

THURSDAY, SEPTEMBER 6, 1900.

A NEW DEPARTURE IN THE TEACHING OF ZOOLOGY.

Introduction to Zoology: a Guide to the Study of Animals, for the use of Secondary Schools. By C. B. Davenport, Ph.D., and Gertrude C. Davenport, B.S. Pp. xii + 412. (New York: The Macmillan Co. London: Macmillan and Co., Ltd., 1900.)

THE senior author of this book is well known in zoological circles for his two-volume work on "Experimental Morphology"—one of the most novel and ambitious of modern text-books; and his wife, whose aid he acknowledged in its preface, now appears as joint author of the present equally ambitious production, which has for its object nothing short of a revolution of the methods of zoological teaching in vogue in the secondary schools of the United States. The key to the plan of the work and nature of its contents lies in the prefatory pronouncement that the "vast majority of secondary students are not to be zoologists, but rather men of affairs," and that "what the ordinary citizen needs" zoologically is (not a course in comparative anatomy but) "an acquaintance with the commonest animals"—a knowledge of "where else over the world the common animals of his State are to be found, and of how animals affect man," and that to know these matters is for him "more important than to know the location of the pedal ganglion of the snail." There can be little doubt that in this resolve the authors are in agreement with a large section of active teachers, but it must not be forgotten that the didactic system of laboratory instruction in vogue, against which they are in the long run entering a protest, has in its development become modified beyond the conceptions and intentions of its founders, and that as originally planned it did not ignore non-anatomical considerations to the extent their attitude implies. In their forcible recognition of the later tendency towards so doing, however, and their bold attempt to overcome it, they have performed a useful task, but experience can alone decide upon the wisdom of the remedy they propose.

Their book is of 336 pages, excluding appendices, and is divided into twenty-one chapters. The first four chapters deal with the Insecta, and then follow one each devoted respectively to the Myriapoda and Spiders, two each to Crustacea, Worms and Molluscs, one each to the Echinodermata, Cœlenterata and the Protozoa, and then a series on the Vertebrates taken in ascending order, the whole closing with a novel chapter on the frog's egg as a study in development. The plan adopted in each chapter is much as follows:—Opening with a concise statement of the systematic position and relationships of an order or other great group of animals conveniently selected (with a definition of its name usually in a footnote), there follows a very brief description of the habitus, and if so be the food and other special topics of interest, of one or more of its familiar species. There is then given a short descriptive account of its more familiar allies, and it may be of its development; and the whole

chapter is brought to a close by an appendix, in the form of a key to the families of the order to which the type chosen belongs, or to the orders of the class or other great divisions of the group under consideration, while in places an accompanying key to the identification of members of allied subfamilies may be added or incorporated. The plainest and most concise terms are adopted, and there is a tolerably free use of illustration, preference being given to photographs of entire animals, often with their natural surroundings, in many cases with marked success; and it cannot be denied that the authors have been desperately earnest in the task of selection and compilation. The body of the work is followed by three main appendices, of which the second is a bibliographic list embodying a none too fortunate selection of books of reference, the third a synopsis of the "animal kingdom," and the first an outline of a course of laboratory work upon the type-organisms selected as titular for the main chapters. Novelty here is as great as with the rest of the book, for in the "Exercises" prescribed, after each type-organism has been referred to its habitat, with brief directions for its capture and preservation in the living state where necessary or desirable, there follow instructions for drawing, and series of questions, framed with a view of compelling the observer to determine details for himself, and not of pointing out the precise nature and limits of the observation he is expected to make, as is customary with most laboratory treatises current. "Hints for observations on the living animal" usually follow, as do "Topics for further study." This very novel scheme is the outcome of experience gained while aiding in the conduct of the zoological affairs of the Harvard University, and as here delimited it is prescribed "for use in schools that can give to the subject five periods per week for half a year," at discretion and with modification determinable by local needs. The book thus embraces a very ambitious programme, and we question if the most hopeful aspect of the undertaking is not simply the better encouragement of field-work and of observation of nature in the open, in respect to which our existing methods do perhaps stand in need of reform.

It appears to us, however, that too much has been attempted within the limits of the book, that there is danger in its too frequent brevity of statement, and that it stands in need of a greater uniformity of treatment. What, for example, is to be gained by merely referring to the Tunicata as "Chordata which are either attached or form colonies, or both" (which is an erroneous statement), and as a group of Invertebrates which "lie nearest to the stem from which the Vertebrates arose," when whole paragraphs are given to far less generally important assemblages of forms? What also the use of defining the Stomatopoda as including "only Squilla," and then Cumacea, Isopoda and Amphipoda as embracing a number of forms? The inclusion of the Sponges in the Cœlenterata; the old-fashioned classification of birds, with the Ratite referred to the order "Cursores"; the inclusion of the Bryozoa on one page among the Gephyrea and Leeches ("Annelida"), and on another among the "Scolecida"! can only be cited as examples of classificatory treatment sorely in need of revision; while among

