posterity as a beacon of truth to warn them against similar errors.

From the theory of Cohn and Pasteur it was to be presumed that bacteria might in some way be separated from each other and cultivated in a pure state. The great mycologist, Brefeld, had emphasised the importance of raising such pure strains or cultures from one single germ or cell of a fungus. Following in his wake, Lister was the first to isolate a pure culture of a bacterium. By perfect bacteriological technique involving a complete understanding of the problem, he succeeded in isolating a pure culture of a microbe, *Bacterium lactis*, which is the cause of lactic-acid fermentation in milk. He grew this microbe in sterile milk and raised a pure strain, constant morphologically and physiologically, from a single cell by a series of dilutions carried out with an ingeniously constructed syringe of his own invention. No one can deprive Lister of the merit of having first isolated bacteria in pure culture outside the body. The year was 1877. Lister also introduced the methods of hot-air sterilisation which are in vogue today. His long paper on lactic fermentation is a classic, and a model of what a scientific research should be.

Like Pasteur, Lister had the supreme faculty of seeing as if by instinct the exact experiment needed to clear up a point of doubt. All his scientific work bears witness to this, but I may refer to one other instance of it. In two or three experiments which he did on the fate of catgut implanted in the tissues, he got out all the essential facts in 1869, and later attempts of others in more than three hundred papers down to 1927 have, literally speaking, neither added to nor subtracted from anything which he taught us sixty years ago. He was a master of the experimental method—a rare and precious gift which, the Abbate Spallanzani truly said, "has always been confined and always will be confined to the few."

Obituary.

Prof. Carl Runge.

WITH the death, on Jan. 3, 1927, of Prof. Carl Runge, of the University of Göttingen, in his seventy-first year, there has passed away an eminent mathematician and a friend to several generations of English-speaking students in Germany.

Runge, whose mother was English, was born in Bremen in 1856 and was educated at Munich and Berlin. In 1886 he was called to the Technical High School at Hanover, where he remained until 1904, when he moved to a professorship at Göttingen in response to an invitation from Klein. Coming in early life under the dominating influence of Weierstrass and Kronecker, it was not unnatural that his first work should be in the field of function theory and algebra, but the urge towards the practical, which directed much of his later work, was soon apparent. Many of his lectures at Columbia University, where he went as an exchange professor in 1909–10, deal with this aspect. At Hanover, as a mathematician in an engineering environment, he had perforce to devise ways and means of adapting methods of mathematical analysis to the practical. Many of his numerical and graphical methods, numerical integration, solution of differential equations and Fourier analysis are now commonplace in engineering training. In this respect his influence on German teaching methods was rather similar to that of Perry in Great Britain. Wherever possible he played an active part in actual practical work, as for example when he assisted in a large geodetic survey, and his appreciation of real problems

reflected itself in his teaching and in his theoretical research. His many contributions to the fields of technical mechanics and aerodynamics are evidence of this.

Runge was, however, something more than an engineer, a mathematician, and a teacher. Among experimental physicists he is known for his fundamental work in collaboration with H. Kayser on spectral series, and his work in this field ranks him among those who have laid the experimental basis of quantum mechanics. He examined the spark and flame spectrum of radium. He investigated the magnetic resolution of spectrum lines, and showed that the apparently complex separation may be expressed as simple fractions of that of the normal Zeeman triplet. With Paschen he devised a concave grating mounting that has been adopted in many laboratories. He was pre-eminently one of those all too few men of science who could turn his mind profitably to any field of scientific inquiry with the certainty of producing creative work. Educationally, in Germany his influence was to give a practical orientation to the theorist, and a theoretical outlook to the practical man. To English-speaking students in Göttingen he was undoubtedly the most English of the professoriat, both in appearance and in mental outlook, and he spoke the language fluently. His son was killed early in the War. H. L.

SIR CHARLES WALSTON.

WE regret to record the death of Sir Charles Walston, the well-known Cambridge archæologist. Charles Walston (formerly Waldstein, the change in spelling having been effected in 1918 at the end of the War) was born in New York of parents of Jewish stock on Mar. 30, 1856. He was educated at Columbia and Heidelberg Universities, and went to Cambridge at the age of twenty-four at the invitation of Henry Bradshaw and Henry Sidgwick as a lecturer in classical archæology.

A brilliant and stimulating teacher, with abundant vitality and unbounded enthusiasm, Walston's qualities as an archæologist and his keen perception of the details of artistic style early won him wide recognition as an authority, and at the same time did much to stimulate the study of ancient sculpture in Cambridge. In 1894 he was elected a fellow of King's College. He held various university posts; among them the readership in classical archæology, the directorship of the Fitz-William Museum, the Slade professorship from 1895 until 1901 and from 1904 until 1911. From 1889 until 1893 he was director of the American School of Archæology at Athens, where he conducted important excavations at Platæa, Eretria, and on the Heraion at Argos (1892–1895). After the expiration of his term as director he retained his professorship at the School until 1896.

Walston's more important publications on archæological and artistic subjects were: "Essays on the Art of Phidias," 1885, "The Work of Ruskin," 1894, "The Study of Art in Universities," 1895; "The Argive Heraion," 1902; "Art in the Nineteenth Century," 1903; "Herculaneum, Past, Present, and Future," 1908; "Greek Sculpture and Modern Art," 1914; and, quite recently, "Alcamenes and the Establishment of the Classical Type in Greek Art," a work of considerable importance and of broad and comprehensive learning, in which he maintained that throughout the early periods up till the fifth century B.C. one facial type, which he called the Minoan, prevailed in Greek art, differing essentially from the classical type. Walston's interests were by no means confined to his special study, and he wrote on a wide variety of subjects of public interest and, during the War, made a number of contributions to the literature of the time, in which he expounded and interpreted national and social tendencies. In this field his most valuable contribution was "Aristodemocracy," published in 1916, while in "Harmonism and Conscious Evolution," 1922, he set out his theory that the æsthetic principle lies at the root of science, morality, and all man's other activities.

DR. C. DA FANO.

DR. C. DA FANO, reader in histology, King's College, University of London, died with unexpected suddenness at his residence at Campden Hill on Mar. 14, in his forty-eighth year. By his death medical science in Great Britain loses one of the ablest exponents of histology.

Dr. Da Fano was the third son of Commendatore Alessandro Da Fano. He received his early training in histology in Golgi's Institute of Histology and General Pathology at the University of Pavia, where he graduated M.D. in 1905 and later (1912) became *Libero Docente* in morbid anatomy. He obtained a travelling fellowship at Milan and worked in Ziehen's neurological clinic, University of Berlin, in 1908, and in the following year with Dr. Bashford at the Imperial Cancer Research Fund, London. After a period of work at Groningen he returned to the University of Milan as vice-director of the Pathological Institute. From 1915 until 1918 he served as captain in the Italian medical corps on the Italian front. In 1918 he went to King's College, University of London, as lecturer in histology, and in 1922 was given the title of reader in histology in the University.

Dr. Da Fano specialised in the histology of the central nervous system. His advanced lectures on that subject attracted large audiences, and the histological specimens by which these lectures were illustrated formed a complete and noteworthy collection. His researches, published in a series of about sixty papers in various journals, were mainly concerned with the Golgi apparatus in cells and the special lesions of the nervous system in such affections as encephalitis lethargica. He had a very extensive knowledge of foreign languages, and he generously devoted a considerable portion of his time to acting as one of the editors of *Physiological Abstracts*. In 1915 he married Miss Dorothea Landau, and leaves a son and daughter.

News and Views.

In an article appearing in the supplement to the present issue of Nature, Sir Joseph Larmor gives a novel interpretation of the local space and time of relativity theory as the absolute space and time of Newtonian dynamics and astronomy. This is clearly not the place to attempt a detailed critical analysis of this important paper, but it may be permissible to summarise a few of the salient arguments. The correlation of past and present astronomical research, as well as the absolute character of atoms, evidenced by spectroscopic research, wheresoever and whensoever they are found, demand absolute time. The welding of local frames of inertia into one coherent fourfold is the business of relativity; the mutual dynamics of masses existing in each local frame proceeds independently by Newtonian principles. The mathematical development is effected by means of the Principle of Least Action, modified to suit the requirements of electrodynamics and relativity and limited as to form by the necessity of conforming to the postulate of invariance. The requisite formulation of a compound Action-density is first minimised as regards its distribution with reference to variation of structure of the fourfold pseudospace, giving structural differential equations of that fourfold, and then by partial integration the Action is reduced to line integrals along the tracks of the atoms in the fourfold.

By a further minimising of the Action in its new form, Sir Joseph obtains the expression, suitable to the fourfold, of the dynamical interaction of the atoms. An essential feature is that the track of the atom is not treated as an isolated geodesic, determined by the gravitational warping of the pseudospace, of which it is both partial cause and effect, but is connected with other tracks through mutual terms in their potential energy, which are shared between the interacting atoms. In an earlier paper by Sir Joseph (*Phil. Mag.*, S. 6, vol. 45, p. 243, 1923) this sharing of potential energy led to a reduction of Einstein's gravitational constant to one-half of its usual value, because there the time t of the invariant space-time interval of relativity theory was as usual identified with astronomical time. In the article now under discussion, this untoward result is avoided by identifying the local time T, *i.e.* the invariant time t now corrected for convection by means of the Lorentz transformation, with the absolute time of Newtonian dynamics and astronomy. This procedure leads to Einstein's values of the displacement of spectral lines and of the gravitational deflexion of rays of light, but apparently not to his result for the progressions of planetary perihelia, a conclusion regarded by Sir Joseph as not unsatisfactory in view of the uncertainty of the progression of the perihelion of Mercury, as shown in recent astronomical discussions. Moreover, it leads to the proper relation between electric mass and energy relative to the fourfold, a relation which is not substantiated at all except on the present Newtonian scheme.

April 5 was the centenary of the birth of Lister, physiologist, pathologist, and the 'father of modern surgery,' and elsewhere in this issue Dr. C. J. Martin and Prof. W. Bulloch describe some aspects of his life and work. Celebrations of the centenary commenced in London on April 4, when H.M. The King received delegates from learned societies, universities, and medical societies in Great Britain, from the Dominions and many foreign countries, who are attending the ceremonies arranged by a joint committee of the Royal Society, the Royal Colleges of Physicians and Surgeons, the Royal Society of Medicine, the British Medical Association, and other bodies. Sir Ernest Rutherford, president of the Royal Society, presented an address to the King, to which His Majesty replied, expressing the hope that the gathering of scientific workers for the centenary celebrations would "strengthen the co-operation of all nations in the accumulation of scientific knowledge for the common benefit of the human race." Personal memories of Lister were given by Sir St. Clair Thomson in an address before the Royal Society of Medicine in the evening, and by Sir Watson Cheyne and Sir George Lenthal Cheatle at a meeting in the afternoon of the Listerian Society. On April 5, the official delegates of centenary celebrations were received by the Prime Minister at the house of the British Medical Association, and on the following day a memorial service was held at Westminster Abbey. We hope to give an account of the proceedings in an early issue. Centenary celebrations at Glasgow began on April 1; those arranged at Edinburgh will be held concurrently with the annual meeting there in July of the British Medical Association.

The text has been issued of the Destructive Insects and Pests Bill, which was introduced into the House of Commons by Mr. Guinness on Mar. 25. This Bill provides that an order under the Destructive Insects Act, 1877, as amended by the Act of 1907, may enable an authorised inspector of the Ministry of Agriculture to take necessary action with reference to any crop infected with an insect specified in the order as being a destructive insect within the meaning of the principal Act, which has been introduced into Great Britain. The Act provides that such an inspector may remove or destroy, or cause to be removed or destroyed, any crop infected, or any crop by means of which the insect is likely to be spread. The Bill also provides for the payment of compensation in respect of any crop removed or destroyed. Until now, very few introduced pests have gained a footing in Great Britain, but the provisions under the new Bill are timely precautions. A few years ago the Colorado potato beetle became established in the Bordeaux district of France and its eradication now seems scarcely possible. The entry of such a pest into Great Britain would constitute a menace to a crop that suffers to an almost negligible extent from insect pests. Notwithstanding precautions against their admittance, foreign pests may secure a foothold, and

the new Bill provides for the necessary action in the event of such an occurrence. The heavy infestation of cherries from some parts of the continent with the cherry fruit fly is another case in point, but happily that insect likewise has not yet become established in Great Britain.

THE first statutory general meeting of the British Mosquito Control Institute was held at the Hotel Cecil, London, on Mar. 30, when the council was elected in accordance with the articles of association approved by the Board of Trade, and by which the Institute is registered under the Companies Acts, 1908–1917, as a company limited by guarantee and not having a share capital. Since the anti-mosquito campaign was begun at Hayling Island about seven years ago, it has become increasingly evident that the work so successfully accomplished there is of more than local interest, and that medical officers of health and sanitary inspectors in many parts of Great Britain, as well as abroad, desire to know how to keep mosquitoes under control. The Ministry of Health can only concern itself with these insects as disease carriers, even though in some districts they make life out of doors almost intolerable in certain months of the year. The Natural History Museum is always willing to identify specimens and give general guidance on methods of dealing with them, but neither it nor the Ministry of Health is concerned with actual field operations by which the mosquito nuisance may be reduced or eliminated. This practical knowledge is, however, available at the British Mosquito Control Institute at Hayling, where there is now a substantial building with laboratory, museum, photographic room, and other facilities for the study of all stages of mosquito life and its regulation. The Institute has been vested in trustees by the founder and director, Mr. J. F. Marshall, whose devoted services in solving problems of mosquito control are widely known and appreciated. Membership is open to all who are interested in the subject, and it is hoped that, in due course, sufficient support will be forthcoming from members and public bodies to make the Institute self-supporting and extend its activities. The council includes among its members Sir Ronald Ross, Sir William Simpson, Sir Arthur Shipley, Dr. Andrew Balfour, Major E. E. Austen, Sir James Crichton-Browne, Dr. G. A. K. Marshall, Dr. C. M. Wenyon, and other entomologists familiar with the mosquito pest, and the chairman is Sir Richard Gregory. The address of the Institute is Hayling Island, Hampshire.

CAPT. C. W. R. KNIGHT'S kinematograph exhibition "Filming the Golden Eagle" should be seen by every one interested in wild life. It began a short season at the Polytechnic Theatre, Regent Street, W.1, on April 2. By means of this excellent film one is enabled to make intimate acquaintance with one of the finest and least common species in the native avifauna of Great Britain. The pictures were taken last year at three different Scottish eyries, and many interesting incidents from the lives both of the young and of the mother bird are shown. In one case, Capt. Knight was even able to follow the young with his camera for some time after they had left the nest and were able to fly. Perhaps the most striking items are the slow-motion pictures of the adult bird in flight: these include photographs of a trained captive eagle catching the lure in mid-air. In addition to various incidental pictures, there are also some short episodes from the lives of other birds, and those of the chaffinch and of the longtailed-tit are particularly good.

A DISPATCH from Cairo dated Mar. 31, which appeared in the *Times* of the following day, announces the discovery at Saqqara by Mr. Cecil Firth, working for the Department of Antiquities, of a tomb of the Third Dynasty of about 2900 B.C. The tomb, which has a rounded top, is situated on part of the wall about a mile long which surrounds the Step Pyramid. It is thought that it may be the tomb of Imhotep, the architect of the Step Pyramid. An interesting feature of the tomb is the work of low relief on the doors of the underground rooms. Each represents Pharaoh Zoser in the finest artistic style of the period, and although the figures stand out only a millimetre, each muscle is distinctly shown. Twelve magnificent alabaster jars nearly three feet high were found.

DR. GANN'S preliminary account of his explorations during the past winter in British Honduras, which appeared in the *Morning Post* of Mar. 28 and two succeeding days, again provides material of much interest to the student of Central American archæology, although it contains nothing so sensational as his discovery last year of the early dated stele at Chetumal Bay. An unsuccessful search for a bilingual record, which might play the part of a Central American Rosetta Stone, in the first Spanish church at Villa Real, the settlement founded by Davila in 1528, was followed by a visit to a camp on the lagoon On Ha on the northern boundary, where excavations on burial mounds produced evidence of Toltec influence on the Maya in the form of a clay squatting tiger with a human head protruding from its mouth. Northwest from Sac Xan on the Rio Hondo, Dr. Gann discovered great ruins of a temple structure 120 feet high, of which the roofs must originally have been at least 160 feet from the ground. It contained a single chamber 58 ft. long, 18 ft. high, and only 3 ft. wide. Chambers in other buildings were as narrow, or even less in width. The Maya ignorance of the principle of the true arch and their employment of the method of overlapping stones in roofing restricted the width of their buildings to at most 16 ft., but nothing proportionately so narrow as these chambers is known in Central America. Dr. Gann conjectures that they were constructed for ceremonial purposes.

AN exceptional opportunity for the comparative study of folk-dances will be offered by the festival to take place at Bayonne on April 27 and 28. It is being organised by the Musée Basque de Bayonne. A team of fourteen dancers of the English Folk Dance Society will take part in the festival and will give

two performances, one at the annual ball in aid of the funds of the Musée, and the second on the afternoon of the following day, when the English dancers will dance in alternation with teams from the Basque provinces of La Soule, Labourde, Basse Navarre, and Guipuzcoa. As some of the dances from these provinces, each of which has its own tradition, are of a very primitive type, yet in certain features present resemblances to some English folk-dances, their presentation at the same performance should be highly instructive. It will be remembered that Miss Violet Alford, both in the paper read before the British Association at Oxford last year and later, in the autumn, at the joint meeting of the Royal Anthropological Institute and the English Folk-Dance Society (Nature, Dec. 4, 1926, p. 824) stressed the significance of the *Danse de l'Ours* of Basse Navarre in relation to the meanings of some of the primitive traits in English dances, and she is now engaged in carrying her researches further in the Pyrenees area. The English Folk Dance Society's party, which will include in addition to the dancers any members of the Society and their friends who wish to avail themselves of this opportunity, will leave for Bayonne on April 24.

Mr. J. Allen Howe delivered the Friday evening discourse at the Royal Institution on April 1, taking as his subject "The Stones of London." Situated on a sub-stratum of clay and incoherent gravel, London, from its very beginnings, has had to go beyond its borders for stone. In the fragments of the Roman Wall we have evidence that its builders sought the slopes of Hertfordshire for boulders of hard sarsen stone, the Downs and the Weald of Kent for chalk, ragstone, chert, and firestone; while the local flint gravel was freely used then as now. The Normans introduced the stone from Caen, of which examples may be seen in the Tower, Westminster Abbey, and other buildings. Beer stone from Devon and the somewhat similar Clunch stone, both from the Chalk formation, were much in demand for carving from about the eleventh century; while for columns, beautifully exemplified in the Temple Church, the marble of Purbeck was the favourite material. From the Great Fire of 1666 a new stone era began for London; although many other stones have been and still are employed, Portland stone from that time began to play a dominant part. The majority of London's buildings are now built or faced with limestone, which is readily attacked by the acid-laden town atmosphere, yielding calcium sulphate in the process; this is in itself a cause of further destruction, as the solution soaks into the stone and there crystallises. In the presence of the acid-bearing air the principal cause of unsightly decay is a state of dampness, which may be conditioned by the aspect, the construction, or the design. Continual efforts are being made to discover a preservative that will not impair the appearance of the stone. The least objectionable of these processes, for example, the various silico-fluorides, are liable to prove ineffective after a comparatively short period, and the latest, Dr. Laurie's silicon-ester, is still on trial. The difficulty with all external applications is imperfect penetration with the consequent danger of skin formation.