definitions given we note a frequent lack of accuracy and precision, as, for example, with that of the *Ophidia* as having their "eyelids absent." The senior author's previous work explains the introduction of experimental observations of the antenniform-ophthalmite order, and brief note is taken of "variation" and abnormality. The social life and "language" of ants, protective resemblance and mimicry among the Lepidoptera, the habits of the spiders, and many other similarly fascinating topics receive in due course passing consideration. The reader will put down the book feeling the better for its refusal and with a desire to know more, while its "keys" to the identification of the common forms of life, oft overlooked because always present, but withal foremost in their claims on our attention, will prove useful and encouraging. We are doubtful, however, whether the authors would not have done better to have attempted less and that more uniformly, and whether they are justified in their refusal that in matters of elementary scientific education the mere "needs" of the ordinary citizen are to be alone gratified. We are by no means convinced that this argument is sound. Their method would seem likely to discount the teacher's important function of deciding what is to be left untaught—a matter of the utmost urgency in elementary scientific work. We shall watch with interest the development of their scheme.

COLOUR PHOTOGRAPHY.

A Handbook of Photography in Colours. By Thomas Bolas, Alexander A. K. Tallent and Edgar Senior. Pp. viii + 343. (London: Marion and Co., 1900.)

THE preface or introduction is written by the publishers, and is immediately followed by an index. Then follow three "sections." (1) 85 pages, by Mr. Bolas, on the "Historical Development of Heliochromy. General Survey of Processes. Direct Heliochromes on Silver Chloride." (2) 205 pages, by Mr. Tallent, on "Three-colour Photography." (3) 27 pages, by Mr. Senior, on "Lippmann's Process of Interference Heliochromy." Each section is quite distinct from the others, except that they are bound into one volume and indexed together; there is therefore much repetition. For example, Maxwell's colour-sensation curves and Abney's revised curves are each given twice (the two renderings, by the way, are not identical), and Lippmann's formula for his emulsion is given at p. 55 and also at p. 332. Careful editing would have avoided such waste of space. Some of the diagrams are drawn with exceedingly thick lines, and are provided with very large heavy lettering, while others incline rather in the opposite direction. Some of the spectra as drawn for showing absorption, sensitiveness and so on, have the red to the left, and others the red to the right-hand side; some are normal, and others are as produced by prisms. It may be said that these are quoted from various sources; but in a volume in which it is thought necessary to explain with a large diagram the refraction of light on passing from air into water, surely a little explanation of these differences is desirable. At p. 180, a spectrum which is normal is described as "prismatic." The volume appears not to have been edited at all, therefore the only way to

do justice to the authors is to regard it as three distinct books.

Mr. Bolas gives an excellent summary of the whole subject, both historical and practical. As a careful compiler should do, he has erred, if it be an error, in including too much rather than too little. Carey Lea's highly coloured partial reduction products of the halogen salts of silver might have been passed by, by some writers, as well as other references to conjectures. Zenker's work and Wiener's investigations are described intelligibly, although concisely; indeed, the author has evidently spared no pains to give every one his due, and to use to the best advantage the small space at his disposal.

Mr. Tallent begins his section with several pages on the properties of light and the construction of ordinary spectroscopes—matter which, we think, might well have been omitted in order to make room for the treatment of subjects for which the reader is often referred to other books or articles. The peculiar firework-like diagram at p. 112, given to illustrate dispersion, is more likely to mislead than assist the student; and some of the other diagrams might have been made more clear, in spite of the extraordinary boldness of the drawing and lettering. Mr. Tallent has gathered together a great deal of information about three-colour work, which he presents in the form of notes rather than as a treatise. It is doubtless advantageous in some cases to supply the raw material only, but the possession of bricks and mortar does not enable every one to build himself a house. If the very popular style of description sometimes adopted were given up in favour of more technical details, and if the practical applications of the various principles were more closely associated with the enunciation of the principles themselves, we think that the book would be more useful to the large majority of those who will read it. But we must be grateful to Mr. Tallent for having made a beginning in the getting together of the hitherto widely scattered items of the subject. His work must be of considerable assistance to any one following him, and we hope that later on he himself may be able to give us a treatise founded on these notes.

Mr. Senior treats only of Lippmann's interference process, and he writes on this with authority, for he has given the matter much practical attention, and has produced some of the best examples that have been seen. He gives his formulæ and methods apparently without any reserve, as well as the published formulæ of other notable workers. He precedes the practical details with a few pages on the optical principles involved, setting forth clearly the character of "stationary waves." We think that most people reading p. 323 would consider it as showing that the colours reflected from a Lippmann photograph are complementary to those of the objects photographed, but it is quite obvious that Mr. Senior does not intend to convey this impression.