The annual lecture to the Graduate Section of the Institution of Mechanical Engineers was given by Sir John E. Thornycroft on Mar. 28, his subject being "Torpedo Boats and their Machinery." It is more than sixty years ago that Sir John I. Thornycroft began steam-boat building at Chiswick, and it was his work and that of Sir Alfred Yarrow which made the Thames famous as the home of the high-speed vessel. There is no more fascinating story in engineering than the history of torpedo craft, from the early boats of 30 tons to the destroyers of to-day of more than 2000 tons. The latter have boilers and turbines of more than 40,000 H.P. giving a speed of nearly 40 knots. Turbines have been fitted for twenty years, but in the four-cylinder triple expansion engines of earlier destroyers mechanical engineering of the nineteenth century reached its highest pitch of excellence. The speed at which they ran, the lightness of their construction, and the conditions under which they worked, were all remarkable. Sir John in his lecture gave comparative figures which showed that the machinery of a liner in 1855 weighed more than 600 pounds per horse-power, while in a modern destroyer the corresponding figure is 30 pounds. In the coastal motor boats built during the War and fitted with internal combustion engines, the weight was only 12½ pounds per horse-power.

At a meeting of the Newcomen Society on Mar. 30, a paper on "Lead Mining and Smelting in West Yorkshire" was read by Dr. A. Raistrick. In the course of his paper Dr. Raistrick traced the history of lead mining in the Yorkshire dales from Roman times down to the present day, giving notes on the method of quarrying the ore, smelting it, and its sale and transport. Lead pigs are in existence bearing the names of Roman emperors, and there is evidence to show that the industry was carried on continuously, practically down to the present time, though to-day little is being done. The cheaper ores from Spain and elsewhere have been the main cause of the decline, but as foreign mines have to go deeper and instal more machinery, the ore will increase in price and thus the Yorkshire mines may again become profitable. The paper contained much of interest to those who study the history of mining.

Purchases during March for the Department of Zoology of the British Museum (Natural History) included a collection of rare land-snails of the genus Nenia from Peru, Bolivia, etc., and a remarkably fine golden eagle from Norway. The Trustees also purchased, for the Department of Geology, seven specimens of an ancient roofed-head amphibian, Protriton, from a new locality in Thuringia. This little salamander-shaped animal is well preserved in a dark oilshale of Lower Permian age; it is one of the Branchiosauria, which owe their name to the indications of gill-arches in the skeletons of immature individuals. A large collection of skulls and heads of African game animals was presented by Major C. H. B.

Grant. These are particularly valuable since they are accompanied by full details of locality, season, and the like; many of them represent species or races that are now in danger of extermination. Among other donations submitted to the Trustees was a small series of fossil-bearing rocks obtained by the Norwegian expedition of 1921 from the palæozoic formations of Novaya Zemlya. A nodule containing a V-shaped burrow, probably formed by a kind of lob-worm, was presented by Dr. S. H. Haughton, who obtained it from the Upper Dwyka shales of the Warmbad District, South West Africa; it suggests that these rocks were formed on a tidal flat. Mr. J. R. T. Regan presented some curious branching structures, probably worm-tubes, found by him in the Totternhoe Stone near Dunstable. Other donations included nummulites from north-west India described by Major L. M. Davies, and type-specimens of shells from a fresh-water sandstone of unknown age in the Fiji Islands collected by Dr. Matley.

THE completion of a second submarine cable connecting Canada with Australasia is an event of considerable importance. E. S. Heurtly, in an article in the *Electrician* for April 1, gives many interesting details of the work. It involved the laying of two cables, one between Bamfield, on Vancouver Island, and Fanning Island (3466 sea miles) and between Fanning Island and Suva, Fiji Islands, a distance of 2054 sea miles. The original cable, which was laid in 1902, had a working speed of about 75 letters per minute. By using amplifiers, however, its speed has been increased to about 135 letters per minute. The maximum speed on the new northern cable is at least eight times as great as that of the original cable, and the received voltage at Fanning Island is at least five times as high. The great improvement in the traffic-carrying capacity of the two cables is due to the 'loading' of the cables by alloys of nickel-iron, which have a very high permeability for very low magnetising forces. The 'chrome permalloy' used for loading the southern cable has better electrical characteristics than that used on the New York-Azores cable. The original cable has one advantage over the new cables, as duplex working can be used with it. Owing to the difference in times between Europe and Australasia there is little overlapping of the messages going in opposite directions, and consequently this is not a serious drawback to the new cables. Accurate measurements of the time of propagation of the signals between Bamfield and Fanning Island have been made by means of a siphon recorder used with an amplifier and a tuning-fork. The mean of all the results shows that the signal takes 0·67 of a second to travel 3466 miles. When signalling, therefore, at 1000 letters per minute, more than 40 impulses may be in the cable at the same time.

ONE of the most remarkable of recently constructed tunnels is the Rove tunnel on the new canal between Arles on the Rhone and the port of Marseilles, by the use of which river traffic can avoid the delta or the crossing of the sea between the terminus of the old canal at Port au Bouc and Marseilles. A fully illustrated article on the canal water appears in *La Science Moderne* for February. The Rove tunnel under the Nerthe hills is nearly four and a half miles long. It has a width of 72 feet, of which 13 feet are utilised by the pathways beside the canal. The depth of water is seven feet and there is room for two streams of canal traffic, with a height above the water line of about 43 feet. Apart from through traffic, this canal promises to be of value in the new scheme, now under way, of making the great Étang de Berre, beyond the northern end of the Rove tunnel, a great port, accessible by large vessels from a wide and deep ship canal at Port au Bouc. Around this extensive harbour is ample room for manufacturing sites. Provided the water power of the Rhone and its tributaries is made available, the port of Marseilles may well become a great centre of manufacturing industry.

THE magazine of the Geographical Association, on reaching its fourteenth volume, has been named *Geography* in place of the original title *The Geographical Teacher*. The change in name involves no change in policy or scope. It is still to be published three times a year and to be devoted to the interests of teachers, but its general appearance and production have been much improved. In addition to the usual short articles, notes for teachers, and reviews of geographical books, the spring number contains Sir Charles Close's presidential address on "Population and Emigration," in which he makes a statistical study of Empire settlement. In the belief that the Dominions can absorb annually about five per thousand of their total population, he estimates that Great Britain could send overseas about 100,000 emigrants a year apart from the number that go outside the Empire. He gives a total of about 168,000 as the reasonable annual emigration.

NO. 4 of the *Quarterly Review of Biology* completes volume 1, and the editors, Profs. Raymond Pearl and R. W. Hegner, are to be congratulated on the success of their initial volume. The trustworthy and readable articles on subjects of current interest and importance in various fields of biology, and the helpful notices of new biological books, have established the reputation of this new *Review* and have made it what its editors intended it to be—useful to the professional biologist, to the worker in other sciences who wishes to maintain his general interest in biological progress, and to the intelligent lay reader. The principal article in this issue (No. 4) is a comparative account by Dr. Adolph H. Schultz of the fœtal growth of man and other primates, which is excellently illustrated by drawings, diagrams, graphs, and tables. The London agents for the journal are Messrs. Baillière, Tindall and Cox, 7 and 8 Henrietta Street, Covent Garden, London, W.C.2.

DR. P. CHALMERS MITCHELL will deliver the annual Huxley Memorial Lecture at the Imperial College of Science and Technology, South Kensington, on May 4, taking as his subject "Logic and Law in Biology."

SIR JAMES BERRY, president of the Royal Society of Medicine and author of standard works on surgical subjects; Sir H. Walford Davies, professor of music, University College of Wales, Aberystwyth; and Sir Frederick Keeble, formerly Sherardian professor of

botany, University of Oxford, and distinguished by his work in pure and applied botany, have been elected members of the Athenæum Club under Rule II., which provides for election by the Committee of "persons of distinguished eminence in science, literature, or the arts, or for public services."

THE annual dinner of the British Science Guild will be held at the Criterion Restaurant, London, on Thursday, May 12. Lord Askwith will preside, and the guests include Sir Alfred Mond, Sir Herbert Samuel, the Hon. W. Ormsby-Gore, Sir William Pope, and Sir Frederick Keeble. Particulars may be obtained from the Secretary, British Science Guild, 6 John Street, Adelphi, W.C.2.

AT the annual general meeting of the Ray Society held on Mar. 24, the following officers were re-elected: *President*, Prof. W. C. McIntosh; *Treasurer*, Sir Sidney F. Harmer; *Secretary*, Dr. W. T. Calman. Dr. G. P. Bidder was elected a vice-president, and Mr. J. Spedan Lewis and Mr. F. Martin Duncan were elected new members of council. It was announced that the Society's issue for 1927 would be the first volume of a "Monograph of British Sea Anemones," by Dr. T. A. Stephenson, which will be illustrated with coloured plates from the author's drawings of the living animals. It is expected that this work will prove unusually attractive as well as of great scientific interest.

APPLICATIONS are invited for the following appointments, on or before the dates mentioned:—An assistant master for mathematics at the Government High School, Nassau, Bahamas—The Board of Education (C. A. (T.)), Whitehall, S.W.1, or The Scottish Education Department (T.), Whitehall, London, S.W.1 (April 11). An assistant pathologist at the Charing Cross Hospital Institute of Pathology—The Secretary of the Institute, 62 Chandos Street, W.C.2 (April 25). Junior assistants in the aerodynamics department of the National Physical Laboratory—The Director, National Physical Laboratory, Teddington (April 30). A lecturer in geography at Armstrong College—The Registrar, Armstrong College, Newcastle-upon-Tyne (May 7). A professor of agriculture at Armstrong College—The Registrar, Armstrong College, Newcastle-upon-Tyne (May 20). An assistant in the Dominion Museum, Wellington, New Zealand—The High Commissioner for New Zealand, 415 Strand, W.C.2 (May 31). An assistant in the Laboratory of Zoophysiology of the University of Copenhagen, mainly for research work in respiratory metabolism and gas analysis—Prof. A. Krogh, The University, Copenhagen. A teacher of design, with special reference to the textile industry, at the Leicester College of Arts and Crafts—The Registrar. A senior biology mistress at the Cheltenham Ladies' College—The Principal.

Our Astronomical Column.

THE BIELID METEOR SHOWERS.—Mr. Willard J. Fisher, of Harvard Observatory, contributes a paper to *Proc. Nat. Acad. Sciences*, Dec. 1926, in which he collects a large amount of material relating to various apparitions of these showers, and plots them in the endeavour to trace the laws of their recurrence. In 1741 and 1798 the shower occurred on Dec. 6 and 7; there were also December showers in 1830, 1838, and 1847, but all since then have been in November, owing to the motion of the node. On plotting the showers they appear to group themselves along four different lines, indicating presumably that there are several condensations of meteors along the orbit, their periods being slightly different. Many of the brighter showers are separated by intervals of 13·0 years (double the period of the comet). It is noteworthy that three of the four lines in the diagram converge towards a point a few years ahead of the present time, when the date of the shower will be Nov. 16. It will be well, therefore, to keep a careful watch for these meteors in coming years.

COMET GRIGG-SKJELLERUP.—It is curious how this comet has consistently been associated with the British Astronomical Association. It was found both in 1902 and 1922 by members of the Association, Mr. J. Grigg of Thames, New Zealand, and Mr. Skjellerup of Cape Town. The suggestion of identity was first made by Mr. R. T. Crawford and Mr. W. F. Meyer of California, but it was Mr. G. Merton, another member of the Association, who finally proved it, and made a prediction for the return of the present year.

Mr. F. J. Hargreaves, the director of the photographic section of the Association, was the first to photograph the comet at the present return, on two successive evenings, Mar. 27 and 28. It was Mr. Merton who detected the very faint images of the comet, Mr. Hargreaves having overlooked them. Further confirmation was obtained by a photograph taken by Prof. Schorr at Bergedorf on Mar. 31. Mr. Hargreaves uses an aero-lens of 20 inches focus, the mounting being home-made. It is a great encouragement for amateurs that this tiny equipment beat the instruments at the Yerkes and Harvard Observatories, which reported in the same week that they could obtain no trace of the comet. The explanation is that such large, faint, diffused objects are specially adapted to small-scale photographs using a large light-ratio. The deduced date of perihelion is May 10·245, 1927, U.T., which is only one-tenth of a day earlier than Mr. Merton's predicted date, May 10·34. This date had been communicated to Mr. F. E. Seagrave, who published ephemerides based upon it, but without mentioning Mr. Merton's name.

The corrected elements are as follows:

T 1927 May 10·245 U.T.
ω 355° 1′ 48″
Ω 215 32 1 } 1927·0
i 17 29 18
ϕ 43 48 58
$\log q$ 9·95068

Period 4·98772 years.

Ephemeris for 0^h U.T.:

		R.A.	Decl.	log r.	log Δ.
Apr.	6.	5^h 58·6^m	1° 25′ S.	0·0123	9·7642
	14.	6 11·8	1 17 N.	9·9896	9·7213
	22.	6 27·3	4 43	9·9707	9·6676
	26.	6 36·1	6 49 N.	9·9633	9·6363

The comet will approach within 19 million miles of the earth early in June. It will probably be a difficult object to observe accurately, being large and diffused.

Research Items.

THE DIVINITY OF THE GUEST.—In the *Ceylon Journal of Science*, vol. 1, Pt. 3, Mr. A. M. Hocart discusses the position of the guest and his relation to his host in ancient Greece, in India, and in Fiji. In ancient Greece no distinction was made between a stranger, a host, and a guest, as they were not distinguishable. Further, not only was the god present with the stranger, and Zeus the patron of strangers, but also he was often regarded either as a god or actually was a god, as is shown in the manner in which Odysseus was addressed in Phaeacia. The exchange of gifts and the return of hospitality, potential or actual, created a bond of hereditary guest friendship out of which grew the consular system in historical times. The idea that the god accompanied strangers was evidently a check on an unhospitable age. In India, in the Atharvaveda the divine character of the guest is worked out in detail, every act of hospitality being identified with some phase of the sacrifice to a god. In the Anguttara Nikaya, the offerings to the Manes include a reception of guests, who are selected either as being learned or virtuous Brahmans, or as being relations through females. In Fiji, various ceremonial observances towards strangers, including the making of gifts, point to their sacred or heavenly character. In Fiji, however, intercourse takes place only through kinsmen, the kinship being either actual or, in case of necessity, fictitious. It is reckoned through the female. There was also a system of official guest friends. It is suggested that the Homeric system may have developed from some such archaic form as the Fijian, India being the common link in which the offerings to kinsmen and guests are distinguished, while in Fiji the recipients are identical; but in both countries divine honours were accorded to guests. The resulting hypothesis is that the divinity of the guest grows out of the divinity of the kinsman, who stands in cross relationship to the host, and this is extended fictitiously to any stranger.

WEAPONS AND ARMOUR OF THE PHILIPPINE ISLANDS.—A description by Mr. Herbert W. Krieger of the collection of primitive weapons and armour of the Philippine Islands in the United States National Museum, which appears as No. 137 of the Museum's *Bulletin*, is of a wider ethnological scope than its title might suggest. The author, in his introductory remarks, deals not only with the history of the collection, which is derived from a variety of sources, and has been given at different times, but also with the development of the types of weapons of the Islands and of their tribal cultures. The various types preserved in metal, bone, wood, and horn, bear traces of the several waves of civilisation that have reached the Philippines. They extend from the primitive digging stick, which may be a club or, with slight adaptations, an axe, a spear, a sword, a knife, or a hoe, down to the cannon of brass and firearms of Spanish manufacture in the possession of insurrectionary native troops. Tribal groups and nationalities manifest in their weapon production and types of body armour and shields a nearness to, or remoteness from, foreign culture influences. No one group has retained exclusively any one type of material culture. Some elements survive from a primitive Melanesian strain; other tribes show borrowings from the aboriginal Negrito; the Batak use the blowgun, a typical Malay weapon, while the Negritos of Zambales and the Luzon east coast use the Malay shield. Fine iron and steel blades, which have come to be recognised as characteristic of the Mohammedanised Moros, show a decorative design on the blade and a blade form invariably of Hindu or Arab character. Although the Spaniards found a crude crucible of stone in use for crushing gold ore and quartz, there appears to have been no stone age in the Philippines. Bamboo furnished in early days all the material required for implements and weapons until those made of iron were introduced from Borneo.

CLASSIFICATION OF HEMIPTERA.—The greater part of Vol. 7 published by the Connecticut State Geological and Natural History Survey, 1923–1925, is occupied by an extensive memoir of more than 800 pages forming Bulletin 34 of the Survey and entitled "The Hemiptera or Sucking Insects of Connecticut." Its author, Dr. W. E. Britton, in collaboration with a number of specialists in different families of the order, has provided a trustworthy and authoritative guide to the classification of Hemiptera, which will be found useful to entomologists in many countries. The bulletin is virtually a text-book on its subject and is well illustrated and provided with a full index.

DISTRIBUTION OF FOOD FISHES IN THE NORTH SEA.—In *Fishery Investigations* (Min. Agric. Fish.) ser. 2, vol. 9, No. 4, 1926, Mr. J. O. Borley provides a series of most instructive charts portraying the quantitative distribution of the marketable sizes of the principal food fishes in the North Sea during the years 1923 and 1924. It should be noted that only fish taken by the trawl are treated; species such as the herring, which are very largely caught in other nets, are dealt with only in so far as they are trawled. The charts are drawn up from the landings of British steam-trawlers, referred to the place of capture. The areas to which landings are referred are small rectangles each 1° of longitude by 30′ of latitude; these vary somewhat in extent with latitude, from 1500 square miles in the southern bight of the North Sea to approximately 1200 square miles in the region of the Shetlands. Each chart depicts a set of contours which indicate the relative frequency of occurrence of one particular trade category of fish, in grades of abundance from less than 1 cwt. to more than 100 cwt. per 100 hours of fishing. A loose key-chart, printed on transparent paper and showing the approximate position and names of some of the chief fishing grounds, is provided, which may be superimposed on the others as desired. The whole work demonstrates very clearly the scientific value of the carefully compiled statistics of commercial landings at British ports. Some notes on the natural history of the fishes dealt with in the charts, prepared by Miss Thursby Pelham from a variety of sources, form a supplement to this publication.

FLEAS AND PLAGUE.—Vol. I., Pt. 4, of the *Ceylon Journal of Science* (Dec. 1926) is devoted to the results of researches by Dr. L. Fabian Hirst on the parasitology of plague. He has returned to the important problem of the transmission of plague by the fleas *Xenopsylla cheopis* and *X. astia*. All attempts to transmit plague between rats, mice, and guinea-pigs by means of *X. astia*—596 fleas and a variety of methods were employed—at room temperature in Colombo during four plague seasons gave negative results. Plague was successfully transmitted to twelve rodents by means of 95 *X. cheopis* in the course of six separate experiments at room temperature. Plague was successfully transmitted from mouse to rat at an artificially reduced temperature (70° F.) by means of *X. astia*; a female flea of this species with 'blocked'

proventriculus transmitted plague to two out of four of the rats on which its bites were observed. Rise of temperature may exert an unequal effect on the transmitting power of two different species of rat-flea. The second part of the work deals with the bionomics of the two species of fleas—egg-laying, life-history, longevity (that of the female being greater), factors which influence biting, etc. A useful list of the rat fleas of the world is given, and appended is a brief account, with seven plates, by Stanley Hirst, of the principal species of Acari parasitic on rats.

POLLINATION EXPERIMENTS WITH PEAS.—More detailed observation of Mendelian ratios is revealing consistent departures from expectation, which have to be explained by differences in the conditions under which the pollen tubes grow down the style of a flower or in the viability and rate of growth of pollen tubes, as well as by reference to other features of flower structure. Dr. C. J. Bond (*Jour. of Genetics*, vol. 17, No. 3) has experimented on these points by pollination of the F_2 hybrids between pea varieties having respectively round yellow and wrinkled green seeds. By pollinating immature stigmas, he finds an increase in the recessives resulting, presumably because the pollen grains bearing the recessive factors, and probably containing more sugar, are more viable or grow faster when the stigma is finally ripe. He also finds a small increase in the proportion of recessives when minimal pollination, *i.e.* only a few pollen grains on the stigma, is used. The explanation of this probably lies in the ovules, as the effect is more marked when the seed-parent carries the recessive characters. Dr. Bond thinks he also gets evidence that the functional ovules in flowers on different parts of the plant bear somewhat different proportions of the dominant and recessive factors. Such results are to be expected with a more detailed knowledge of the physiology of the ovule and pollen development in the plant.

SPONTANEOUS COMBUSTION OF HAYSTACKS.—The losses to agriculture due to the spontaneous combustion of haystacks prove to be considerable. In *Matériaux pour l'étude des calamités* for July-September 1926, Mr. G. Laupper goes into the problem at length and shows from statistics drawn from Switzerland and Germany that such fires are commonest after a good hay season and are least frequent in poor hay years. The monthly incidence also shows a clear maximum in July and August, with high figures for October and November. The summer maximum he associates naturally with the initial high temperature of the hay after its thorough exposure to solar rays before and after being made into ricks, while a good hay season means that the hay is rich in hydrocarbons, the decomposition of which is at the root of the trouble. The yearly loss to agriculture through stack fires in Germany is calculated to be about one million pounds and in Switzerland to be little less. No sure means of prevention have been discovered. Layers of straw or salt in the ricks have been proved valueless, and ventilation is not a certain cure. The only measure that can be recommended is spreading the hay as soon as abnormal temperature is noticed.

THE SURVEY OF INDIA.—The General and Map Publication Reports of the Survey of India for 1925–26 have been published. The total area of new surveys of all kinds completed during the year was 42,489 square miles. About 45 per cent. of the total area assigned to the department has now been surveyed. Work for the new geodetic level net of India made steady progress. Tidal observations were continued as in past years. Map publication included five new sheets of the one-million map of India and adjacent countries, which is now nearing completion except for Arabia; twenty-seven new 'degree' sheets, sixty-nine half-inch and 127 one-inch sheets. The modern topographical map of India thus grows steadily, though only a little more than one-third of the total number of sheets have yet been published. The reports contain full index maps to the sheets available.

SIZE AND FIGURE OF THE EARTH.—Newton's theory of gravitation was held up for several years on account of lack of accurate knowledge of the size of the earth, and Newton himself first estimated the earth's figure from its speed of rotation. The determination of the size and figure of the earth has during the last two centuries exacted enormous labour from geodesists. It is generally assumed that the earth is approximately an ellipsoid of revolution, so that only the equatorial radius and the flattening have to be determined. Observations made in different regions of the globe are, however, rather discordant, the differences amounting to several parts in 100,000 as to the size and about 1 per cent. in the flattening. The labour which the observations have involved is so great that every effort should be made to make the fullest use of them. One difficulty in utilising the separate arcs which have been measured results from the fact that they have been discussed with respect to different figures. The figure of Clarke (1880) suits the European observations well, but a considerably different figure was deduced by Hayford from American observations, and this latter was adopted at the Madrid meeting of the Union of Geodesy and Geophysics as the reference figure for future calculations. To simplify comparisons, particularly with Clarke's spheroid, accurate tables have been computed for the Royal Geographical Society, and by means of these Mr. A. R. Hinks has discussed the principal geodetic surveys. He shows the impossibility of separating the two unknowns from arcs near the equator, and shows that different arcs fit different spheroids, and that those in India and South Africa do not fit any spheroid well. The difference in the results cannot arise from errors in the geodetic observations, but the astronomical observations may be effected to a considerable extent by local attraction, as in India. The probability is, however, that the approximation of the earth to a spheroid is only rough. Mr. Hinks points out that gravity observations can also be treated by a graphical process, and that they likewise indicate departure from a common spheroid when different regions of the earth are considered.

HELIUM CONTENT OF JAPANESE MINERALS.—On heating certain minerals containing helium, approximately 50 per cent. is evolved, and the method has been used by J. Sasaki to determine the helium contents of some Japanese minerals. The gases obtained by heating the powdered substances in an evacuated quartz-glass tube are passed over solid potash, red-hot copper oxide, and soda-lime to remove carbon dioxide and hydrogen. By sparking with oxygen in a eudiometer, nitrogen is converted into nitric oxide, which is absorbed by moist potash floating on the surface of the mercury, and the excess of oxygen is allowed to combine with melted phosphorus. The remaining impurities are removed when the residual gas is subjected to a discharge in a modified Geissler tube with liquid electrodes of a sodium-potassium alloy, and to the action of charcoal cooled in liquid air. Estimates of the geological ages of two of the minerals have been calculated by

Rutherford's method and appear together with the other data in the December issue of the *Bulletin of the Chemical Society of Japan*. The figure for monazite is 90 million years, and that for fergusonite 150 million years.

MAGNETIC ELEMENTS IN THE UNITED STATES.—The United States Coast and Geodetic Survey has recently issued two small pamphlets (Nos. 353, 360, price 10 cents each), one detailing the results of magnetic observations by the Survey during 1925, the other giving a chart, for the whole of the United States, of magnetic declination and its secular change per year, for the epoch 1925. The Survey issues such isogonic charts and secular-change data every five years, suitable stations being reoccupied during the intervening periods, in order to obtain the data necessary to carry the charts forward. With the chart is a full explanation of its construction and use to surveyors, also instructions to enable a surveyor to determine the declination with the aid of a compass and observations of the sun or stars. Tables are given for use in connexion with such celestial observations, and also tables of secular change in declination for a large number of stations, at intervals from 1750 to 1925. The first pamphlet (No. 353) gives observations of declination, dip, and intensity at respectively 330, 123, and 121 stations, widely scattered throughout the States, and including also some in the Philippines, Greenland, and the Aleutian Islands.

INDOOR ELECTRICAL ILLUMINATION.—It was stated by Mr. J. W. T. Walsh, of the National Physical Laboratory, in a paper on illuminating engineering which he read to the Institution of Electrical Engineers on Mar. 3, that 90 per cent. of the people in Great Britain carry on their work after daylight hours by an inadequate illumination and an unsuitable system of lighting. To quadruple the illumination and distribute it properly would result in better health and higher efficiency. The sources of illumination used in the early days cast unpleasant shadows. To get over this defect the indirect system of lighting, in which all the light from the source was reflected upwards to the ceiling and was then diffused over the room, was devised. The result was an almost complete absence of shadow, which, although suitable for a few special purposes, such as drawing-office work, was found to be most inconvenient for other work, such as sewing, where the shadows cast by the individual threads are a help. As a consequence of this defect, the modern semi-indirect system of lighting has been evolved. In this system part of the light is transmitted downwards through a bowl of diffusing material, while the remainder is emitted upwards to the ceiling as in the indirect system. The author considers that each of the three systems has its own field of usefulness. He thinks that in a lecture theatre, the totally indirect system has a tendency to appear lifeless and gloomy even though the amount of the illumination is ample. Some direct sources of light ought therefore to be provided in addition. The reflexion of a bright source of light from a polished surface or from a glossy paint or enamel often causes an objectionable glare. Methods should always be devised to obviate this.

ELECTRICITY SUPPLY.—In the *Journal of the Institution of Electrical Engineers* for March, Mr. J. R. Beard gives a report of the progress made in the transmission and distribution of electricity during the past year. He mentions that for many years the installation of transformer substations out-of-doors has been common abroad, and now, owing to the high cost of buildings, it is becoming common in Great Britain. Until recently all substations for converting from alternating to direct current were manually operated. Owing mainly to the increase in the rates of wages, automatic apparatus for starting up, shutting down, and controlling the apparatus in these stations is now largely used. Experience has shown that automatic control gives greater security than manual control. A recent development is 'supervisory control,' in which the operation of a number of automatic substations can be regulated from a central control point. This combines the accuracy of automatic control with the intelligence of manual control. All the substations on the 170-mile 3000-volt main line electric railway in Natal are operated automatically. Mr. Beard mentions one curious fact in connexion with low-voltage supply in Great Britain and the United States, namely, that while a pressure of about 230 volts is general in the former, a voltage of 115 is used in the latter. The reason seems to be that in the early days the life of the low-voltage lamps was much longer and their efficiency was much higher than that of high-voltage lamps. It is almost the universal custom in America for the supply authorities to supervise and maintain consumers' lamps. In Great Britain this is left to the consumer. Twenty years ago the low-voltage lamps were much cheaper to maintain, and so the over-all efficiency with their use was greater than that with high-voltage lamps. This, combined with the cheaper wiring systems used, explains why 115 volts is still the standard pressure in the United States. Mr. Beard sums up in favour of alternating current distributed in the three-phase four-wire system.

DOPES AND DETONATIONS.—A second communication from the Air Ministry Laboratory by Prof. H. L. Callendar and collaborators, dealing with the effect of antiknock compounds on engine 'knock,' appeared in February issues of *Engineering* (pp. 147, 182, 209). The previous report (Reports and Memoranda, No. 1013) led to the conclusions that detonation was due to the presence of nuclear drops in the charge in the cylinder during explosion, and that 'antiknock' concentrated in the drops, decomposed and protected them from oxidation by the formation of a metallic film or, in the case of the organic dopes, by dilution with a substance of high critical temperature. Such an explanation being inadequate to explain the different behaviour of various dopes, the present communication extends the work on the chemical side. It is found that detonation in paraffin fuels and ether is due to the accumulation of peroxide in the nuclear drops during rapid compression. The amount of peroxide formed would not in itself be sufficient to cause the detonation observed, but acts as a primer causing simultaneous ignition of the drops. The metallic dopes are considered to act by reducing the peroxides as fast as they are formed, preventing their accumulation, and thus delaying the ignition of the drops. The processes of slow combustion of various fuels are investigated by observing the temperature at which combustion becomes appreciable, the dopes being shown in this way to delay oxidation by preventing peroxidation of the fuel. A striking experiment is described, showing the difference in the kind of ignition obtained when the vapour of paraffin is ignited in a hot tube as compared with paraffin spray. In the former case the vapour burns with a quiet flame; in the latter the mixture burns with slight explosions and flashes of flame. The present communication adds to our knowledge of the behaviour of combustible mixtures.

Light and Growth.

THE action of light on plants has had a perennial interest for plant physiologists, and recently the subject has received some concentrated attention. Ferdinand Hercik (*Publications de la Faculté des Sciences de l'Université Masaryk*, No. 74, 1926) has tried to correlate the action of light and the surface tension of the expressed sap of his plants. He finds that the sap of normally grown seedlings of Lupinus, Sinapis, and Pisum has a greater surface tension than sap from stems of etiolated seedlings. On the other hand, sap from leaves of normally grown seedlings has a smaller surface tension than sap from leaves of etiolated seedlings. Now etiolated plants have usually greater stem growth and less leaf growth than normal plants, and the author correlates the greater surface tension with less growth and the smaller surface tension with greater growth. If, however, seedlings have the same length, then the surface tension of their respective saps is the same irrespective of the conditions under which they have been grown. The author has not traced the causal chain between the surface tension of the sap and the actual phenomena of growth.

In a series of papers in the *New Phytologist* (vol. 24, 5, and vol. 25, 3 and 4), Prof. J. H. Priestley deals with the problem from a slightly different viewpoint and advances some tentative explanations of his results. In the case of the broad bean (*Vicia Faba*) he was able to destroy some of the more marked etiolation phenomena by only very brief exposures to light—two minutes in every twenty-four hours. He points out that any change produced on etiolated plants by the action of light must be initiated, not by the effects of photosynthetic products, but by the photocatalytic effect of light upon the products of metabolism. For example, cells from the cortical region of an etiolated broad bean tip are incapable of being plasmolysed in a 17 per cent. cane-sugar solution, but, after exposure to artificial light for one hour on two successive days, are plasmolysed readily. The author considers that the photochemical action of light releases protein and fatty substances from the developing walls of the cells intervening between the central cylinder and meristem; and these walls, now consisting of purer cellulose, readily permit of the transfer of the nutrient sap from the central cylinder, with an ensuing more diffuse and more superficial development of merismatic tissue. In this way growth, which in the etiolated plant is confined to tips of stems, becomes redistributed.

The phototropic curvature of grass and cereal coleoptiles, the subject of much experimentation, is explained by Prof. Priestley on the basis of the foregoing hypothesis. Thus the side of the coleoptile exposed to the light becomes in consequence more permeable, with greater guttation through the apical hydathode from the vein nearer the light. The cells of the lighted side will therefore extend in length less than those of the darkened side, producing a curvature towards the light.

Following still another line of attack, Prof. Y. Yoshii has experimented on the influence of the relative length of day and night on plants (*Science Reports of the Tôhoku Imperial University*, 4th series, vol. 2, 2). His results, in the main, confirm and extend the work of Garner and Allard in grouping plants into two categories, long and short day plants, according to the length of daily illumination necessary for the production of flowers (*Jour. Agri. Res.*, 18, p. 553, and 23, p. 871). The evidence adduced leads to the conclusion that there is probably another group of plants which are nearly or entirely indifferent to photoperiods, but affected by other factors as to time of flowering. The author finds that the optimum photoperiod for reproduction does not result in maximum vegetative growth, and that closely related plants, sometimes even varieties of the same plant, may behave quite differently as regards photoperiods; for example, the late variety of rice plant is a short day plant, while the early variety is indifferent to regulation of light period. This seems to suggest that some other factors besides those concerned in photosynthesis are involved. If the photoperiod is the key to the distinction between spring and winter varieties of wheat, then researches along this particular line may have some application in the practical field of crop production.

Yorkshire Ammonites.[1]

THE amateur geologist who collects Yorkshire ammonites may approach the collection of papers before us with expectation, but he is likely to be disappointed if he hopes to identify his specimens from the descriptions there given. The work is not for the amateur, but for the specialist; and even he will have to dig deep in involved sentences to find the information which only so patient and expert a worker as Dr. Spath can give. These little papers have really an immense scope, gathering up and pronouncing upon outstanding uncertainties in the systematics of the main groups to which belong all ammonites commonly found in the Lower Lias; supplying new generic names where needed; and tilting at the evolutionary conceptions of previous ammonite workers.

To promote the first aim, Dr. Spath appeals to Yorkshire geologists to go into the field and collect Yorkshire ammonites bed by bed. In proposing new generic names, he considers that the quotation of a genotype is sufficient diagnosis. That would be more justifiable if the genotype were a species known by an existing holotype, and not mainly or merely by a figure. It is also probable that ammonite specialists the world over will miss the new genera thus casually proposed in notes on a local fauna in a journal which caters for amateur naturalists rather than professional palæontologists.

The fact is that Dr. Spath has tried to pack into these modest papers matter far beyond their scope, and he has condensed it almost to the limits of intelligibility. We feel that he could expand his remarks on evolution into an enthralling thesis, but here we can catch only the barest outline of his scheme. He has nothing but scorn for those who find comfort in supposed ammonite lineages, but he does not give them instead a clear-cut theory of evolution. The following points, however, seem to stand out: (1) The two great families, namely, Phylloceratidæ and Liparoceratidæ, persisted almost unchanged throughout the Mesozoic, and were the radical stocks whence group after group repeatedly sprang, rapidly evolved in many directions, and quickly died out. (2) Already in Triassic time all possible forms of ornament and whorl-shape had been tried, only to reappear again and again in later stocks (we must not say lineages). This seems to support

[1] Hull Museum Publications, No. 143. "Notes on Yorkshire Ammonites." By Dr. L. F. Spath. Reprinted from the *Naturalist* for April-July, Sept.-Dec., 1925; Feb., May, June, Sept., Nov., 1926.

a doctrine of Trends. (3) Even within a single species the young show very great variability, and on reaching maturity converge to a common form, thus refuting, in Dr. Spath's opinion, the doctrine of post-embryonic recapitulation. (4) New characters often appear first in the young, again proving that the doctrine of post-embryonic recapitulation is unsound. All these evolutionary pronouncements are of great interest, and would bear critical consideration, but here they can only be noticed, not discussed.

University and Educational Intelligence.

BRISTOL.—The following appointments have been made: In the Department of Chemistry, Dr. W. E. Garner, University College, London, to be professor of physical chemistry in succession to Prof. J. W. McBain, and Dr. Morris W. Travers, to be reader in applied physical chemistry and an honorary professor of the University. In the Department of Physics, Dr. J. E. Lennard-Jones, reader in mathematical physics, to be professor of theoretical physics; Dr. H. W. B. Skinner to a Henry Herbert Wills research fellowship in physics. Dr. L. C. Jackson was also appointed to a Henry Herbert Wills research fellowship some time ago.

It is hoped that the building of the Henry Herbert Wills Physics Laboratory will be completed in the summer, and that it will be ready for use by the beginning of next session.

CAMBRIDGE.—Field-Marshal Sir William Birdwood has been elected to an honorary fellowship at Peterhouse, a College with which he is closely connected by family ties.

R. O. Redman, St. John's College, has been elected to the Sheepshanks Exhibition in astronomy at Trinity College. The subject for the Adams Prize for the period 1927-28 is announced as "The Variations in the Earth's Magnetic Field in Relation to Electric Phenomena in the Upper Atmosphere and on the Earth." A theoretical contribution to the origin of the various phenomena and their qualitative and quantitative relations with each other is asked for.

LONDON.—The following Doctorates have been conferred: D.Sc. in statistics on Mr. E. C. Rhodes (University College) for a thesis entitled (1) "On a Skew Correlation Surface," (2) "The Precision of Means and Standard Deviations when the Individual Errors are correlated," (3) "The Comparison of Two Sets of Observations"; D.Sc. (Engineering) on Mr. W. H. J. Vernon (Imperial College—Royal School of Mines) for a thesis entitled "The Atmospheric Corrosion of Metals (Second Experimental Report to the Atmospheric Corrosion Research Committee)."

MANCHESTER.—Dr. Alex. M. Smith has been appointed lecturer in agricultural chemistry and adviser under the Ministry of Agriculture advisory scheme.

THE Ella Sachs Plotz Foundation has issued its third annual report, from which it appears that thirty-eight applications for assistance in 1926 were received. Thirteen grants were made, seven of them to scientific workers outside the United States. For the present, research on problems in medicine and surgery is favoured, and preference is given to a group of investigations on a single subject; for example, four grants have been given each year for work bearing on the subject of chronic nephritis. Applications for grants for 1927–28 should be sent to Dr. Francis W. Peabody, Boston City Hospital, Boston, Massachusetts, before May 15.

Calendar of Discovery and Invention.

April 10, 1864.—The modern process of manufacturing open hearth steel was started by Pierre-Emile Martin, who melted together pig-iron, scrap, and iron ore in a Siemen's regenerative furnace. Martin's French patent was taken out on April 10, 1864. Two hundred years ago, Réaumur described the conversion of wrought iron into steel by fusing it with pig-iron, but his experiments never went beyond the laboratory stage. The open hearth process was introduced into America in 1868. In 1880 that country produced 1,074,000 tons of Bessemer steel, and 110,000 tons of open hearth steel. Forty years later these figures had increased to 8,883,000 tons of Bessemer steel, and 32,672,000 tons of open hearth steel, the total production being nearly equal to half a ton of steel per head of population.