The publishers, in their preface, state that thirty-one years ago they published the pioneer work on photography in colours (by Ducos du Hauron), and they feel satisfaction now in following up the line they "opened up over a quarter of a century ago." All who are interested in the subject will feel thankful to Messrs. Marion and Co. for having done so.

C. J.

OUR BOOK SHELF.

Probleme Kritische Studien über den Monismus. Von Dr. H. v. Schoeler. Pp. viii + 107. (Leipzig: Engelmann, 1900.)

DR. VON SCHOELER'S critique of monism is the work of a mind which, with all reverence for scientific fact, has nothing but disdain for post-scientific theory. The monism of which Haeckel, for instance, or Romanes is the exponent, has captured many scientific intellects, but it is in Dr. von Schoeler's view an arbitrary conceptual construction. It leaves the problems still with us. Of the ultimates of physics, of biology, of psychology, we know but little, and that little makes against such monism. Life is more than knowledge, and will find emancipation neither in science nor in religion, but in art.

Dr. von Schoeler's discursive criticisms of a variety of attempts at construction, or steps towards construction, are of somewhat unequal value, but not uninteresting. They enter into some detail, and might well give pause to any one who is inclined to build a system without straw to his bricks. But, if it be true that a man's *ney* has no meaning apart from the underlying and implied *yea*, the unsatisfactory character of our author's positive teaching must reflect upon his polemics. The way in which he couples Plato and W. K. Clifford on p. 95 suggests doubts as to his insight. Those who allow that current mechanical theories are tending more and more to immaterialism, that organic evolution reduced to its facts cannot assert even descriptive continuity unhypothetically, and that for a deduction of consciousness from the non-conscious we have not so much as the point of departure, will be left cold by Dr. von Schoeler's appeal for Diploismus, and his enthusiasm for Goethe's *Weltanschauung* made complete in the light of Kant's. The duality for which he goes to Bruno's *geminii efficientes* falls even for Dr. von Schoeler within a monism (v. p. 97, ll. 1-4). And Kant's provisional dualism does not exclude a hypothetical monism, idealist or agnostic. Only the resolution of it from the standpoint of understanding is not achievable, and from any other standpoint it cannot be more than hypothetical.

It is doubtful, finally, whether Dr. von Schoeler quite understands in what sense a system admits certain unexplained points as truly problems, and in what sense it claims to solve them. Is the origin of motion a problem recognised by monism as one which it must attempt to solve? And is not metaphysic always, so to speak, a *post mortem* examination? The "gray in gray" of philosophy is a commonplace: "the owl of Athene wings for flight only when twilight falls." H. W. B.

Diamond Drilling for Gold and other Minerals. By G. A. Denny. Pp. x+158. (London: Crosby Lockwood and Son, 1900.)

AT the Paris Exhibition of 1867 much interest was aroused by Leschot's invention for cutting through hard rock by diamonds in rapid rotation. Originally intended for use on a small scale, this method was soon applied by Major Beaumont and others to deep boring; and the great improvements made of recent years in the construction of the instruments used, and the large amount of experience that has been gained by their general use in mining districts, have added so much to the importance of the subject of boring, that it is no longer possible to deal with it adequately in a chapter of a general treatise on mining. An independent work is needed. In German, this exists in Tecklenburg's monumental work. In English, however, Mr. Denny's handbook is the first to give a detailed account of the use of modern diamond core-drills in searching for mineral deposits. The work, which covers 158 pages, contains much information of a practical character, including particulars of the cost of

apparatus and of working. It is, unfortunately, limited in its scope. South African conditions are alone considered, and the descriptions of the drills are confined to machines made by two American firms. The numerous well-designed drills of English and Continental make are not mentioned. The work cannot, however, fail to be of value to any one contemplating using diamond-drilling machines for the examination of mineral lands in South Africa.

The author gives some interesting results, deduced from his own experience, of the rate of progress of machine diamond drilling in various rocks. For holes up to 1000 feet he finds that, including all normal delays, the rate averages per week: in limestone, 150 to 200 feet; in Carboniferous sandstone, 150 feet; in slate, 100 to 150 feet; in greenstone, 110 feet; in basalt, conglomerate, diabase, diorite and dolomite, 100 feet; in porphyry, 90 feet; in quartz, 85 feet; in granite, 73 feet; and in chert, 60 feet. As regards the cost of drilling, the author points out that diamond drilling on the Witwatersrand is almost always done by contract, the reasons being that men with the requisite experience are not easily secured, and that a mining company rarely has sufficient work to justify the outlay upon the plant. The average tender for a hole 3000 feet deep would work out at about 37s. 6d. per foot, the price being fixed on a sliding scale, say 25s. per foot for the first 500 feet, and rising by 5s. per foot every 100 feet. If the company undertook the work on its own account, the cost per foot would be about 26s. 8d., or 3950l. for the 3000 feet. This with 2340l., the cost of drilling outfit, brings the total cost of the hole to 6290l., as compared with 5625l., the contractors' price. It is to be regretted that the author has not compared these prices with those obtaining elsewhere. The bore-hole at Paruschowitz in Upper Silesia, for example, the deepest in the world, completed to a depth of 6566 feet in 1893, was bored by the diamond drill. The average rate of progress was 16½ feet a day, and the cost was 3761l., or 35s. a yard. Details of the average working cost of diamond drills in Victoria and New South Wales, which are published annually in the Government reports, might advantageously have been cited for purposes of comparison. B. H. B.