April 11, 1709.—The most famous of all prizes for scientific work is the Copley Medal of the Royal Society. It was founded by Sir Godfrey Copley, Bart., who by his will dated Oct. 14, 1704, and proved April 11, 1709, bequeathed to Sir Hans Sloane and Abraham Hill "one hundred pounds in trust for the Royal Society of London for improving natural knowledge, to be laid out in experiments or otherwise for the benefit thereof as they shall direct and appoint." No award was made until 1731, when Stephen Gray, an inmate of the Charterhouse, received a prize for his electrical experiments. On Nov. 10, 1736, the Royal Society resolved to convert the bequest into a gold medal, Desaguliers receiving the first, and since then the medal has generally been awarded annually. Copley was a member of Parliament and held various public offices. In 1881 the then representative of the family, Sir Joseph Copley, transferred to the Royal Society a sum in Consols sufficient to provide in perpetuity an annual bonus of £50 to be given to the recipient of the medal (v. also NATURE, Dec. 4, 1926, p. 823).

April 13, 1869.—The successful braking of trains was first solved by Westinghouse. A head-on collision between two trains directed his attention to the matter, and the chance reading of an account of the use of compressed air in boring the Mont Cenis Tunnel led to his experiments with an air brake. His first steam-air brake was patented on April 13, 1869. In 1872 he described the automatic brake, and the following year brought out his ingenious triple valve. In the famous trials on trains carried out by Sir Douglas Galton in 1878–9, the brake of Westinghouse proved its superiority, but it was afterwards much improved, Westinghouse alone taking out altogether 103 patents in connexion with it.

April 15, 1777.—A hundred and fifty years ago, in a letter dated April 15, 1777, Volta suggested to Prof. Barletti of Pavia the possibility of firing a pistol at Milan by the discharge of Leyden jars at Como, the two places being joined by an iron wire.

April 15, 1845.—Liebig is regarded as the virtual founder of agricultural chemistry. His famous work, "Die organische Chemie . . ." appeared in 1840, and it was on a barren plot of land outside Giessen that he made his experiments. His researches also led to the foundation of the artificial manure industry, and he himself, through James Muspratt, on April 15, 1845, took out an English patent, the object of his invention being "to restore to the land by means of a manure the mineral elements taken away by the crop which had been grown on and removed from the land."

April 15, 1893.—The finest pre-turbine British liner was the s.s. *Campania*, which on trial on April 15, 1893, developed 31,050 h.p. and attained a speed of 23·18 knots, her displacement being 18,000 tons. E. C. S.

Societies and Academies.

LONDON.

Royal Society, Mar. 31.—Sir Robert **Hadfield**: Alloys of iron and manganese of low carbon content. The range of alloys covers 0·06 per cent. to 38·90 per cent. manganese, also one additional alloy containing 83·50 per cent. manganese. With 4·00 per cent. to 10·00 per cent. manganese the alloys have a comparatively high Brinell hardness, in the region of 400, and are brittle; from 15·00 per cent. to 39·00 per cent. manganese, characteristics are observed similar to those of manganese steel, though only to a limited extent—that is, a comparatively low Brinell hardness, in the neighbourhood of 200, with considerable tenacity and ductility and fair capacity for work-hardening. The alloy containing 83·50 per cent. manganese is hard, brittle, and unforgeable. With 16·00 per cent. or more of manganese the alloys are non-magnetic, whereas in the presence of 1 per cent. of carbon not more than about 7 per cent. manganese is required to take away or suppress the magnetic qualities of the iron. The electrical resistance, while increasing with manganese percentage up to 87·2 microhms per cubic centimetre for the 38·90 per cent. alloy, does so in a fairly continuous manner and without any changes of a critical character such as those observed for the specific magnetism. In their corrodibility the alloys show under some conditions a somewhat improved resistance as compared with ordinary steel, but not such as to make them of any practical value in this connexion. In their microstructure the alloys with increasing manganese percentage pass at 4 per cent. from a pearlitic structure to a martensitic, which at about 16 per cent., that is, the point where almost completely non-magnetic qualities appear, changes into the austenitic type.

E. **Griffiths**: The thermal and electrical conductivity of a single crystal of aluminium. A method is described for the determination of the thermal conductivity which does not necessitate any machining of the crystal. Tests were made at various temperatures, the value of the thermal conductivity at 100° C. being 0·55 C.G.S. units. The specific electrical resistivity is $2{\cdot}89 \times 10^{-6}$ ohms per centimetre cube at 18° C.

W. L. **Webster**: The transverse magneto-resistance effect in single crystals of iron. The change of resistance of single crystals of iron produced by a transverse magnetic field has been investigated. Measurements were made with the current along a {100}, {110} or {111} crystal axis, and with the field in a series of positions in the plane normal to these directions. The phenomenon is of a double nature. There is in all cases a gradual decrease in resistance approximately proportional to the field, and probably due to the action of the field on the conducting electrons. Superimposed on this effect there is a sudden change in resistance between 5000 gauss and 12,000 gauss, the sign depending on the direction of the current and the magnitude on the direction of the field. This second effect is probably caused by the change of orientation of the atoms accompanying magnetisation.

W. A. **Bone**, R. P. **Fraser**, and F. **Witt**: The initial stages of gaseous explosions. Part iii. The behaviour of an equimolecular methane-oxygen mixture when fired with sparks of varying intensities. Sparks of varying intensities were passed between electrodes fixed half-way along a horizontal glass tube (35-50 cm. long by 2-2·5 cm. diameter), both ends of which were *closed* in one series of experiments but *open* in another. The new evidence, which mainly lies in the photographs taken, shows (*a*) the occurrence, under ordinary sparking conditions, of what seems to be a definite 'induction period' as a preliminary to the actual combustion; (*b*) initial propagation through the medium of a 'ghost-like flame' condition involving only a very partial combination of the gases; and (*c*) the main combustion, following later as the result of the superposing of a compression wave, or the like, upon a system which during the phase (*b*) has already become highly sensitive to chemical changes.

F. T. **Meehan**: The expansion of charcoal on sorption of carbon dioxide. Wood charcoal expands when it sorbs carbon dioxide, and the process is reversible. The relations between expansion, pressure and temperature are similar to those connecting quantity of gas sorbed with pressure and temperature. Thus at constant temperature the expansion is related logarithmically to the gas pressure; at constant pressure the expansion is inversely proportional to the temperature. The same relations hold above and below the critical temperature of carbon dioxide. As the expansion is uniform in the three original grain directions, it appears that carbonisation destroys the structure of wood, leaving an isotropic product.

J. E. **Lennard-Jones** and W. R. **Cook**: The equation of state of a gaseous mixture. A theoretical formula is given for the equation of state of a gaseous mixture, and from it is deduced a generalisation of Dalton's partial pressure law. The forces between the unlike molecules of a mixture can be deduced.

Aristotelian Society, Feb. 21.—A. **Wolf**: Some aspects of the philosophy of Spinoza. The paper dealt with some common misinterpretations of Spinozism. The chief of these are (1) the quasi-Kantian interpretation of the Attributes as subjective ways of regarding Nature, instead of as objective characters of Nature; (2) the mistranslation of *infinite* attributes by *innumerable* attributes, instead of simply "all the Attributes," which may not exceed the two known to man, namely, extension and thought; and (3) the logico-mathematical, instead of the dynamic, interpretation of the attributes in relation to finite objects. The last was specially emphasised, as it obscures the relation of Spinoza to the science of his time and of ours. Reality for Spinoza was essentially activity, energy. Spinoza criticised Descartes' conception of matter as mere extension, saying that from such inert matter the world of physical phenomena could not be derived. For Spinoza matter was essentially energy occupying space. The inert idea of matter had eventually to be abandoned, and, in spite of Newton's protest, matter came to be regarded as kinetic of its own nature, so as not to need an external mover. Similarly with Spinoza's conception of thought; ideas, he insisted, are not dumb pictures on a tablet, but active assertions. While European psychology was for many generations obsessed with the conception of mind as a passive tablet on which sense stimuli make impressions, Spinoza already anticipated present-day dynamic conceptions in psychology, as he anticipated the general kinetic conceptions of physics.

Geological Society, Feb. 23.—W. D. **Lang** and S. **Smith**: A critical revision of the rugose corals described by W. Lonsdale in Murchison's "Silurian System." These forms include some of the earliest-described British Silurian forms. A detailed examination has been made of their external characters and the internal structure with the object of putting the nomenclature upon a sound footing.—L. G. **Anniss**: The geology of the Saltern Cove area (Torbay). The series here termed Red Shale Group (Upper Frasnian and Lower Fammenian) are overthrust on the north

by the Staddon Grits and Shales (Upper Coblentzian), and on the south by the 'Massive Limestone' (probably Lower Frasnian). The 'Massive Limestone' forms the high ground on the south and also the summit of Sugar Loaf Hill, between which denudation has cut a deep valley exposing the Upper Devonian as a 'window.' The latter is a series of Red Shales, thin limestones, and tuffs. From these beds goniatites have been collected, which fix the fossiliferous horizon on Zone 1γ of Wedekind. Associated with the Upper Devonian is a decomposed albitedolerite; this rock has no connexion with the intrusions of the Torquay and Dartmouth areas, but is comparable with those of the Ashprington and Totnes areas.

Association of Economic Biologists, Feb. 25.—F. **Tattersfield** and C. T. **Gimingham**: During laboratory and field experiments on contact insecticides, an apparatus and technique have been devised for the quantitative study of the toxicity of contact insecticides, both to adult insects and to insect eggs, and some relationships between chemical constitution and toxicity in certain groups of synthetic organic compounds have been worked out. The results of the laboratory work have led to experiments in the field with certain compounds, highly toxic to insect eggs, which may prove to have practical value for winter spraying. The toxic properties of extracts of some tropical plants have also been studied.

Society of Public Analysts, Mar. 2.—E. Richards **Bolton** (Presidential address). The new preservatives regulations were welcomed. The adulteration of food is steadily decreasing, partly owing to the activity of the authorities, and partly to the efficiency of public analysts. Manufacturers should avail themselves of the services of a chemist to maintain the purity of their products and advise them in order to enable them to avoid any contravention of the law. The food of Great Britain was never in a purer state than it is at the present time.—A. W. **Knapp**, J. E. **Moss**, and A. **Melley**: Cacao butter substitutes and their detection. The most useful single test is the determination of the 'titre' of the fatty acids, and in the absence of certain other fats (*e.g.* coconut oil) this test enables the amount of Borneo tallow in admixture with cacao butter to be approximately determined after reference to a curve. A new method of determination has been based on the fact that the green colour of Borneo tallow is not bleached by ultra-violet light, whereas the yellow colour of cacao butter is readily bleached.—H. W. **Bywaters**, F. T. **Maggs**, and C. J. **Pool**: The determination of illipé butter in chocolate. Melted illipé butter becomes turbid at a much higher temperature than cacao butter, and the turbidity temperature determined under definite conditions is practically constant for different specimens of the two fats. If a third fat (*e.g.* milk fat) is also present, the percentage of illipé butter may still be found by reference to a curve, provided that the amount of the third fat can be ascertained.—A. F. **Lerrigo** and A. L. **Williams**: A study of the determination of saccharin, colorimetrically and by the ammonia process (work done under the Analytical Investigation Scheme). None of five colour reactions of saccharin studied under variable conditions gives quantitative results. The ammonia process (in which saccharin is converted into the ammonium salt of sulphobenzoic acid, the ammonia in which is determined by distillation) has been adapted to the determination of small quantities of saccharin.

Linnean Society, Mar. 3.—A. J. **Wilmott**: The Irish Spiranthes called *S. Romanzoffiana* Cham. Specimens from County Cork and Lough Neagh are distinct; the southern one is *S. gemmipara* Lindl., and the northern one *S. stricta* Rydberg.—J. **Davidson**: On the occurrence of intermediates in *Amphis rumicis* L. and their relation to the alate and apterous viviparous females. In *Aphis rumicis* L. (Hemiptera, fam. Aphididæ) both alate and apterous viviparous females (virginoparæ) develop in the parthenogenetic generations. The alate forms tend to produce apterous forms, and the apterous virginoparæ produce only apterous forms or a mixed progeny of apterous and a variable percentage of alate forms. From time to time intermediate individuals develop. Compared with their immediate alate and apterous relations in the same generation, these intermediate forms behaved as apterous forms.

EDINBURGH.

Royal Physical Society, Feb. 21.—Isobel **Deans**: The genus Hicksonia: an account of a new species. A new species, *Hicksonia köllikai*, is described. Attention is directed to the occurrence of telestid-like spicules which suggest the derivation of telestids from clavularids.—D. **Chalmers**: Worm parasites of common marine fishes. The results of an examination of specimens of sixteen species of North Sea fishes. Thirty-one species of parasitic worms are described, including three new, or hitherto unrecorded in the present host.—C. **Cumming**: Reinvestigation of the eye of the mole. Embryonic development and histological structure of the eye of the mole are described. The whole of the eye shows a simplification. The lens is degenerate, the retina partly so; normal image perception is impossible.

PARIS.

Academy of Sciences, Feb. 28.—S. **Winogradsky**: Researches on the degradation of cellulose in the soil. Hutchinson and Clayton, in 1919, isolated the first typical representative of the group of aerobic bacteria attacking cellulose, and the author has followed the same general method. A dozen forms have been isolated falling in two groups, Cytophaga, the type discovered by Hutchinson and Clayton, and vibrions. In the latter group, the fibrolytic action is much less marked than with the Cytophaga, but they spread over paper with great rapidity.—A. **Weinstein**: A problem at the limit in an indefinite band.—Paul **Lévy**: The iteration of the exponential function.—G. **Pòlya**: The singularities of the lacunar series.—D. V. **Jonesco**: A class of functional equations.—C. **Cerf**: The integration of systems in involution of partial differential equations.—**Mandelbrojt**: A complement to the theorem of M. Fatou.—G. **Sugot**: The integration of the differential equations of the gyroscopic movement of a projectile.—**Kolossoff**: A transformation of the equations of elasticity.—J. **Vorobeitchik**: The horizontal flight of an aeroplane with great radius of action.—J. **Thovert**: The propagation of aerial waves in large subterranean cylindrical mains. The proved lack of uniformity of temperature in large underground mains will tend to give low values for the velocity of sound in such tubes. It would appear to be impossible to apply a suitable correction.—**Belin** and **Holweck**: Television. First results in the transmission of moving images.—J. **Cabannes** and P. **Daure**: The absolute measurement of the intensity of the light diffused by benzene in the liquid state. On the basis of measurements on the light diffused by benzene and other liquids, the authors conclude that it is not at present possible to deduce the Avogadro number from measurements of the diffusion of light by liquids.—Pierre **Jolibois**, Henri **Lefebvre**, and Pierre **Montagne**: The chemical yield in the decomposition

of carbon dioxide under small pressure by the condensed spark. The experimental results cited agree with the theoretical conclusions deduced from the study of the thermal dissociation of carbon dioxide. The energy of the electrical discharge is only partially utilised in the form of chemical energy, and the figures expressing the yield are notably lower than those calculated on the supposition that the spark produces in the gas uniquely a heat development absorbed quantitatively by the gas.—Albert Kirrmann: A method of synthesis of α-bromoaldehydes. The general method proposed is the action of phosphorus chlorobromide, PCl_3Br_2 on the acetals $R . CH_2 . CH(OR)_2$. This reaction gives the α-bromaldehyde R . CHBr . CHO together with RBr, HBr, phosphorus trichloride and oxychloride. The method is practicable starting from C_4, and gives good yields above C_5. The physical properties of five bromoaldehydes prepared by this method are given.—Paul Gaubert: The formation in the insoluble state of two hydrates of magnesium platinocyanide.—Ch. Gorceix: The variation of longitudes can be attributed to another cause than the drift of the continents.—C. E. Brazier: The periodicity of the magnetic disturbances observed at Parc Saint-Maur and at Val-Joyeux. The results of a statistical analysis of 36 years' observations tend to show that the days on which there are magnetic disturbances succeed each other at intervals of which the approximate duration will be equal to one of the numbers obtained by multiplying the period of synodic rotation of the sunspots by a simple fractional factor, between 0·5 and 3.—R. Combes: The nitrogen in a ligneous plant in the course of a year's growth.—Volmar and Samdahl: The constitution of α-kirondrine. Owing to the small quantity available for study the constitution of α-kirondrine could not be completely determined. It is a bitter toxic principle which is neither an alkaloid nor a glucoside but a lactone containing one or more aldehyde groups.—A. Demolon and G. Barbier: Study of the mechanism of the exchanges of ions in the clay-lime complex.—A. Rochon-Duvigneaud and M. L. Verrier: The existence of serous pockets in the orbit and in the eye of the teleosteans.—Béhague, Garsaux, and Charles Richet, jun.: The rhythm and respiratory frequency of animals submitted to a barometric depression.—Pierre Lesne: The subfossil Gyrinus of Belle-Isle-en-Mer.—Armand Dehorne: The annual reproductive cycle of *Dodecaceria concharum* at Le Portel.—Louis Bounoure: The primary gonocytes in the embryos of toads from eggs submitted to uterine super-maturation.—A. Fernbach, M. Schoen, and Motohichi Mori: Some observations on the so-called elective fermentation. It has been held that the differences in the velocity of disappearance of various sugars in a mixture was due to differences in the resistance that the cell-wall of the living yeast offered to the passage of the various sugars. It is now shown that these differences do not depend on the presence of the living yeast, but are also shown by zymines prepared according to the technique of Albert, Buchner, and Rapp. The causes of this selection still remain obscure.—A. Marxer: The proteolytic ferment of *Bacillus subtilis*.—Maurice Letulle and Louis Vinay: Experimental cancer of the lung.

VIENNA.

Academy of Sciences, Jan. 27.—F. Hölzl: The alkylisation of ferrocyanic acid.—R. Frisch: The action of slow cathode rays on rock-salt.—H. Küpper: Elucidation of morphogenesis and tectonics at the edge of the Vienna basin.—A. Smekal: The coloration of rock-salt crystals by radium radiation.

Official Publications Received.

BRITISH.

The Preservation of Ancient Cottages. An Appeal by the Rt. Hon. Stanley Baldwin; with a Note by Thomas Hardy. Pp. 16+8 plates. (London: Royal Society of Arts.)

Transactions of the Royal Society of Edinburgh. Vol. 55, Part 1, No. 10: On the Feeding Mechanism of a Mysid Crustacean, Hemimysis Lamornæ. By Dr. H. Graham Cannon and Miss S. M. Manton. Pp. 219-253+4 plates. (Edinburgh: Robert Grant and Son; London: Williams and Norgate, Ltd.) 6s.

British Museum (Natural History). Picture Postcards. Set E43: Exotic Butterflies, Series No. 7. 5 cards in colour. 1s. Set E44: Exotic Butterflies, Series No. 8. 5 cards in colour. 1s. (London.)

Shirley Institute Memoirs. Vol. 5, 1926. Pp. viii+349+iv. (Manchester: Shirley Institute.)

Reports of the Progress of Applied Chemistry. Vol. 11, 1926. Pp. 742. (London: Society of Chemical Industry.)

Transactions and Proceedings of the Perthshire Society of Natural Science. Vol. 8, Part 3, 1925-26. Pp. 119-157+xxix-xxxviii. (Perth: Perth Natural History Museum.) 3s. 6d.

Uganda Protectorate: Geological Survey Department. Occasional Paper No. 2: The Geology and Palæontology of the Kaiso Bone-Beds. Part i: Geology, by E. J. Wayland; Part ii: Palæontology, by Members of the British Museum (Natural History) Staff—Mammalia, by Arthur T. Hopwood; Reptilia, by W. E. Swinton; Pisces, by Erol Ivor White; Mollusca, by L. R. Cox. Pp. 71+9 plates+2 maps. (Entebbe.) 6s. 6d.

The Physical Society. Proceedings, Vol. 39, Part 2, February 15. Pp. 99-170. (London: Fleetway Press, Ltd.) 6s. net.

Nigeria. Fifth Annual Bulletin of the Agricultural Department, 1st August, 1926. Pp. 209. 5s. Annual Report on the Agricultural Department for the Year 1925. Pp. 15. (Lagos: Government Printer.)

Department of Agriculture, Ceylon. Bulletin No. 77 (Bulletin No. 43, Rubber Research Scheme, Ceylon): The Inter-Relationship of Yield and the Various Vegetative Characters in Hevea Brasiliensis. By R. A. Taylor. Pp. 67. 40 cents. Bulletin No. 78: Manuring in relation to the Control of the Shot-Hole Borer of Tea (*Xyleborus fornicatus*, Eichh.). Part i by F. P. Jepson; Part ii by Dr. C. H. Gadd. Pp. 49. 40 cents. Bulletin No. 79 (Bulletin No. 44, Rubber Research Scheme, Ceylon): The Construction of Smoke Houses for Small Rubber Estates. By T. E. H. O'Brien. Pp. 7+4 plates. 40 cents. (Peradeniya.)

The Zoological Society of Scotland. An Appeal for Funds for the Scottish Zoological Park. Pp. 40. (Edinburgh.)

Department of Commercial Intelligence and Statistics, India. Agricultural Statistics of India, 1924-25 Vol. 1: Area, Classification of Area, Area under Irrigation, Area under Crops, Live-Stock, Land Revenue Assessment and Harvest Prices in British India. Pp. ii+ix+81. (Calcutta: Government of India Central Publication Branch.) 1.5 rupees; 2s. 3d.

Aeronautical Research Committee: Reports and Memoranda. No. 1046 (Ae. 232): The Effects of Body Interference on Airscrew Performance. By W. G. Jennings. (A.3.d. Airscrews, 94.—T. 2293.) Pp. 8+3 plates. (London: H.M. Stationery Office.) 6d. net.

The Journal of the Institution of Electrical Engineers. Vol. 65, No. 383, March. Pp. 297-388+xxx. (London: E. and F. N. Spon, Ltd., 10s. 6d.

The Journal of the Quekett Microscopical Club. Edited by W. S. Warton. Ser. 2, Vol. 15, No. 92, February. Pp. x+211-288. (London: Williams and Norgate, Ltd.) 3s. 6d. net.

Report of the Committee of the Privy Council for Scientific and Industrial Research for the Year 1925-26. (Cmd. 2782.) Pp. iv.+178. (London: H.M. Stationery Office.) 3s. net.

Ministry of Health. Reports on Public Health and Medical Subjects, No. 37: A Report on the Occurrence of Glass Fragments in Foods packed in Glass Containers. By George C. Hancock Pp. iv+36 (15 plates). (London: H.M. Stationery Office.) 1s. net.

British Research Association for the Woollen and Worsted Industries. Annual Report, 1926. Pp. 23. (Headingley, Leeds.)

Memoirs of the Geological Survey of India. Palæontologia Indica. New Series, Vol. 7, Memoir No. 3: A Review of the Genus Gisortia, with Descriptions of several Species. By E. Vredenburg. Pp. iv+124+32 plates. (Calcutta: Government of India Central Publication Branch.)

Report of the Department of Industries, Madras, for the Year ended 31st March 1926. Pp. iv+98+ii. (Madras: Government Press.) 12 annas.

Forest Bulletin No. 69: The Mechanical and Physical Properties of Himalayan Spruce and Silver Fir. By L. N. Seaman; assisted by C. R. Ranganathan. Pp. iii+26+5 plates. (Calcutta: Government of India Central Publication Branch.) 1.1 rupees; 1s. 9d.

Canada. Department of Mines: Geological Survey. Summary Report, 1925, Part A. (No. 2113.) Pp. 248. Summary Report, 1925, Part B. (No. 2114.) Pp. 46. Economic Geology Series No. 3: The Iron Ores of Canada. Vol. 1: British Columbia and Yukon. By G. A. Young and W. L. Uglow. (No. 2093.) Pp. ii+253. 40 cents. (Ottawa: F. A. Acland.)

Canada. Department of Mines: Victoria Memorial Museum. Museum Bulletin No. 43, Biological Series No. 11: List of Mushrooms and other Fleshy Fungi of the Ottawa District. By W. S. Odell. (No. 2089.) Pp. iii+15. (Ottawa: F. A. Acland.) 10 cents.

University of Reading: The National Institute for Research in Dairying. Annual Report, for the Year ending 31st July 1926. Pp. 62. (Reading.)

Report on the Health of the Army for the Year 1925. (Vol. 61.) Pp. iv+152. (London: H.M. Stationery Office.) 3s. 6d. net.

The Institution of Professional Civil Servants. Annual Report of Council for the Year 1926. Pp. 44. (London.)

Report of the Marlborough College Natural History Society for the Year ending Christmas, 1926. (No. 75.) Pp. 91. (Marlborough.) 5s.

Torquay Natural History Society. Transactions and Proceedings for the Year 1925-6. Edited by the Rev. James H. Balleine and H. L. Earl. Vol. 4, Part 4. Pp. 289-386. (Torquay.)

Report of the Rugby School Natural History Society for the Year 1926. Pp. 54. (Rugby.)

Journal of the Marine Biological Association of the United Kingdom. New Series, Vol. 14, No. 3, March. Pp. 557-835. (Plymouth.) 10s. net.

The Newcomen Society for the Study of the History of Engineering and Technology. Transactions, Vol. 5, 1924-1925. Pp. xii+139+22 plates. (London: Science Museum.) 20s.

FOREIGN.

The Carnegie Foundation for the Advancement of Teaching. Bulletin No. 18: Games and Sports in British Schools and Universities. By Howard J. Savage. Pp. vii+252. (New York City.)

Proceedings of the Imperial Academy. Vol. 3, No. 1, January. Pp. ii+43. (Ueno Park, Tokyo.)

Agricultural Experiment Station, Michigan State College of Agriculture and Applied Science. Special Bulletin No. 161: Varieties and Locations as Factors in Apple Production. By V. R. Gardner. Pp. 45. Circular Bulletin No. 98: How to Make and Preserve Cider. By F. W. Fabian. Pp. 20. Circular Bulletin No. 99: House Plants. By Alex. Laurie. Pp. 18. Circular Bulletin No. 100: Michigan Farmers' Tax Guide. By R. Wayne Newton. Pp. 11. (East Lansing, Mich.)

University of Illinois Engineering Experiment Station. Bulletin No. 158: The Measurement of Air Quantities and Energy Losses in Mine Entries. By Prof. Alfred C. Callen and Cloyde M. Smith. Pp. 77. 45 cents. Bulletin No. 159: An Investigation of Twist Drills. By Bruce W. Benedict and Albert E. Hershey. Pp. 76. 40 cents. (Urbana, Ill.)

Smithsonian Institution: United States National Museum. Contributions from the United States National Herbarium. Vol. 22, Part 10: The North American Species of Scutellaria. By Emery C. Leonard. Pp. viii+703-748. (Washington, D.C.: Government Printing Office.)

Smithsonian Institution: United States National Museum. Bulletin 138: The Fossil Stalk-Eyed Crustacea of the Pacific Slope of North America. By Mary J. Rathbun. Pp. viii+155+39 plates. 50 cents. Bulletin 139: Fire as an Agent in Human Culture. By Walter Hough. Pp. xiv+270+41 plates. 50 cents. (Washington, D.C.: Government Printing Office.)

Department of the Interior: U.S. Geological Survey. Bulletin 784: Bibliography of North American Geology for 1923–1924. By John M. Nickles. Pp. iii+280. 40 cents. Bulletin 788-B: Topographic Instructions of the United States Geological Survey. B: Triangulation. Compiled by E. M. Douglas. Pp. ii+47-87+4 plates. 10 cents. Bulletin 788-C: Topographic Instructions of the United States Geological Survey. C: Transit Traverse. Compiled by E. M. Douglas. Pp. iv+89-116+3 plates. 10 cents. Bulletin 788-D: Topographic Instructions of the United States Geological Survey. D: Leveling. Compiled by E. M. Douglas. Pp. iv+117-160+2 plates. Bulletin 790-A: Pedestal Rocks formed by Differential Erosion and Channel Erosion of the Rio Salado, Socorro County, New Mexico. Papers by Kirk Bryan. (Contributions to the Geography of the United States, 1926.) Pp. ii+19+3 plates. (Washington, D.C.: Government Printing Office.)

Department of the Interior: U.S. Geological Survey. Water-Supply Paper 553: Surface Water Supply of the United States, 1922. Part 12: North Pacific Slope Drainage Basins. B: Snake River Basin. Pp. vi+295+2 plates. 40 cents. Water-Supply Paper 554: Surface Water Supply of the United States, 1922. Part 12: North Pacific Slope Drainage Basins. C: Lower Columbia River Basin and Pacific Slope Drainage Basins in Oregon. Pp. v+186+2 plates. 25 cents. Water-Supply Paper 559: Relations between Quality of Water and Industrial Development in the United States. By W. D. Collins. Pp. iv+43+5 plates. 15 cents. Water-Supply Paper 565: Surface Water Supply of the United States, 1923. Part 5: Hudson Bay and Upper Mississippi River Basins. Pp. v+199+3 plates. 30 cents. Water-Supply Paper 580-B: Water Power and Irrigation in the Jefferson River Basin, Montana. By John F. Deeds and Walter N. White. (Contributions to the Hydrology of the United States, 1926.) Pp. ii+41-116+1 plate. (Washington, D.C.: Government Printing Office.)

Department of the Interior: U.S. Geological Survey. Forty-seventh Annual Report of the Director of the Geological Survey to the Secretary of the Interior for the Fiscal Year ended June 30, 1926. Pp. ii+96. (Washington, D.C.: Government Printing Office.)

Meddelanden från Lunds Astronomiska Observatorium. Serie 2, Band 5, No. 41-50: Festskrift tillägnad C. V. L. Charlier på hans Sextiofemårsdag den 1 April 1927 av Lärjungar. Pp. 20+15+86+16+13+35+60+8+9+97+17+23+8+20+12. No. 34: Studies in Stellar Statistics. v: On the Galaxy of the B-Stars. By C. V. L. Charlier. Pp. 33+10 plates. No. 35: On the Calculation of the Characteristics of the Apparent Proper Motion Distribution of the Stars. By W. Gyllenberg. Pp. 12. No. 36: Statistical Notes on the Draper Catalogue. By C. V. L. Charlier. Pp. 36+28 plates. No. 112: Einige Bemerkungen über die räumliche Verteilung der Sterne. Von K. G. Malmquist. Pp. 7. No. 113: On the Zero Point of the Period-Luminosity Curve. By K. G. Malmquist. Pp. 7. (Lund: C. W. K. Gleerup.)

U.S. Department of Agriculture. Department Bulletin No. 1439: Fish Oil, an Efficient Adhesive in Arsenate-of-Lead Sprays. By Clifford E. Hood. Pp. 22. 10 cents. Department Bulletin No. 1476: A Progress Report on the Investigations of the European Corn Borer. By D. J. Caffrey and L. H. Worthley. Pp. 155. 35 cents. (Washington, D.C.: Government Printing Office.)

University of Washington Publications in Anthropology. Vol. 1, No. 5: Klallam Ethnography. By Erna Gunther. Pp. 171-314. (Seattle, Wash.: University of Washington Press.) 1.25 dollars.

New York Academy of Sciences. Scientific Survey of Porto Rico and the Virgin Islands. Vol. 7, Part 1: Plant Ecology of Porto Rico. By H. A. Gleason and Mel. T. Cook. Pp. 96+20 plates. 2 dollars. Vol. 7, Part 2: Plant Ecology of Porto Rico. By H. A. Gleason and Mel. T. Cook. Pp. 97-173+plates 21-50. 2 dollars. (New York City.)

Proceedings of the United States National Museum. Vol. 70, Art. 19: Diagnoses of Undescribed New Species of Mollusks in the Collection of the United States National Museum. By William Healey Dall. (No. 2668.) Pp. 11. Vol. 70, Art. 21: A Stony Meteorite from Forksville, Mecklenburg County, Virginia. By George P. Merrill. (No. 2670.) Pp. 4+3 plates. (Washington, D.C.: Government Printing Office.)

Contributions from the Jefferson Physical Laboratory and from the Cruft High-Tension Electrical Laboratory of Harvard University for th year 1925. Vol. 18. 43 papers, not paged. (Cambridge, Mass.)

Diary of Societies.

SATURDAY, APRIL 9.

ROYAL INSTITUTION OF GREAT BRITAIN, at 3.—Sir Ernest Rutherford: The Alpha Rays and their Application to Atomic Structure (4).

MONDAY, APRIL 11.

ROYAL IRISH ACADEMY, at 4.15.

ROYAL SOCIETY OF MEDICINE (War Section) (Annual General Meeting), at 4.30.—Major T. J. Mitchell: Man-power and the Medical Service in Relation to some of the Principles of War.

ROYAL COLLEGE OF SURGEONS OF ENGLAND, at 5.—C. E. Shattock: Demonstration of Joints.

INSTITUTION OF ELECTRICAL ENGINEERS (Informal Meeting), at 7.—T. Hodge and others: Discussion on The Maintenance of Small Electric Power Plants.

INSTITUTION OF ELECTRICAL ENGINEERS (North-Eastern Centre) (at Literary and Philosophical Society, Newcastle-upon-Tyne), at 7.—Dr. A. Ekstrom: The Applications of Electricity to Agriculture.

INSTITUTION OF ELECTRICAL ENGINEERS (Western Centre) (at South Wales Institute of Engineers, Cardiff), at 7.—J. R. Beard and T. G. N. Haldane: The Design of City Distribution Systems, and the Problem of Standardisation.

CERAMIC SOCIETY (at North Staffordshire Technical College, Stoke-on-Trent), at 7.30.—Annual Meeting.

RAILWAY CLUB (at 25 Tothill Street, S.W.1), at 7.30.—J. F. Gairns: The Importance of Secondary Train Services.

ROYAL INSTITUTE OF BRITISH ARCHITECTS, at 8.—Prof. P. Abercrombie: The Planning of East Kent.

ROYAL SOCIETY OF MEDICINE (Odontology Section), at 8.—Prof. Gottlieb: Diseases of the Gingival Margin.

SURVEYORS' INSTITUTION, at 8.—G. Turville Brown: The Sugar Beet Industry in Great Britain.

TUESDAY, APRIL 12.

SOCIETY FOR THE STUDY OF INEBRIETY (at Medical Society of London), at 4.—Dr. R. W. Branthwaite and others: Discussion on The Inebriates Act of 1898.

ROYAL SOCIETY OF MEDICINE, at 5.30.—General Meeting.

INSTITUTION OF PETROLEUM TECHNOLOGISTS (at Royal Society of Arts), at 5.30.—E. H. Cunningham-Craig: Jet and Jetonised Material.

INSTITUTE OF MARINE ENGINEERS, at 6.30.—T. Clarkson: The Recovery and Utilisation of Heat from the Exhaust Gases of Internal Combustion Marine Engines.

LONDON NATURAL HISTORY SOCIETY (at Winchester House, E.C.), at 6.30.—J. A. Simes: Butterfly Hunting in Central and Southern Europe (Bacot Memorial Meeting).

ROYAL PHOTOGRAPHIC SOCIETY OF GREAT BRITAIN, at 7.—E. J. Bedford: Big Fleas and Little Fleas; or Notes from a Nature Photographer's Diary.

INSTITUTE OF BRITISH FOUNDRYMEN (Lancashire Branch, Burnley Section) (at Municipal College, Burnley), at 7.15.—Annual General Meeting.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND (at 39 Elmbank Crescent, Glasgow), at 7.30.—J. G. Worker: Latest Developments in Underfeed Stoker Practice in the United States.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS (Middlesbrough Branch) (at Cleveland Scientific and Technical Institution, Middlesbrough), at 7.30.—W. C. Freeman: The Production and Modern Applications of Dissolved Acetylene.

QUEKETT MICROSCOPICAL CLUB, at 7.30.—Prof. R. R. Gates: A Naturalist on the Amazon.

INSTITUTION OF ELECTRICAL ENGINEERS (Scottish Centre) (at Royal Technical College, Glasgow), at 7.30.—S. Mavor: The Applications of Machinery at the Coal Face.

WEDNESDAY, APRIL 13.

EUGENICS SOCIETY (at Royal Society), at 8.30.—Dr. J. W. Heslop Harrison: Induced Mutations and their Importance for Evolution.

THURSDAY, APRIL 14.

SOUTH LONDON ENTOMOLOGICAL AND NATURAL HISTORY SOCIETY, at 7.

PUBLIC LECTURE.

SUNDAY, APRIL 10.

GUILDHOUSE (Eccleston Square), at 3.30.—Rev. Father Andrew: Christianity.

CONFERENCES.

APRIL 11 TO 13.

FRENCH ASSOCIATION DES ANATOMISTES (jointly with the Anatomical Society of Great Britain and Ireland) (at University College).

APRIL 20 TO 24.

JOURNÉES MÉDICALES MARSEILLAISES ET COLONIALES (at Marseilles).—Prof. Cantacuzène: The Rôle of the Streptococcus in the Etiology of Scarlet Fever.—Dr. Mayer: Recent Advances in the Treatment of Cancer.—Prof. Ottolenghi: Malaria.—Dr. N. Bernard: Beri-beri.—Prof. Imbert: Bone-grafting.

APRIL 25 TO 28.

GERMAN SOCIETY FOR INTERNAL MEDICINE (at Wiesbaden).—Discussions on Psychotherapy, introduced by Gaupp and Fleischmann; Results of Recent Functional Investigations of the Stomach and Duodenum, introduced by G. Katsch.—A joint meeting with the German Röntgen Society will be held on April 28, with a discussion on the Significance of Röntgen-ray Examination of the Lungs and Mediastinum for Internal Medicine (excluding Tuberculosis), introduced by Dietlen, Assmann, Haenisch and Lorey, and Fleischner.

Supplement to NATURE

No. 2997. APRIL 9, 1927

Newtonian Time Essential to Astronomy.*

By Sir JOSEPH LARMOR, F.R.S.

"Let us now praise famous men."

THE HISTORICAL PROBLEM.