Symons's British Rainfall, 1899. Compiled by H. Sowerby Wallis. Pp. 251. (London: Edward Stanford, 1900.)

A PORTRAIT of the late Mr. G. J. Symons, the founder of the British Rainfall Organisation, and an appreciative tribute to his memory, are naturally found in this volume—the first to appear without his name upon the title-page. The thirty-nine volumes for which Mr. Symons was responsible form a real monument to his industry and scientific work. Mr. Sowerby Wallis, who was associated with him for thirty years, will continue the work along the lines which have hitherto proved so successful.

The usual particulars are given concerning the rainfall and meteorology of various parts of the British Isles during the year 1899, as observed at about 3500 stations. The average rainfall of the ten years 1890-1899 is discussed in an article, the values being given for a hundred stations well distributed over the three kingdoms. The discussion is only provisional, but so far as it has gone it indicates that over a large part of the kingdom the rainfall in the period considered was deficient by from 5 to 10 per cent. and upwards. Over an area of about 300 miles long by 100 miles wide, stretching right across the country from south-west to north-east, the fall for the period shows a deficiency of 10 per cent. or more. In other words, accepting the values discussed, it appears that little more than eight and a half years' rain fell over a large part of Central England in the ten years 1890-1899.

LETTERS TO THE EDITOR.

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Railways and Moving Platforms.

In reference to Prof. John Perry's letter in NATURE of Aug. 30 on the subject of "Railways and Moving Platforms," will you kindly allow me to state that I worked out a scheme for moving platforms for railways in India in the year 1877, and that a paper of mine on the subject was published in the professional papers of the Thomason Civil Engineering College at Rurki in India in 1877 or 1878?

My plan was to have alongside of the main line a length of about a mile of level line, with a steep incline at either end, for the moving platform.

The moving platform would acquire sufficient speed on these inclines to run alongside of, and be made fast to, a train on the main line running in the same direction at reduced speed.

After the platform had been made fast, and passengers and crates of luggage transferred to a similar platform on the train, the train was to increase its speed, and finally release the platform with sufficient way on to carry it up the incline at the other end of its run, so as to be in readiness for the next train from the opposite direction.

This represented the case for moving platforms in its simplest form to suit Indian traffic. Details, of course, can readily be supplied.

W. SEDGWICK
(Lt.-Col. late R.E.).

September 3.

The Migration of Swifts.

REFERRING to the letter of Mr. O. H. Latter in NATURE of August 30, there are swifts' nests in the roof of my house, and the birds went to their nests as usual on the evening of August 11, but on the following evening, Sunday, August 12, they had gone. In other houses close at hand swifts remained on the 13th and 14th, but by the evening of the 15th all had disappeared. On one occasion some years ago a solitary swift remained after his companions had departed, and consorted with the neighbouring house martins until the last week in September.

A curious occurrence was observed by me on May 26 last, when the swifts had already been for some time with me. But on the afternoon of that day I was on board the Transatlantique Company's steamer crossing the Mediterranean from Marseilles to Algiers in order to observe the total eclipse of the sun. The boat left Marseilles at one o'clock, and at 4h. 40m., by which time we were seventy miles from the land, a flock of birds was seen following the ship in the distance. In a few minutes they were flying round the ship, and turned out to be common swifts. They were estimated to be about 200 in number. They gradually forged ahead, leaving the ship behind, and in a few minutes were lost in the distance. Several of the passengers made a note of the occurrence. The course followed by the swifts was one or two points to the right of the ship's course, or about S.S.W., in the direction of the Balearic Islands.

WILLIAM ANDREWS.

Steeple Croft, Coventry, September 1.

The Reform of Mathematical Teaching.

THE deeply interesting letter of Mr. David Mair on the above subject in a recent number of NATURE will no doubt be attentively perused. Many, I imagine, could echo his experience when he says, speaking of 100 boys at a "well-taught school," "hardly one failed to write out the construction and proof, but only one of the hundred carried out the practical construction. Clearly our present Euclidian teaching has little to do with geometry."