WHEN Newton undertook the unprecedented task of exploring the dynamics of the motions of the heavenly bodies, sparsely scattered in the vast depths of cosmical space, the preliminary and novel problem in front of him was naturally to settle their bearings. He formally established the principle that, though there may be one essential space, or æther, all spatial frames of reference are equally permitted in material dynamics provided their motion relative to this standard frame and so to one another is one of uniform translation. Thereby, for example, he was justified in referring the internal motions of the planetary system to the sun as if it were a fixed centre, although it is in motion with velocity then unknown: going even deeper, he showed how the apparent regular revolution of the directions of the stars could be proved, by experiment, to include them within the range of a frame of the dynamics constructed locally so as to be appropriate to the events on the earth as a whole.[1] But he curtly laid down the postulate that there is one universal reckoning of time. He even went on, in another context in more speculative vein, to assign to this physical absolute time a transcendental significance,[2] which has made it a battle-ground of philosophers from Leibniz onward. On these fundamental topics no degree of precision can be excessive.

The next essential progress in general ideas relevant to permitted frames of reference for dynamical science came from James Thomson, the engineer brother of Lord Kelvin, as late as 1884.[3] He recognised that the totality of such permitted frames form an interchangeable group: he invented for them the name 'frames of inertia,' which has been recently supplanting the term Galileian co-ordinates introduced in the relativity theory. He even propounded the fundamental question: given three systems of bodies in independent motion in the same space, under what conditions is it possible to discover a moving frame of reference in that space (and therefore a group of frames) relative to which their motions are all uniform translatory? The very idea of a frame of reference, as something requiring a name, seems to have originated with his direct and acute, but sometimes tedious, thought. He recognised the problem of simultaneity, but could not solve it: that had to wait for the modern group-theory. About the same time (1870) C. Neumann published discussions, that attracted far wider attention, in which motions are framed by being made relative to 'the body Alpha.'

In the higher theoretical astronomy rotating frames of reference have however been practically in use ever since Newton, but more formally since the brilliant initiative of Euler in referring the dynamics of a rotating solid body to itself.

The simplicity of the Newtonian frames of space and absolute time was disturbed practically, by the fact that our celestial knowledge comes by rays of light which suffer delay in transmission. Principles of correction, taking cognisance also of the motion of the observer, were introduced by the great practical astronomer Bradley, during Newton's lifetime, which have remained adequate until this day.

But close tests on the propagation of the light itself, initiated by Michelson (1881) after an idea broached by Maxwell, indicated that things pass as if the velocity of light were practically the same absolute constant within all local environments, unaffected by the directions and magnitudes of their convections through space. This result, then unexpected and even paradoxical, became the stimulus to modern projects of complete local relativity, based on a general postulate (1900) that each local scheme of events is, so far as relates to the atoms of matter, self-contained. Its theoretical proof, up to the second order of approximation even within the atoms if only their structure is electric, rested on a principle of correspondence which had in Lorentz's hands already (1892) given an easy explanation of the aberration of light and other first-order effects. Such theories, necessarily only approximate for application within the atoms, culminated in impressive practical form (1915) in the inclusion of gravitation by Einstein, leading to his astronomical predictions and their subsequent verification.

The confirmation (1919) of Einstein's prediction of the deviation of rays of light in the sun's gravitational field, at once placed these later developments of the dynamics of relativity in a privileged position, and made their critical study imperative. Later the eclipse result has been enhanced by a gradual consensus of expert opinion regarding the alleged gravitational influence on the atomic periods of free vibration: but the original close

* Communicated to NATURE early in February 1927.

[1] Cf. the weighty scholium at the end of the *Definitiones* in the "Principia," where Newton lays down the necessity of a formal foundation of *Axiomata sive Leges motus.*

[2] Cf. the condensed theological metaphysic of the final *Scholium Generale*; also the Queries at the end of the "Opticks."

[3] *Proc. R. S. Edin.*: "Collected Papers," pp. 379-403.

explanation, by the theory, of the outstanding small residue of the advance of planetary perihelia has become less cogent on account of uncertainties of the astronomical problem.

Could Orbits be Isolated Geodesic Curves ?

These predictions all rested on a postulate that in a planetary system of orbits, as represented symbolically in an Einstein-Minkowski fourfold continuum, each gravitational orbit is separately on its own account a quasi-geodesic curve, like a line of shortest length. But it has been held (1922) to be intrinsically impossible to reason on the basis that the warping of this auxiliary fourfold continuum is determined by the representative orbits within it, while at the same time each orbit is determined by the warping of the fourfold. The influences have to be treated as mutual: the necessary intrinsic invariance of Nature, holding amid all the accidents of arbitrary modes of reference, which at first pointed to the geodesic postulate as a suitable choice, must thus belong, as the invariant Hamiltonian Minimal Action does in the actual dynamical astronomy, to the system as a whole, not to the orbits separately. When, however, the orbital problem was examined [4] in the representative fourfold on this basis of a single mathematical Action function, originating in a field-Action, binding into a unity all the mutual influences, it appeared that the constant of gravitation had to enter into the expression for the Einsteinian absolute symbolic interval of fourfold space-time in the form γ instead of 2γ, leading to smaller potency of gravitation on light so that the two predicted optical effects of gravitation must each be halved.

The only criticism of this result of which I am aware was a remark to the effect that, if this is really so, then there must be something wrong with the application of the method of Minimal Action. Yet that method has continued to be, without substantial modification, the essential and eminently convenient foundation of the general fourfold mathematical theory of relativity. The astronomical verifications in agreement with the Einsteinian values, as they became generally accepted, have thus pointed insistently for several years to the necessity of finding some way of reconciliation of this alleged fundamental discrepancy in the theory. It was indeed clear enough that the rôle of astronomical time in the formulæ, as taken over from Einstein's own adaptation for his geodesic postulate, was unsatisfactory; but nothing better presented itself, though a slight error here involves great consequences. Various attempts at reconciliation, essayed by the writer during the last four years, have shown themselves inadmissible. It is easy, for example, to solve the problem, which is simply that of fitting gravitation within the domain of the optical and electrical relativity postulate, by means of a scalar potential of gravitation, introduced alongside the fourfold vector potential that is the expression of the electric and optical field: but that course, otherwise apparently unexceptionable, does not suggest any interaction between gravitation and light. Thus the actual astronomical detection of such an influence, as stimulated originally by Einstein's formulation, and carried through in the first instance in eclipse expeditions guided by Davidson and by Eddington with the help of the Astronomer Royal in the preparation, has now come to control the whole discussion in its own right.

[4] *Philosophical Magazine*, Jan. 1923, pp. 243-256.

Dynamical Time Inherent in the Intrinsic Structure of Matter, not in Formal Frames.

The reconciliation of this discrepancy that will now be put forward is held to place the modern mathematical theory of relativity on its intelligible physical foundation. An actual astronomer is not an isolated solitary flying particle of the abstract mathematical theory. In his annual journeys at high speed round the extensive circumference of the earth's orbit, he takes his instruments and his landscape of reference along with him, without which he would be helpless: more important still, he takes his astronomical records extending over centuries of time, which have to be permanently intelligible and consistent to all brother astronomers, actual and potential, at all times and all places and moving in concert with their environments with all conceivable speeds. There must be something of the absolute involved here. The solution now offered is that our astronomer's own local space and time *are* absolute Newtonian space and time: that, unless we turn back from and reject the whole *corpus* of modern spectroscopic atomic doctrine, it is not possible to wriggle out of Newton's *dictum* of the necessity in dynamics of a universal continuous measure of time. Nor indeed do the creators of modern relativity attempt to do so, except in so far as many of them have become uncomfortable under the Einsteinian universal invariance of the time-space auxiliary fourfold interval, which as here interpreted involves and even imposes absolute time.

In the Einsteinian form of fourfold Action it is the modification of the time-like variable that dominates almost completely, as regards the actual universe with its slow motions, the forms of the symbolic tracks, because t enters into ds in the form cdt: when we have learned how to transform the symbolic track into an actual orbit in space and time with close accuracy as regards t, a much more rough adjustment will suffice spatially. Hence the importance of the utmost precision in the time-specification.

The extension of the environments of the astronomers, as enshrined in frames of the local standard, or so-called natural, space and time universal in character and the same for the environments of them all, into wider regions, is troubled by the fact that their only practical means of distant communication is by rays of light or other electric signals, which are delayed in transmission and affected by the motions of the observers. As regards astronomical observations that difficulty was discovered and surmounted

as early as 1727 by Bradley, who, especially by his fundamental principle of aberration, founded and even perfected the science of practical astronomy. But not merely an approximate practical consistency; an absolute mathematical fit is required, though possibly of a kind which may never attain to verification, if the accumulated work of astronomers is to be intelligible in ideal completeness to intellectual scrutiny, notwithstanding every variety of position and motion of possible observers and recorders and the complexities of light-transmission, of all which complications an ideal foundation for the records of astronomical history must in theory take exact cognisance.

It is held that the demand for universal intelligibility thus introduced, though of a generality which transcends any special *corpus* of physical science and so may appear at first sight to be unfruitful as being metaphysical, does point to a necessary and attainable actual construct within this domain of knowledge, that of astronomy and physics. Knowledge is rendered possible because, though the intrinsic times of all observers everywhere have to be identical because the local atoms are absolute in relation to their environments, yet the epochs or origins from which these times are measured in the various localities do not come into consideration at all, only intervals of time being concerned in the astronomical dynamics. It is this indetermination *à priori* of epochs, in conjunction with the absorption of all possible conventions of local frames into simple invariance of the fourfold interval, that confers the requisite flexibility, permitting all the identical local reckonings of space and durations of time, of all observers everywhere in all ages, to be consolidated precisely within one wider auxiliary conglomerated fourfold scheme of mathematical representation.

The course of an astronomer's life, by the interpretation here advanced of the natural demand for relativity, works itself out of necessity under the sustaining local influences, is relative to his sub-permanent natural surroundings — this being indeed a type of postulate already recognised in mathematical form for similar reasons in the more minute cosmos of the atomic theory of elastic bodies. Our astronomer thus cannot know whether his environment is careering through space or not; that question must be meaningless to him, except so far as it is opened out by probable inference from the messages coming to his marvellously adapted sense of vision by light from the distant regions of the cosmos. In any case it is only his local smoothed-out frame of convenient reference, in which the occurrences that affect him are set, that can in any scheme of feasible simplicity thus be regarded as careering through space. He can and does construct his own Newtonian dynamical science of the motions observable within his local frame, often involving large relative velocities, even including local so-called centrifugal forces; and he could do this effectively though with far more trouble without calling upon light at all, just as if he and his associates were blind. Unless indeed the motion of the suitable local frame relative to adjacent permitted frames proves to be so erratic as to involve conspicuous differences of speed in its own adjacent parts, such as are called rotation: and then the remedy is to reduce the importance of the rotation, as can be done by increasing, by subdivision of frames, the fineness of the meshes of the analysis, so diminishing the extent of the local landscape which is the differential element, effectively uniform, with which a quasi-geometrical theory operates. Rotation of frames of reference, modifying velocities to an extent depending on the effective radius of the frame, appears on this view as a secondary and avoidable feature: in illustration, the rotation of the local element has added no term directly to the usual dynamical equations for a differential element of volume of a strained elastic solid.

The fact that the Lorentz transformation has to relate to convection without rotation is thus not now a harmful restriction. Moreover, on our view the influence of rotation can in any case be confined within the local frames, for it can be taken to belong to the dynamics of the bodies in the frame and not to the frame itself: a law of centrifugal force need not now belong to an unlimited frame and so extend away in increasing intensity, to be compensated at infinity. The original Newtonian argument from a spinning bucket, or in equivalent actuality the Foucault pendulum or gyro-compass, can demonstrate with the aid of light that the relative invariant property expressing fixity of gyrostatic directions within the frame, which the internal local Newtonian dynamics involves and can discover locally in self-contained manner, does actually extend outside as far as the fixed stars, which thus prove to be included within the region of spatial extension over which the play of physical theory is effectively Newtonian or uniform.

The directional fixations, unlike time, are thus local, not absolute; and the relevant question is, how far does the frame, for which they can be taken practically to subsist, extend: thus removing an insistent but, like unbounded centrifugal force, an unnecessary absolute. Or conversely, if we adopt as the expression of the natural notion of relativity, this idea that the convenient frames of reference of dynamics cannot be expected to extend uniformly to infinity or further than they can be tested, it points naturally towards trying a variable continuum, in which indirectly, as one may even say, Einstein discovered a suitable symbolic representation for an invariant gravitation. On the other hand, our immediate personal domain of local dynamics of matter can be so small that optical relativity merges practically in Newtonian relativity, the delays and other complications of light becoming negligible: but there is nothing to exclude another wider uniform frame, regarded as flitting across it, whose contents may be when so desired referred to it instead of their own frame, by aid of the Lorentz transformation which conserves the optical invariance all over it. This is the essential feature emphasised here, that the relations of pure relativity are concerned only with the specifications of localities in space and time,

and prescribe the modes of adjustment and continuation of the group of the permissible local frames of reference: that the mutual dynamics of the masses existing in each local frame proceeds independently by Newtonian principles, if, as in Nature is actually the case, they arise in a landscape practically permanent as regards the larger features each within its own most convenient frame.

For example, on this formulation of the natural notion of relativity, an astronomer will be under no temptation to undertake a violent journey through the cosmos in order "to return on the previous night" as has been said and so rejuvenate the activities of his life, any more than he will be tempted to go to the antipodes in order to stand on his head.

Only relations are directly accessible to our knowledge, and in this domain most conspicuously of all. No progress has yet been made, any more than in Newton's day, in unravelling the essential nature of gravitation. No reason can be assigned why it is just as intense as we find it, or why it exists at all. What can be established by the Einsteinian verified predictions is that, being in some unknown way an essential feature of the physical universe, it does fall into line, as one had anticipated that it ought to do, with electrodynamics and optics in obeying the principle of local relativity, the regional self-containedness of local material phenomena, as above elaborated.

Dynamics in a Two-Dimensional Cosmos.

The analogy, and contrast, drawn from the Gaussian intrinsic geometry on a surface of variable curvature, by which these beautiful recent developments in a fourfold mathematical theory of universal relations in space and time were doubtless suggested, can be pushed a considerable way in this direction. We consider now not an individual explorer, but a whole population, whose activities are confined close to the surface on which they subsist, their thin cosmos of which alone they are conscious. Each community have their local world of events occurring in their local landscape on this sheet, and may construct, with a view to express the orderly succession of these events, their own local science of dynamics and physics. This science is conveniently laid down for each of the groups within a local frame of reference, which is flat or Euclidean, and can be envisaged as a uniform reference-lattice of straight lines; also in a local scale of time regarded abstractly as flowing uniformly, while determined practically by the prominent uniformities of recurrence in their phenomena. But when their region is extended too far, a misfit in their simple scheme rapidly develops; for the surface of their activities curves round, as we outsiders know but the inhabitants do not.

A theory of a wider cosmos cannot, however, arise at all unless the local populations possess some means of communication with one another. Let us consider a forest of threads stretched tight over their surface, and imagine that messages can be transmitted along them from each group to the others: these threads are so far the analogues of our suitable paths for transmission of rays of light. Without them, all these local frames of flat geometries and their related dynamics in natural time would subsist, but in isolation; without a very refined use of them there could be no kind of relation established between standard axes defining the expression of directions, in any two of the local regions, just as there is no overt relation between the epochs of the absolute times in our local regions also internally self-contained. But such inter-connexions can be worked up for them by constructing an auxiliary universal geodesic geometry (for example, spherical trigonometry) resting for its expression on the stretched threads, a conglomerate scheme which includes and also sums up all the local geometries. Though unbounded for them, it may even be restricted essentially, unknown to the inhabitants, to a finite, even possibly cyclic, domain as a complete frame for their cosmos, if the surface expressing our external, but to them abstract or symbolic and difficultly explorable, frame for the expression of their experiences closes up like an ellipsoid or solid ring: thereby relieving essentially the indetermination of the infinite. Their local plane geometries are here implied, that is, are postulated, to be all identical in type and scale —also their local experiences to be of the same type and therefore the time in which they are naturally set—that is, they are absolute in their dynamics.

This type of scheme involves, and is secured in its widest generality by, the analytic postulate, after Gauss and Riemann, that the squared interval of length on their surface, expressible as a quadratic function of the differentials of any two functions defining any lattice of co-ordinate curves determining position on the surface, is transferable all over it without change of value after the manner of a terrestrial surveying chain, is in fact mathematically invariant and absolute. Yet really all that our present science of differential geometry is usually capable of dealing with is gradual transfer, explored step by step on the basis of local differential equations. Here the rays of light are more potent than the threads or the geometry, for they can translate directly a finite interval of time, expressed in absolute atomic periods, across an almost unlimited range in the cosmos.

This is something beyond geometry, which imposes itself on the formal pseudo-geometric continuum determined by the postulated fourfold invariant interval. This latter, as already remarked, is able to create the fourfold scheme, because it can condense local frames, with all speeds of convection, within one element. How far this extraneous physical feature, the presence of light, tightens up the pseudo-geometric scheme we do not now stop to inquire; except to remark that it accentuates the absoluteness of time, as *sui generis*, already suggested and indeed provided for by the different sign of the relevant term in the expression for the quadratic interval itself. Nor will we consider the more recent problem set by Weyl and Eddington and followed up by Einstein, which really is how far a much wider type of frame for events, imposing

only local relation between vector displacements of points, can be constructed so as to involve in itself, be consistent locally, and beyond by continuation, with the different and more tangible kind of foundation provided by postulation of invariant intervals such as distance—for it would seem, as has been already remarked, to be too loosely hung together to be identical with a geometric frame even combined with an arbitrary electric field, though such frames may well subsist inside it.

Other Elucidations and Contrasts.

There may be some instruction also in an analogy of our Newtonian Absolute Time T with the Kelvin Available Energy, A, in thermodynamics. At each temperature of a material system under discussion, intervals of A are measured as definite amounts of absolute energy; which is in fact the essence of the perpetual-motion postulate of Carnot, there the analogue of the present one of a local absolute time. But in passing to a different temperature of the material system the origin or epoch of measurement of A has been lost, and it becomes necessary to include A as a feature in a wider auxiliary theory, introducing a new and universal formal quantity, the entropy of Clausius, in addition to energy and of different essence. But alternatively we can usually do without any such general scheme by relying, as is familiar in special problems, on special isolated cycles of change resting directly on the Carnot-Clausius principle, our general knowledge of Nature supplying the relevant foundation—just as here we might perhaps reason directly on the relations between the local Newtonian frames instead of merging them in the one fourfold consolidation which their law of mutual correspondence permits.

We may also perhaps illustrate in another different manner. The pseudo-spatial construct of Einstein-Minkowski has given us an inkling as to how the cosmos of discrete events in history may be laid out, as it would be present to the sensorium (to adopt Newton's term) of a divinity who would have knowledge of all occurrences, but necessarily in an incoherent manner; for coherence is foreign to direct awareness of the totality of things, being the compensation permitted to imperfect knowledge, to some degree artificially and arbitrarily, by relating the succession of events in some kind of co-ordinated fourfold index, or frame, of reference. This gradual development of coherence in the range of our experience in space and time, which is scientific method, must run into some calculus of representation, in this generalised problem provided by the multiple algebra of tensors. The mathematical theory, brilliant as it is, soon indicates that this consolidated point of view, apparently losing all distinction between past and future, would transcend human intellectual ability to develop, except in its very rudiments; at any rate until mankind have learned to deal with a formal pseudo-space in four dimensions with the same intuitive familiarity that they now cope with ordinary space in three dimensions.

On the other hand, the actual science of astronomy is an affair not merely of going on "observing coincidences of point-events" in the heavens, but of accumulation of coherent records extending over centuries, permanent human documents in which all the new observations must find absolutely consistent places. There can be no science without memory and without records. For it to be humanly feasible to find out, for example, from minute discussion in the long-continued records, whether there really is a very small residue, unexplained by Newtonian theory, in the precession of the apse of the planet Mercury, must demand, if even only as a practical measure, some definite way of reckoning duration that is independent of the accidents of place and time and motion of observers; just as the instinct of Newton briefly postulated. And when in the setting out of a timeless cosmic history in a fourfold transcendental scheme, our special human knowledge, in space and time, acquired in marvellous manner from the advance of optical science, that an atom say of hydrogen must be taken to be intrinsically the same whether it be in a seething star or on the earth, so is absolute, obtrudes itself into this hitherto merely abstract historical spread, and demands, what is indeed a very small fraction of what it involves, an absolute universal (Newtonian) time for itself in its own material environment, determined by its own permanent vibrational properties, science must eagerly grasp at this revelation as in fact bringing the Promethean fire down from heaven, and rendering, as the philosophers say, human knowledge possible in this domain.

If the present course of argument is valid, the essential proof hitherto that this inference from the absoluteness of the atoms is in fact the right one, is just the confirmation in actuality of the Einstein predictions as to the gravitational influence on light, especially on the period of vibration, which, as one has been forced to hold for the last four years, would otherwise rest on a foundation largely accidental. Without that direct astronomical verification, insistence nowadays on absolute local times might well seem an anachronism.

If we could contemplate history like gods, looking equally before and after, generalised matter and energy might conceivably present themselves, as the elaborated mathematical representation in the fourfold implies, each as a tensor having as many as ten essential components: and they might be perhaps within limits identical and interchangeable. But within the frame of structure of the absolute standard thought that is valid and exchangeable amongst the human race, there have been at length recognised these wonderful absolute atoms existing as matter in their own rights without any sign of ageing or decay, being still in Maxwell's phrase "the foundation stones of the material universe"; and there has also been gradually acquired an idea of conserved energy which it has been useful to postulate as likewise universal and fundamental: and these two stand out as independent features of the foundations on which physical science builds; though related by the circumstance that the electric field belonging

to an atom is proved mathematically to add to its inertia, otherwise naturally an absolute possession, by virtue of the energy of that field.

When two atoms approach and, by overlap of their fields, release in the form of radiation some of these intrinsic field-energies then partially superposed, a proportionate part of the inertia of the atoms goes away along with it, subtracted from their translational energies when the atoms become separated again unless indeed they have suffered permanent internal change in the process. This works out consistently: energy of electric activity, even of free radiation, carries inertia with it, and thus carries momentum too. But the assertion that the whole of the mass of an ultimate atom is energy would remain a barren though permissible[5] figure of speech, unless it means to assert a postulate that mass is somehow practically all separable electric and other field-mass arising from *motional* energy of merely formal nuclei with separable æthereal fields. This would compete with the idea of an electron as a field of *static* strain-energy essentially and irrevocably locked together around a centre. A development by Minimal Action, as indicated in what follows, can provide room for both kinds of mass, the intrinsic and the exchangeable, within the postulate of absoluteness of the atoms.

Gravitation remains Unexplained.

The original case for the postulate that orbits are separately geodesic curves in the gravitational auxiliary fourfold was based, very forcefully, on the Newtonian identity of mass and weight, which otherwise remains a challenge, as an unexplained universal feature of matter. According to the marvellously precise results of Eötvös, working with his modification of the Michell-Cavendish torsion-balance, the force of gravity is found to be the same per unit inertial mass as exerted on all kinds of matter, this being actually verified beyond the order of 10^{-7} which is nearly as far as the order of the observed optical and electric relativities, namely 10^{-8}. If we reason on the basis of the Faraday type of concept, thinking however of a pre-ordained unchanging field of gravitational activity, then a collection of bodies composed of various kinds of matter move down the field in company, though with acceleration, not separating if they start with the same speed, almost as if they drifted in a current of fluid. If this field of gravitation is interpreted as merely a warp in a frame of space and time, this would naturally be regarded as a modification of the inertia which makes every free body describe, after the manner of Newton's First Law of Motion, on its own account alone, a representative path in a space-time auxiliary fourfold, determined by the purely quasi-geometrical property of minimal intrinsic quasi-length: and that is the gist of the geodesic postulate. But the other side of this consolidation of inertia with amenity to gravitation presents itself, when we reflect that a field of gravitation can vary, and so should have an assignable origin: which Newton found in an influence emanating from all the masses in the field, yet of a type of exceeding simplicity functioning just as if it were simple attraction according to his inverse-square law.

The Einstein mathematical theory can determine, at any rate as here amended, by self-consistent algebra in an abstract space-time fourfold extension, as a domain symbolically enshrining paths and masses of the bodies, a warp which proves to be necessarily restricted to a special type—just what is needed to represent gravitation. It has still to assume, however, after Newton and without explanation, that the mass which operates in this different function, that of creating the field, also is identical with the inertia mass. One may indeed reply that the geodesic postulate says nothing about mass: but it does determine a track along which the entity that determines the gravitational warp of the fourfold continuum is distributed, much as a magnetic field is determined by the tracks of electric currents,—a track which as above cannot be both direct cause and direct effect.

Though indeed the direct astronomical evidence to verify this identity of attracting mass with inertial mass may not as yet be very exact, the principle reposes firmly on a basis of its own, different from that of the Newton-Eötvös result; namely Newton's consideration that the accelerating influences between two masses rigidly connected together must be exactly balanced if motion is not to increase spontaneously without limit and so destroy any steady order of Nature. The argument from Eötvös carries only part of the way: this Newtonian doctrine of conservation of momentum is essential as well. But the latter is mutual dynamics of bodies, rather than geodesic geometry of an isolated track in a warped pseudo-space. It involves mutual relation between all the bodies in the field, bodies which also create the field: and this concurs with the previous conclusion that the path of each single body can hardly be regarded, except by an argument moving round in a circle, as a minimal inertial track in a continuum which that track itself has a share in modifying or even creating.

A study, in the light of this point of view, of the crisp exposition of principles in the first four sections of Einstein's earliest formal exposition of 1916 shows how easily it could have been turned round into the present direction. His 'natural' or absolute time, here adapted into the forefront of physical theory, is there practically put away in favour of a fourfold variable, transcending space and time,[6] and necessary to the auxiliary algebraic tensor theory, which is no more time than entropy is energy. It was natural in advance to presume that the symbolic path of a body, at any rate of an infinitesimal particle, was expressible as a minimal inertial track as if in a pre-determined continuum, until it appears as here maintained that this could not conform to actual gravitation as one mutual force between two bodies.

[5] But only up to the second order.

[6] It seems to have imposed itself originally in a very interesting exploring discussion, 'on the influence of gravitation on light,' *Ann. der Physik* (1911), § 3, English translation, p. 105, prior to the opening out of the general problem.

The discipline known as the mathematical theory of relativity would on the present view become a condensed census of the mutual necessary relations of the group of permitted frames of reference, in which investigators variously situated in space, time, and motion may conveniently and consistently formulate the physics of the local worlds, of infinite variety, to which they belong: but the cosmos is far more than its frame or even than our most far-reaching yet still superficial analysis of it within that frame.

It is a modified Newtonian physical foundation that has here been summarily set out. After all, if the present view justifies itself, it will be no derogation to the brilliant scheme of mathematical co-ordination of the general relations of gravitational and electric fields worked out by Einstein, and indeed not pressed by him (originally at any rate) to any transcendental issues. And on any view we have to admit that gravitation, like the great bulk of the rational exact principles of uniformity discovered by science in Nature, physical and biological, still in essence continues to lie beyond our scrutiny.

Relation of Absolute Time to the Auxiliary Fourfold Hypercosmos.

It is becoming widely recognised—it seems now to be Einstein's own considered opinion—that an absolute transferable interval of space-time, the analogue of a universal measuring chain, cannot be avoided, however eager be the quest for an unconditional relativity of physical knowledge. It is here maintained that the difference in sign gives the time-element a footing independent from space in that symbolic absolute interval: in a sort of analogy to this, the general fourfold invariant tensor has been recognised recently as involving fundamentally, for the abstract relativity theory, two independent tensor *data*, a symmetric one and a skew one. When absolute time is thus taken out, the remaining part of the interval, giving the foundation for spatial determinations, is to be associated with an absolute lattice-frame locally uniform or Euclidean.

The pseudo-spatial auxiliary fourfold continuum of Einstein is made up by fitting together, so to say by dovetailing, the sub-groups consisting of all the local convected frames of reference (frames of inertia) which are suitable to enshrine the local Newtonian dynamics of ordinary experience belonging to the various environments in the cosmos. These variously convected local frames of reference, adapted for each domain of experience, but all condensed into one element in the auxiliary fourfold, which is effectively differential in the sense of differential geometry, may be presumed, in the search for a *locus* for gravitation, not to fit together into one universal group symbolically extending over the whole fourfold pseudo-space, without some straining of each of them, such as would cumulate sensible effects at places further removed from the centres of their localities. An essential feature is that this warping is here put on the frame, in preference to an equivalent warping of the laws of the local Newtonian dynamics that the frame enshrines. It is now well recognised that it might be put on either: the frame might be taken to be absolutely uniform throughout the universe, at the cost of complicating the expression of the experience formulated within it.

The essence of relativity as a practical proposition is that a scheme of knowledge is relative to some suitable frame of reference: it may be a matter of facility of exposition how much of universal relations is put into the frame, and how much is treated as belonging to the local dynamics of the system of bodies whose phenomena are referred to that frame. This is the key to the present treatment: everywhere there is the convenient frame of reference: it is relative to that basic frame, not to one another, that the local events are most simply and concisely expressed: such local frames, convenient and practically indispensable, have to be grouped together, consolidated into one compound scheme in order that scientific knowledge gained in the locality, in space and time, of one of them should be transferable into the localities of the others. That becomes possible, because all local frames, however differently convected, can be consolidated within one element of the fourfold by the Lorentz transformation, so that, the convections being thus disposed of, only space-time distributions remain to be fitted together, by strain if that proves to be necessary for the convenient expression of Nature.

The choice, however, of the local frames has here developed into more than a matter of convenience. The thorough absoluteness of the symbolic Einsteinian interval, involving, as here asserted, absolute time as well as a universal measuring chain for all local spaces, now working in concert with the marvellous practical instrument we have come to possess for exploring material systems far outside our own dynamical environment, allows us not indeed to envisage directly the universal symbolic composite frame which subsumes all the actual local ones, but to carry through experimental tests for the formal validity of any attractive mathematical representation thereof that we may be able to contrive. The rays of light enable us actually to transfer directly the intervals of t, one of the fourfold auxiliary set of co-ordinates in this composite universal frame, being that one which is more specially related to time, from one part of the universe to another.

The differentials (δt) of this co-ordinate that are associated with the ray-pulsations stand locally in connexion with intervals of absolute time (δT) which are intrinsic for all environments, by a relation that may involve local gravitation among other things: it is the spectrometer that can provide the test whether this constructive process for communication with distant systems is in actuality verified,—and that in a way that Newton could hardly even have imagined. First the absolute period of vibration (ΔT) of the solar hydrogen atom is to be transferred into an equivalent interval $\kappa\Delta t$ ($=\Delta T$) in the universal auxiliary co-ordinate t of the minimised fourfold; then the very same absolute period, namely ΔT, of a terrestrial hydrogen atom may be observed,

and also can be transferred into the equivalent interval $\kappa'\Delta t'$ expressed in this co-ordinate t by the ratio κ' appropriate to terrestrial instead of solar environment; thus giving $\kappa\Delta t = \kappa'\Delta t'$. As it is the auxiliary period Δt that is transmitted by undulation along the ray and received into the spectrometer, that instrument functions *as if* it were measuring directly two different actual periods $\Delta T/\kappa$ and $\Delta T/\kappa'$. For vibrating atoms at rest in the solar frame $\kappa = (1 - 2V_s/c^2)^{\frac{1}{2}}$ where V_s is the gravitational potential of the sun: for a terrestrial atom κ' is practically unity. This agrees with the Einstein prolongation, now only *apparent* not intrinsic, of the periods of the solar radiation. If the atom were moving with speed v in the solar frame of reference, instead of being at rest, the Lorentz transformation as *infra* would seem to impose another factor $\epsilon^{-\frac{1}{2}}$ or $1 - \frac{1}{2}v^2/c^2$, on the period, which is in the opposite direction but wholly swamped by the Doppler effect.

This feature, that every interval Δt is conveyed without change all along the representative ray-path of the auxiliary fourfold, is based on the nature of the undulation along a ray; it rests in theory on the circumstance that the electrodynamic optical equations, as transferred into the invariant form inherent in this composite fourfold (*xyzt*), are satisfied in undulatory manner, not exactly but to adequate approximation, by making the variable t enter in the expression of the solutions only through a universal periodic factor e^{ipt}. It is the absoluteness of the hydrogen or other atom, steadily maintained through all vicissitudes of place and motion even doubtless of acceleration of its environment, referred to its own frame that accompanies it, for which internally the translatory motion means nothing, that provides a universal natural measure of an absolute flux of time T, namely that of any one of its intrinsic types of vibration: it is the spectrometer alone that in quite recent times has become available to extend our local dynamical experience practically and directly into a universal scheme of intervals of time everywhere absolute, such as is involved symbolically in the universality of the Einstein space-time measuring interval.

In terms of universal Newtonian time thus acquired, the permanent results of astronomy have to be expressed: for its accumulated records must be in accord with the local measuring appliances, pendulums, gyrostats, marks of local direction, position, etc., on which observers wherever they be in space and time and however convected have to rely. This postulate of local frames of reference in space and time, enshrining their material dynamical contents, everywhere Newtonian and absolutely identical just because dead matter and its manifestations are presumed to be identical in type everywhere, is already latent in the preconception of a *continuous* differential geometry applicable to the fourfold: that the frames can be thus consolidated therein, conveniently and manageably to sufficient approximation, along mathematical methods such as the one that Einstein has opened out, is from the present point of view consistent with our fundamental requirement that as knowledge proves to be possible and enduring, the modes of its acquisition and record by all potential observers of natural phenomena, however variously situated in the cosmos, must be consistent among themselves.

Theoretical Coherence is ensured under Least Action.

It remains to indicate briefly how these ideas modify essentially the mathematical analysis and its interpretation, without unduly disturbing Einstein's famous three tests, postponing for the present other issues that incidentally arise.

We base the whole development, after Einstein, Hilbert, and Lorentz, and recently Whittaker who has attempted a striking electrodynamic generalisation, with ideal security and simplicity, on one invariant scalar integral, extended over the fourfold conglomerated representative continuum in which the symbolic history, past and future, of the cosmos is spread out, namely,

$$A = \int (G + L + \lambda) d\tau.$$

That integral is the closest available analogue, in this mixed (*xyzt*) continuum, of the Action integral of Lagrange and Green framed in ordinary space with independent time, as applied to develop the laws of undulatory disturbance whether in a continuous elastic material body or in an æthereal optical medium. Here L is the analogue of the Action-density of the elastic or electric field; λ is a constant which may be needed to satisfy the restrictions of our point of view, the analogue of a pressure which was familiar in early optical theory as necessary to adjust across an interface undulations purely transverse like those of light, occurring in a medium supposed to be incompressible; G is a multiple of the Riemann scalar curvature-invariant which confers just the suitable intrinsic freedom when the basic fourfold is now contemplated after Einstein as non-uniform, while its element of extension $d\tau$ then involves the familiar scalar factor $\sqrt{g}$.

This formulation of a compound Action-density, which is to become expressive of universal dynamical history, is first to be minimised as regards its distribution, with reference to variation of structure of the fourfold pseudo-space, as in the end controlled by its material contents expressed symbolically by their historic tracks therein. This variation leads to structural differential equations of that fourfold, thus conferring on it a definite character of the Riemannian geometric type. Within the pseudo-spatial connecting structure thus established, the Action can now be integrated by parts, leading to boundary terms along with a different spatial integral: it may be that the spatial integral vanishes, and this will occur under quadratic conditions. The boundary for such integration in the fourfold consists, in an atomic theory, of the surfaces of very thin filaments enclosing the historic tracks of the atoms and electrons which alone are out of bounds: the boundary integral is reducible practically to line-

integrations along those tracks. The Action A may thus, on account of the structure of the field as already settled by its own variation, be expressible as made up of parts associated with the material system alone as represented by the historic tracks of the atoms or finite masses. It is now to be further minimised[7] with respect to variation of these historic tracks, that is, of the representation of the history of matter: that will lead to the expression, suitable to the fourfold, of the dynamical equations of interaction of the atoms, in fact to a *symbolic* dynamics of the matter that is present in the field, now latent, which itself arises from that matter as nuclei or mathematical singularities of suitable type, in accordance with the laws determined by the previous variation in the field itself: all this mutual complexity being held firmly in check by its origin from a single Action formula.

THE GUIDANCE OF CLASSICAL ELECTRIC THEORY.

This process is directly suggested, and has even been guided, by cognate Maxwellian electric theory:[8] the special case of a system of linear electric currents in space affords a close analogue of the historic linear tracks of atoms. In that theory the energy of the currents—there a kinetic part T and a potential part W—is postulated to reside, possibly as strain and motion, in the dynamical field of the interconnecting medium or æther. An Action-density L in this medium, or kinetic potential $-L$, is formulated analytically, being equal to $T-W$. The Action $\int L d\tau' dt$, $d\tau'$ being spatial, thus expressed by local elements, is minimised over all the field, thereby adjusting the electrodynamic field to a coherent structure, presented in the form of its Maxwellian absolute circuital equations. With this field-structure, so determined, the energy, and the Action, become condensible into expressions in terms of the currents alone that are the sources of the field, in the form of line-integrals involving their circuits: the result as regards the kinetic part is represented by F. Neumann's energy formula, on Amperean lines, for linear currents in terms of the ancient current elements such as ιds, namely a mutual energy

$$T = \Sigma\int\int \frac{1}{r_{pq}} \iota_p ds_p \iota_q ds_q \cos(ds_p ds_q).$$

Incidentally and more precisely, when the current is expressed in ultimate form as made up of electrons, the complete Action, as it has now to be, in form suitable to the fourfold, is

$$A = \Sigma\int\int \frac{1}{r_{pq}} (e_p dx_p e_q dx_q + e_p dy_p e_q dy_q + e_p dz_p e_q dz_q - c^2 e_p e_q dt_p dt_q);$$

for this form is invariant (except in one feature as regards r_{pq} which leads to a different story that would now carry us too far) and involves the two sets of independent variables $(x_p y_p z_p t_p)$ and $(x_q y_q z_q t_q)$ in the fourfold, expressing position of each pair of interacting electrons but not any one universal time t. Reverting to Maxwellian theory, the forces between the bodies carrying the electric currents are then determined by further variation applied to the Neumann formula, now with respect to change of form of their circuits, in time, by variation with respect to position without further reference to the field, still in the background but already previously settled: and that in fact constitutes the Neumann energy-theory. If we wish to avoid specifications in terms of any concept of mutual forces, this process of minimising a scalar Action by variation can lead direct to the complete set of equations of motion of the conductors that carry the currents.

One essential point the analogy brings out prominently. It will not do, after Hilbert and most writers on this subject, merely to add some suitable invariant form of line-integral to the field Action A in order to express the interactions of the material atoms. The Faraday-Maxwell doctrine is that the energy, or in complete general dynamics the invariant Action, all resides in the field, there being no other; coherently, in that the field adjusts itself minimally to laws that permit this energy, other than free energy expressed as radiation, to be associated permanently with its sources, the atoms or electrons constituting the currents, and thus to be treated as belonging to them.