Grave dissatisfaction in regard to the study of Euclidian geometry has long been voiced in Great Britain and in France, and the reason for the continued lamentable state of things in that special scientific direction is not, I think, far to seek. When Euclid, as a practical teacher, made use of his Propo-

sitions, theory and practice had doubtless that close association which Mr. Mair appears rightly to desire as a remedy for the present extraordinary condition of Euclidian study.

Now, if we assume that Euclid's own pupils were first of all drilled in a thorough knowledge of the sub-geometric properties of the cube, we are led largely to modify the supposed indictment against Euclid's method.

Again, Euclid seems to me to have used constructions, not only of a strict, but of a particular or edificial nature; so that, properly viewed, each succeeding proposition carried, not only its specific teaching or lesson, but beautiful groups also of surrounding truths of an implicit character.

If the foregoing remarks be valid, it is easy to see that only two serious faults can be charged against Euclid's method—namely, the use of false diagrams and indirect demonstrations. The former, of course, being misleading, are not in harmony with the modern Herbartian cumulative principles of "educative instruction."

As to the second fault, the splendid argumentation of the famous Simson in his "Notes" will not, I fear, greatly avail in Euclid's favour. Mr. Mair rightly vindicates for the pupil the power of "educational interest," another Herbartian doctrine, by the by; and I agree with him that "geometry is in worse case than algebra," because with the latter, I opine, the notion of "zero" inevitably leads the mind towards the necessary cubical standard.

No one could reasonably wish the true Euclidian or edificial geometry to be suppressed, but might without presumption press for a reform in the way of presenting all geometrical truths by a direct reference to those sub-geometric conditions which have equal rank with the oldest of nature's immutable laws.

If for any school or pupil, instead of enlarging the mental vision, and creating intellectual joys, the Euclidian tasks savour of prolonged drudgery, mystery and confusion, as they assuredly often do, such toil should perforce be abandoned to prevent, at least, waste of time and energy, not to speak of the gain to human happiness.

Possibly in the broad expanse of the educational economy the universities of the world may eventually suggest practical reforms of a vital kind in the teaching methods that affect mathematical science.

I am not competent to pursue the subject to any length, but I might remind students that, although by a sort of repartee to a kingly personage Euclid said there was "no royal road to geometry," he did not say there was no royal gate to it, and that I trust I have, however faintly, herein indicated.

August 25.

HENRY WOOLEN.

The Trembling of the Aspen Leaf.

IT is well known that the vibratory motion of the leaf of the aspen and other poplar trees is caused by a flattening of the petiole at its junction with the lamina. The lower part of the leaf-stalk is elongated and rigid, thus forming a basis upon which the flattened portion of the stalk can, in virtue of its elasticity, move to and fro as the wind acts upon the leaves of the tree. It is stated by Kerner that this adaptation prevents the leaves striking against each other and the branches of the tree, whereby they might get bruised. In this connection it is a noticeable fact that the poplars which exhibit this property of leaf-vibration most strongly have sparsely distributed leaves, and the foliage is scanty in comparison with other trees of the genus, especially the abele, or white poplar.

With reference to the abele, it may be noticed that the leaves which possess the trembling motion in a slight degree are covered with a white felting, which Kerner asserts is an adaptation to protect the stomata from the excess of atmospheric moisture which prevails in the damp situations and river-sides where this tree commonly grows. Yet, it may be noted, the aspen is found in precisely similar conditions, and must be affected injuriously by any influence that would act unfavourably upon the abele. Now, it has occurred to me that the real use of the vibratory motion of the aspen leaf may be an adaptation to throw off rapidly the excess of aqueous condensation liable to take place upon the foliage of trees growing in marshy situations. I should very much like to hear the opinions of some of your readers on this point, which, if a true solution of the matter, is interesting from the fact that the same end is

secured by very different means in two plants of the same genus, and so very much alike in all other particulars.
Hobart, July 25. HENRY J. COLBOURN.

Electricity direct from Coal.

WITH reference to the announcement made in the *Daily Mail* of September 1, that Thomas A. Edison had completed a machine for the generation of electric power direct from coal without the use of engines or dynamos, may I ask you to reprint a few lines from an article on electric traction I wrote for you, and which you published on April 12, 1894?

"Before electric traction can be employed on a very large scale, we must possess a means of producing the electricity on the spot and at the time it has to be used, or, in other words, we must possess a battery in which the energy of coal can be transformed directly into electric current, so that we may do without storage batteries in which to carry electric energy about, or heavy copper conductors through which to convey it at moderately low tension from the spot where it is produced to where it is used, or light aerial conductors through which to convey it at high tension.

"How long we shall be without this, or how many minds are engaged in the solution of this or some such problem, we know not, but the moment it is solved, and solved doubtless it will be, there will be such a transformation scene in the industrial applications of electricity as one can hardly conceive. It would mean that for almost all purposes except those in which heating is required electricity would or could be used. An electric light-producing battery in every house, quite independently of any mains in the streets; an electric power-producing battery to carry us whither we would on rails or on the streets; and in every house to put an end to all the evils attendant on crowded factories and workshops, in crowded streets and towns; such and other advantages would result from turning electricity from a servant into a master, from a mere transformer of energy into a source of energy."

E. F. BAMBER.

48 St. James's Square, W., September 3.

Artificial Deformations of Heads, and some Customs connected with Polyandry.

WITH reference to your note on M. Charles de Ujfalvy's recent article in *l'Anthropologie* (p. 323, ante), I may be allowed to call your attention to the ancient Korean practice of artificially deforming their heads, which was apparently similar to the method adopted by the Huns as well as the Hûna kings of India. Thus, the Chinese "History of the Later Han Dynasty," written in the fifth century, *sub.* "Eastern Barbarians," says: "The people of Ma-Kan (in the south-western part of the Korean peninsula) wish their heads flat; so the head of every child just born they compress with stone to deform it."

The special horned head-dresses worn by the polyandric women of the White Huns put in mind the old Japanese usages, described by Fujioka and Hirade in their "History of the Japanese Customs and Manners," Tokio, 1897, vol. i, p. 169: "In the festival of the god of Tsukuma, every woman had to go in procession after the holy sedan-chair, with a number of pans on her head proportionate to her immoralities. In the temple of Usaka, while the priest was praying in a feast-day, every woman was scourged on similar principles."

KUMAGUSU MINAKATA.

I Crescent Place, South Kensington, August 11.

Huxley and his Work.

ON p. 13 of "One Hundred and One Great Writers," issued by the *Standard*, and presumably edited by Dr. Garnett, occurs the following remarkable account of Huxley and his work. "Huxley's work is that of the populariser, the man who makes few original contributions to science or thought, but states the discoveries of others better than they could have stated them themselves." Comment is needless. F. W. HENKEL.

Markree Observatory, Collooney, Ireland, August 23.

THE CAUSES OF FRACTURE OF STEEL RAILS.

WHEN the down Scotch express was running through St. Neots station, on the Great Northern Railway, on December 10, 1895, a rail broke into seventeen pieces, part of the train left the metals, and a serious accident resulted. Several features of the report on the mishap, drawn up in the ordinary course by the late Sir Francis Marindin, might well have occasioned deep thought, notably the conclusion that the first fracture of the rail took place over a chair at a minute induced flaw, which did not exist when the rail was manufactured.

The whole report, however, is suggestive rather than explanatory, and the result was the appointment by the Board of Trade of a committee to investigate the question of the loss of strength of steel rails caused by prolonged use. The committee was a very strong one, and contained some distinguished steel manufacturers, engineers, metallurgists and chemists. They collected a vast amount of information, much of it apparently considered unsuitable for publication, and made long series of experiments, many of them, judging from the report, more easily made than their results explained.

Finally, after four years' work, they have issued a report with the satisfactory feature that practically no change is recommended to be made in the mode of management of the permanent way by the railway companies.

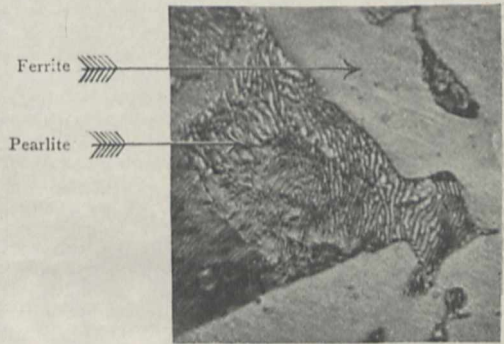


FIG. 1.—Steel rail. X 850 D. Showing pearlite and ferrite.

Nevertheless, although no legislation seems likely to result from the labours of the committee, the evidence that has been collected and published in the appendices to the report is of great scientific interest. The experimental work that was undertaken was divided among the members of the committee. A number of rails found broken on the road, or discarded as worn out, were selected for examination. Prof. Unwin took charge of the tests on their hardness, tensile strength and bending strain, and Mr. Windsor Richards of those on their resistance to the shock of falling weights; Sir William Roberts-Austen made micrographical examination of the rails, and Dr. Thorpe analysed them. Sir Lothian Bell includes in his comprehensive memorandum details of a number of mechanical tests on rails, and Prof. Dunstan gives an interesting account of the effects of atmospheric corrosion.