We have to determine what form the corresponding generalised Action, thus reduced to material form, ought to take in the fourfold problem. The Neumann formula suggests a double integral extended along each pair of the circuits or historic tracks. Under certain limitations (now postponed) it is reducible to a single integral, analogous to the Maxwellian kinetic form involving the electric potential $(FGHV)$, namely

$$\Sigma\int e_p(F_p dx_p + G_p dy_p + H_p dz_p - c^2 V_p dt),$$

involving with Maxwell dt not dt_p. There arises also naturally here, in regard to the fourfold, a local part deriving from mutual activities of the nature of self-induction between the sub-filaments of the cylinder-track of the moving electron, which adds a term $\mu_p ds_p$, where μ_p is a constant expressive of the familiar electric inertia; this part is directly suggestive of the modified Einsteinian intrinsic inertial form now to be introduced, to which an electric part like the above is to be added as the reduced expression of electrodynamics.

PREVIOUS ANALYSIS BY ACTION REVEALED DISCREPANCY WITH FACT.

In the previous effort towards this type of gravitational theory, already referred to (*Phil. Mag.*, Jan. 1923), a linear form of integral was assumed for this reduced Action, as being the nearest analogue of the Einstein geodesic form which connects itself so readily with dynamical orbits. This restricted the choice to the only available type of invariant linear form, which is

$$A = \Sigma\int -cm_p ds_p;$$

where locally in each frame ds^2 reduces by suitable change of co-ordinates to the absolute intrinsic standard form $c^2dT^2 - d\sigma^2$ where $d\sigma^2$ is Euclidean, while all over the fourfold it is expressed con-

[7] This is not the procedure for determining *actual* orbits in space and time. This reduced Action has the requisite invariance, from its mode of formation: and it can now be transferred from the timeless fourfold into a frame in space and time as *infra*, when it becomes the ordinary dynamical Action of the planetary system as referred in space and time to that frame.

[8] Cf. "Æther and Matter" (1900), Ch. vi, especially §§ 56-9.

tinuously in terms of universal co-ordinates by an invariant quadratic differential.

We now introduce the Schwarzschild expression for the spatial-gravitational field as modified by the symbolic track of a mass m moving with changes of its speed restricted to be very slow compared with the velocity of light, namely

$$ds^2=c^2\left(1-\frac{km}{c^2r}\right)dt^2-\left(1-\frac{km}{c^2r}\right)^{-1}dr^2-r^2d\theta^2-r^2\sin^2\theta d\phi^2.$$

Or better for the problem of several interacting planets, the earlier but less exact Einstein expression

$$ds^2=c^2\left(1-\frac{km}{c^2r}\right)dt^2-\left(1+\frac{km}{c^2r}\right)(dx^2+dy^2+dz^2),$$

which is spatially isotropic and so adapted to superposition of disturbing influences. Our direct immediate concern is the question whether, in order to express gravitation within the scheme if that proves to be possible, k must be identified with its absolute constant γ, or with 2γ, the first alternative halving the gravitational effects on light as originally predicted. With sufficient accuracy for this purpose we have for the field of a system of planets the collective isotropic form

$$ds_p=cdt_p\left\{1-\Sigma\frac{km_q}{c^2r_{pq}}-\left(1+\Sigma\frac{km_q}{c^2r_{pq}}\right)\frac{v_p^2}{c^2}\right\}^{\frac{1}{2}},$$

$$v^2=\frac{dx^2}{dt^2}+\frac{dy^2}{dt^2}+\frac{dz^2}{dt^2},$$

from which by further approximation in which the square root is expanded, keeping only the most important terms, we obtain for the Action the expression

$$A=\int\Sigma dt_p\left(\tfrac{1}{2}m_pv_p^2+m_p\Sigma\tfrac{1}{2}\frac{km_q}{r_{pq}}+\ldots\right)+\text{constant}.$$

Now compare this with the ordinary dynamical Action from which by itself alone the entire system of equations of motion of any planetary astronomical system is derivable, namely,

$$A'=\int(T-W)dt=\int\Sigma dt(\tfrac{1}{2}m_pv_p^2+\tfrac{1}{2}m_pV_p),\quad V_p=\Sigma\frac{\gamma m_q}{r_{qp}},$$

where V_p is the gravitational potential of the other masses at m_p. The former expression involves a plurality of independent co-ordinates t_p as free variables, one belonging to each body on its historic track: the latter has the one time-variable t. The former variables must somehow be reduced to a single one, in order to be expressive of the progress of history from stage to stage.[9] In default of anything better, we previously, following the usual tacitly adopted course, simply substituted the same dt for each of these independent differentials dt_p; as the result we had

$$A=\int\Sigma dt\left(\tfrac{1}{2}m_pv_p^2+\tfrac{1}{2}\frac{k}{\gamma}m_pV_p\right).$$

On that pure assumption it proves to be possible to establish the necessary agreement between A and A', merely by equating k to γ: whereas the geodesic postulate that each orbit is determined by itself alone from its own equation $\delta\int ds_p=0$, with the same identification of dt_p with dt, would obviously, with Einstein, make k equal to 2γ.

Thus by use of the single invariant mutual Action, instead of the plurality of geodesic forms which as we hold are only spuriously invariant, both optical effects of gravitation were, on adopting perforce the usual procedure, reduced to half their observed values.

The weak link in the argument was recognised at the time, and has been already here sharply indicated. As nothing better suggested itself, the usual course was followed by replacing the independent co-ordinates t_p, t_q, . . . expressive in part of the positions of the bodies on their tracks in the fourfold, by one universal time-variable t. In another aspect, instead of conducting a general variation of position in the fourfold, it was restricted to displacements confined to hypersurfaces transverse to t; which is not an invariant or intrinsic process, because t may belong to any slicing whatever of the fourfold.

Newtonian Time now introduced.

We now claim to be in a position to do better, as the Newtonian absolute time T has been acquired. The t_p is the variable of the type of time that is appropriate to the material system m_p referred to the convenient frame of our problem in which all the local systems are taken as moving, this one with velocity v_p. It can be placed in relation to T, which is the time-variable appropriate to its own frame, changing relative to the others, in which m_p is always at rest, by a Lorentz transformation expressed at each stage, if x_p is taken for brevity along v_p, by equations of type ("Æther and Matter" (1900), p. 174: Lorentz, *Proc. Amsterdam Acad.* (1904): Einstein, *Ann. der Physik* (1905))

$$\delta X=\epsilon^{\frac{1}{2}}(\delta x-v\delta t),\quad \epsilon=\left(1-\frac{v^2}{c^2}\right)^{-1},$$

$$\delta T=\epsilon^{\frac{1}{2}}\left(\delta t-\frac{v}{c^2}\delta x\right).$$

Here, now introducing subscripts, δX_p, δT belong to the particular planet's own frame, δx_p, δt_p belong for each planet to the solar frame to which the motions of all the planets have to be referred in a theory which includes them all. It is the transfer from δt_p to the universal δT, which is none other than the (reversed) familiar very slight relativity shrinkage of time, of order 10^{-8}, that rises to be an essential feature for orbits because δt always occurs with a factor c. The transfer is effected by the relation $\delta t_p=\epsilon_p^{-\frac{1}{2}}\delta T$; provided we can ignore the addition $-v_p/c^2\,.\,\delta x_p$ to δt_p in the formula, which expresses a change of epoch of T with locality analogous in Lorentz's striking comparison to change in civil terrestrial time for different longitudes. If our local standard frame of inertia, that is, such that dynamics of its material content is practically uniform and Newtonian, is not of too great extent, this omission makes no practical difference: the theory has however to remain approximate, though abundantly covering actuality, in this as in other respects, leaving the practical issues for systems involving speeds of a higher order than planetary still a riddle.

We can now introduce into the Action this unique absolute time T as subsisting intrinsically within every moving system m_p. But it may still be objected that t, as usually introduced in place of

[9] It is just the negation of this consideration that has led to deposing time into an accident of place and motion, and so to abolishing history.

t_p, t_q . . . could be regarded as the absolute time on the sun, to which the motions of all the planets are thereby referred. This remark may suggest a contradiction in our processes: but it is removed by reflecting that though T is measured in the same unit on the sun and on a planet, being absolute, yet it is measured from different epochs, which we cannot specify, and which do not keep constant for the succession of elements of T because the planet's own frame of T is continually changing relative to that of the sun. The only δT that is a continuous differential of a function T, for the environment of the planet in which the process of variation is carried through, is by Newtonian postulation that one which constantly belongs to it, with its optically vibrating atoms, when referred to a frame continuously carried along as part of itself. It is this T that is the unambiguous cumulating time of the records of the astronomers, who work each in his own essential local landscape in which, as in all others, it inheres.

Reverting after these explanations to our analysis, by a simple substitution for dt^2 within the radical, we now have immediately, using isotropic forms for ds^2, with sufficient approximation [10]

$$A=\Sigma\int -c^2m_p\left\{\left(1-\Sigma\frac{km_q}{c^2r_{pq}}\right)\left(1-\frac{v_p^2}{c^2}\right)dT^2-\left(1+\Sigma\frac{km_q}{c^2r_{pq}}\right)\frac{d\sigma_p^2}{c^2}\right\}^{\frac{1}{2}},$$

$$=\Sigma\int -c^2m_pdT\left(1-\Sigma\frac{km_q}{c^2r_q}-\frac{2}{c^2}v_p^2+\ldots\right)^{\frac{1}{2}},$$

as $dt_p=\left(1-\frac{v_p^2}{c^2}\right)^{\frac{1}{2}}dT$, $d\sigma_p^2=dx_p^2+dy_p^2+dz_p^2=v_p^2dT^2$,

the product terms of higher order under the radical in A now, be it noted, cancelling out. Comparison with the Newtonian Action now restores k to the value 2γ as with Einstein; but the result may still differ (see, however, footnote *infra*) by second order terms from the Newtonian Action in a way which might affect sensibly the secular advances of the perihelia of the planets.

We claim in fact to have discovered how to transfer, with sufficient approximation, the reduced form of Action, constructed in the conglomerated fourfold in order to secure the requisite invariance, into the solar frame in space and time of the planets, which is competent to contain it and will lead to the development of dynamical astronomy by further variation in the usual manner with respect to the planetary positions.

Introduction of the factor transforming from the co-ordinate dt_p to a universal time dT has thus affected the kinetic energy of each body as it occurs in the reduced integrand of the Action with a factor 2, together with minor changes: and to restore large-scale agreement with the astronomical Action A' the potential energy has to be affected with the same factor, which requires us to make k equal to 2γ instead of γ. This new inconvenient common factor 2 would then be absorbed by amending the original Action form to $A=\Sigma\int -\frac{1}{2}cm_pds_p$, a change that will presently prove to be essential as regards the relation of mass to energy.

[10] If a track p is regarded as made up of filaments which influence one another the summation $\Sigma km_q/c^2r_{pq}$ ought to be increased by a constant k_p which is a sort of gravitational self-induction like that of an electric current on itself. This would function as a field-addition to mass, did it not cancel out as occurring in two places with opposite signs: there is no field-inertia of gravitation.

But a point arises here that demands close scrutiny, as it may be a main source of obscurity. Reduced to standard local form the transferable invariant ds is expressed by $ds^2=c^2dt^2-d\sigma^2$; as ds is thus cdt for a frame in which the $d\sigma^2$ of a track locally vanishes, it has been customary in the theory to call $c^{-1}ds$ standard time. If this is meant to be the same dT as the present interval of absolute time, it involves the relation

$$dT=c^{-1}ds=\left(1-\frac{v^2}{c^2}\right)^{\frac{1}{2}}dt=\epsilon^{-\frac{1}{2}}dt,$$

whereas our present result, derived from an immediate comparison of frames, is the direct opposite one, $dt=\epsilon^{-\frac{1}{2}}dT$. The justification for it is, briefly, that the Minkowskian fourfold determined by invariance of ds is not a frame of reference for matter in motion; its element of extension is rather a complex of local frames with all speeds of convection. Neither matter nor motion is discernible within the fourfold: it is on the present view a necessary consolidation of the relations of the permitted (locally inertial) frames, in any one of which the actual world can be framed as bodies in motion. But it bears traces of this composite origin, from groups of local frames with all possible motions of convection, in the historic tracks which are indirectly symbolic of the movement of bodies as exhibited in any of the merged constituent frames.

The $c^{-1}ds$, though it has been called standard time, has nothing to do with any moving material system: it is to the local material system itself in its own frame, as the essential *datum*, not to any or all of the other extraneous permitted frames of reference in their various convections relative to it, that the absolute time belongs. Though perhaps a relation between the epochs of T in two local systems is determinable ideally by counting the alternations in t along the undulatory ray connecting them, yet as time progresses the ray rapidly changes owing to their motions and no practicable relation could ensue. Or, expressed differently, the frame of the planet is constantly changing relative to the solar frame, which prevents a steady difference of time-epochs between their frames.

When we come, however, to determine the deflection of a ray passing near the sun it is the spatial gravitational field adjacent to the sun with which we are concerned. Referring the rays to the frame of the sun, the electrodynamic theory shows that the coefficient of dt^2 in the expression for ds^2 expresses with adequate approximation the square of velocity of light near the sun, while the curvature of the ray is by Huygens' principle the local gradient of velocity along its normal.[11] Thus the Einstein deduction for the deviation of the ray holds good with his coefficient 2γ as now restored, but on a different foundation, in place of γ.

Relation of Electric Mass to Energy demands Newtonian Time.

The point has not yet been considered that the time-like co-ordinate t in the fourfold is not unique; for it is one of the impressive features in general relativity-theory that any mode of slicing of the

[11] This needs closer elucidation, now postponed.

hypercosmic fourfold may equally well express it. But what we are concerned with in our actual approximations is the simplified case which Levi-Civita has called Einsteinian statics, in which ds^2 involves no products of dt with other differentials: the ambitions of the wider abstract theory are scarcely practicable, and may be excessive. The motions of all local systems which have speeds small compared with light are then represented by historic tracks, now in a real (x, y, z, ct) fourfold, which are almost parallel: and the co-ordinates $t_p, t_q, \ldots$ of the various systems are suitably measured along some direction for t nearly parallel to them all. It is this simplification which makes an approximate development of the fourfold scheme practicable for actual astronomy, while leaving its relations to actuality unsolved for higher speeds.

It will be noted that in circumstances where the gravitational potential is negligible, the direct inertial part of the Action, as now expressed by

$$A = \ldots + \Sigma \int -\tfrac{1}{2} c m_p ds_p,$$

where $$ds_p = c dt_p \left(1 - \frac{v_p^2}{c^2}\right)^{\frac{1}{2}}, \quad dt_p = \left(1 - \frac{v_p^2}{c^2}\right)^{\frac{1}{2}} dT,$$

becomes $$A = \ldots + \Sigma \int -\tfrac{1}{2} c^2 m_p \left(1 - \frac{v_p^2}{c^2}\right)^{\frac{1}{2}} dt_p$$

$$= \ldots + \int \{\text{const.} + \Sigma \tfrac{1}{2} m_p v_p^2\} dT,$$

when each system is referred to its own intrinsic absolute time; thus indicating that essential mass of an atom, as distinct from inertia derived from an attached field to some degree separable, is an intrinsic constant m_p unaffected by its relation to frames of reference, as naturally it ought to be.[12] It would only be electric field-mass that is affected by its velocity in the frame, being related to field-energy relative to the frame.

Moreover the latter relation, fundamental though it be, is *not* substantiated at all except on the present Newtonian scheme. For an electric system it is common ground that the relevant reduced Action, of fourfold invariant type, must be of form, again with the new adjusting factor $\frac{1}{2}$,

$$\tfrac{1}{2} \Sigma e_p \int (F_p dx_p + G_p dy_p + H_p dz_p - c^2 V_p dt_p),$$

where $$F_p = \Sigma e_q \dot{x}_q / r_{qp}, \quad V_p = \Sigma e_q / r_{qp}.$$

For a static electric system it is thus, closely,

$$-\tfrac{1}{2} \int \Sigma c^2 e_p V_p dt_p, \text{ becoming } -\int W dt,$$

where W is its electrostatic energy, when all its electrons are travelling together so that t_p is the same for all. On introducing Newtonian time, but not otherwise, this is

$$-\int W \left(1 - \frac{v^2}{c^2}\right)^{\frac{1}{2}} dT,$$

which is the familiar form of Action indicative of varying inertia according to a law which makes the energy $W(1 - v^2/c^2)^{-\frac{1}{2}}$, thus showing its dependence on the translatory motion. For example, to our second order of approximation this Action is

$$\int \left(-W + \frac{W}{\tfrac{1}{2} c^2} v^2 + \ldots\right) dT,$$

indicating an increase of inertia of amount W/c^2.

[12] In a field of large uniform gravitational potential V_P an increase of inertia of m_p depending on V_p/c^2 is simulated: but that point of view is confused. The Action is the sole arbiter, which here determines the total result of the field as orbital motions.

Conclusion.

The conservation of Newtonian absolute time for local material systems, as supplied by their intrinsic vibrating atoms of matter, within the Einstein mathematical method of fitting the existence of gravitation into the optical relativity, has thus led to his value of the displacement of spectral lines, also as we have seen to his value for the ray-deflection, but not to his result for the precessions of planetary perihelia.[13]

It is noticeable how little use of the mathematical tensor theory is required for the general argument on the scope of relativity: it here provides only the form of ds^2 for the gravitational field within the solar system, as affected by each mass that is present, and that form is required only to a rough approximation, in order to identify a representation of gravitation within the formulation by ds^2 of the invariant fourfold, though closer calculation is necessary in order to determine the deflection of actual rays and the precessions of planetary perihelia.

Finally it will be observed that the present scheme has to be throughout an approximate one, leading as is claimed in a natural manner to the two optical effects of gravitation as now widely accepted. It works with frames of ordinary space and time, correlated in an auxiliary mathematical fourfold. It may be regarded as the continuation of the previous approximate scheme of electric equivalence of frames, of long ago, "Æther and Matter" (1900), Chapters vi, xi, which at that date covered adequately all the verified facts of optical and electrodynamic relativity, and justified the postulate of its universal validity at any rate up to the second order: without noticing, however, as Lorentz afterwards discovered by an equivalent independent electrodynamic formulation, that the formulæ on which it was based are obviously valid without approximation for the Maxwellian field; though valid only problematically, if at all, within the domains of the atoms, except to the second order of approximation there regarded as imposed on that account. The hypothesis of unrestricted exactness, regardless of structure in the atoms, has eventuated in wide and profound formulations towards hypercosmic schemes, which constitute the modern mathematical theory of relativity. The physical interpretations here advanced rest of course on the most brilliant Einsteinian fourfold device for involving gravitation within optical local relativity; that seems to have now become justified,—but as here urged when it is reconstructed into more consistent and Newtonian setting—by the astronomical tests, as the right type of mathematical formulation; in contrast with modes, one for example making use of a scalar gravitational potential in the fourfold, that might otherwise be in competition with it.

[13] When the approximation to the reduced Action for the Sun-Mercury system is carried to the second order, it appears that its form comes out of the type of the Newtonian Action for an elliptic orbit. If this is confirmed, then on the present theory there would be no influence on the secular progress of the perihelion: which, amid the astronomical complications, and in face of the smallness of the outstanding residue, can scarcely now be regarded as an unsatisfactory conclusion. The masses have to be predominantly intrinsic, as in the text.

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