Interest naturally centred around the St. Neots rail. It was found to be of ordinary composition, and the mechanical tests applied to it showed that the steel was of variable, but, on the whole, of good quality. It was only on microscopic examination that the extraordinary character of the rail became evident. Good rail steel, according to Sir W. Roberts-Austen, consists of "ferrite," or iron free from carbon, and "pearlite," which is a mixture of alternate bands of ferrite and "cementite" (the carbide corresponding to the formula Fe₃C). The structure is shown in Fig. 1, a reproduction of a micro-

graph of rail steel magnified 850 diameters, in which the light constituent is ferrite, and the alternate bands of ferrite and cementite together make up the constituent pearlite. Well-developed pearlite with a conspicuous banded structure is characteristic of good rail steel. It is the form of carbide produced by slow cooling. When, however, steel is hardened by "quenching," pearlite is no longer to be found, and the whole mass consists of interlacing crystalline fibres devoid of banded structure, and is called "martensite."

With regard to this, Sir William Roberts-Austen says: "The detection of martensite in a rail should at once cause it to be viewed with extreme suspicion, as showing that the rail is too hard locally to be safe in use." An examination of the running edge of the St. Neots rail (Fig. 2) showed that a surface layer of about 1/100th of an inch thick existed, in which the carbide was mainly in the form of martensite.

This surface layer forms the lighter upper part of the figure, while the darker portion below it shows the usual assemblage of pearlite and ferrite granules. The actual unning edge is shown against the dark space at the top

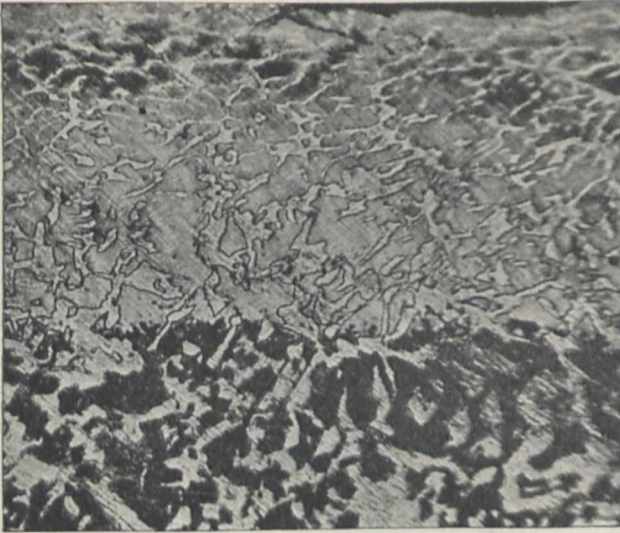


FIG. 2.—St. Neots rail, running edge. Pearlite passing into martensite. $\times 140 D.$

of the figure. Martensite was also found in small patches in some other worn and broken rails, but to a far less extent, the St. Neots rail being unique in this respect.

The questions that naturally presented themselves on this discovery were, first, How far would this structure account for the brittleness of the rail? and secondly, How had the martensite been produced? With regard to the first question, the rolling surface of the St. Neots rail was found to be traversed by a number of transverse cracks (Fig. 3), some just passing through the hardened skin, others running into the substance of the rail. The upper surfaces of rails are subject to tension over chairs by the weight of passing trains applied between the chairs, and cracks are formed in this way. To realise the importance of these cracks, it is only necessary to turn to Mr. Martin's memorandum. He found that a heavy steel rail nicked with a chisel to a depth of 1/64th of an inch broke under the weight of six hundredweight let fall from a height of twelve feet, while the same rail, if not previously nicked, resisted successfully the fall of a ton weight from a height of twenty feet. The loss of strength due to these minute cracks is therefore amazing, and can only be accounted for on the hypothesis that shallow nicks are readily induced by

shock to spread through the mass. The induced flaws of Sir Francis Marindin might thus be explained.

On the other hand, a warning note is struck by Prof. Unwin, who points out that minute transverse fissures are common on the rolling surfaces of old rails; and as only one rail in 2000 or 3000 breaks on the road, the others being discarded as worn out, it must be rare for such fissures to spread into the substance of the rail. It is suggested that if much silicon is present, the spreading of fissures becomes more rapid; but the St. Neots rail contained only 0.09 per cent. of silicon, an amount well within the limits of composition put forward by Messrs. Windsor Richards and Martin as suitable for rail steel.

On considering the problem of how martensite can be formed on the rolling surfaces, it is again evident that the St. Neots rail is a remarkable exception. All old rails become "hammer-hardened" on the surface by long use, and their strength and percentage of elongation may be increased by annealing, but no clear case of any production of martensite in this way could be obtained. The effect produced by the "cold-rolling" action of

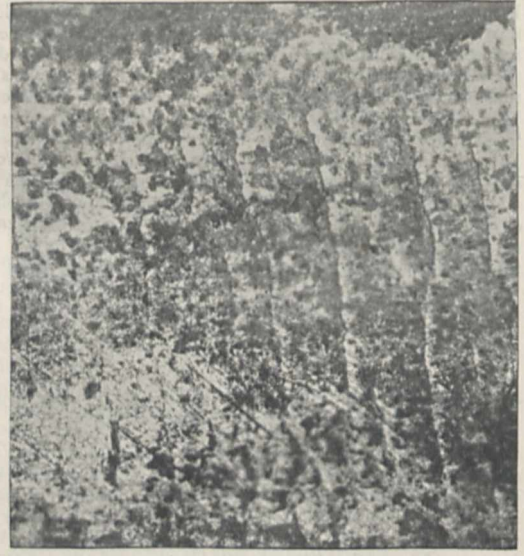


FIG. 3.—St. Neots rail, rolling surface. $\times 5 D.$

passing trains on steel is shown in Fig. 4, which is a photograph enlarged 140 diameters of the running edge of a rail taken up after ten years' wear. The direction of the granules is changed in the surface layer, but otherwise the structure is unaltered. Roberts-Austen succeeded in producing a structure like that of the St. Neots rail, but only by local heating with an electric arc. With regard to this, he observes that this experiment "points to the probability that local heating of a rail by skidding, followed as it would be by the rapid abstraction of the heat by the mass of the cold rail, can produce patches of martensite, though it may be very difficult in the laboratory to imitate the actual conditions by mechanical means." He seems to think that "the structure of the St. Neots rail would point to the changes having been effected while the rail was actually in use."

Although the St. Neots rail has thus baffled the committee, inasmuch as they cannot say definitely whether other rails are likely to be altered in the same way, it is evident that one of the most important results of their labours will prove to be the full realisation of the fact that steel possesses a complex structure which can be studied with the microscope, that this structure varies greatly with the mechanical and thermal treatment to

which it has been subjected, and that the durability of the rail depends on its structure.

Apart from the micrographical appendices, much interesting information may be obtained from a study of the mechanical tests, and some of the conclusions drawn by Prof. Unwin from these are among the most definite in the report, though they do not go far to explain the St. Neots mishap. It is found, for instance, that rails

the Mayor and Mayoress have invited the Association to a *conversazione* in St. George's Hall. The building will be elaborately decorated, and music will be provided by a large string band, under the conductorship of Mr. I. Shepherd. There will be exhibits of various scientific novelties in different parts of the building; and the galleries will be specially levelled-up for refreshment and supper buffets. The 2nd West York Artillery Volunteers are providing a Guard of Honour to line the staircase.

At the conclusion of Prof. Gotch's lecture on Friday night there will be a smoking concert at the Technical College in honour of the President, for which various well-known elocutionists have been engaged.

On Monday, September 10, the Mayor and Corporation are inviting all persons attending the meeting to a large garden-party in Lister Park. The portion of the park where the guests will chiefly collect will be that above the lake. Around or in this space there will be several refreshment tents, and in front of each will be little tables in the open, surrounded by chairs, after the style of the foreign *cafés*. The lake will be decorated by means of Venetian masts and flags; while some new boats will be out, with boatmen in suitable garb in charge of them. The Black Dyke Band plays near the lake, and the band of the Bradford Rifles at the high end of the park. Archery and other amusements will be provided; and in one corner there will be some ballooning experiments under the direction of the Rev. J. M. Bacon, who is well known just now in connection with the trials which, in conjunction with Admiral Fremantle, he has been making

in improved military signalling from balloons. Probably Mr. Bacon will be accompanied by the Admiral. It is proposed to erect a 70-foot pole about 30 yards from the balloon, and another, of equal height, in the furthest corner of the park; and, somewhere between the two, it will be attempted to explode a mine by means of wireless telegraphy, an experiment which was recently successfully performed at Newbury. Mr. Nevil Maskelyne will take part in the wireless telegraphic experiments, in order to exhibit the new receiver which he has patented and sold to Lloyd's.

On Tuesday the Mayor and Corporation are inviting the Association to a *soirée* in St. George's Hall. The arrangements will be somewhat similar to those on the occasion of the Mayor's function on the preceding Thursday, excepting that the music will be provided by the band of the Artillery Volunteers.

On Wednesday various private garden-parties will take place. Mrs. Henry Illingworth has invited 150 members of the Association to visit her grounds, for tea, tennis and croquet; and there will be music for those who prefer to rest after their labours. There will also be a garden-party at Ferniehurst, Baildon, by the kind invitation of Mr. and Mrs. G. C. Waud; a procession of prize-winning hackneys will take place in the course of the afternoon; and also sheep-dog trials, for which most of the celebrated dogs in the North Country have been brought together.

Messrs. Wm. Fison and Co. have also invited a hundred members to a garden-party at Greenholme, where, after tea, they will have an opportunity of visiting the turbine machinery and their textile works. Another function on the same day will be a garden-party at Royds Hall, by the kind invitation of the Low Moor Iron Company. The visitors will first be taken round the foundries to see some smelting work, and to examine some of the most striking parts of the machinery.

On the evening of Wednesday (the 12th) there will be

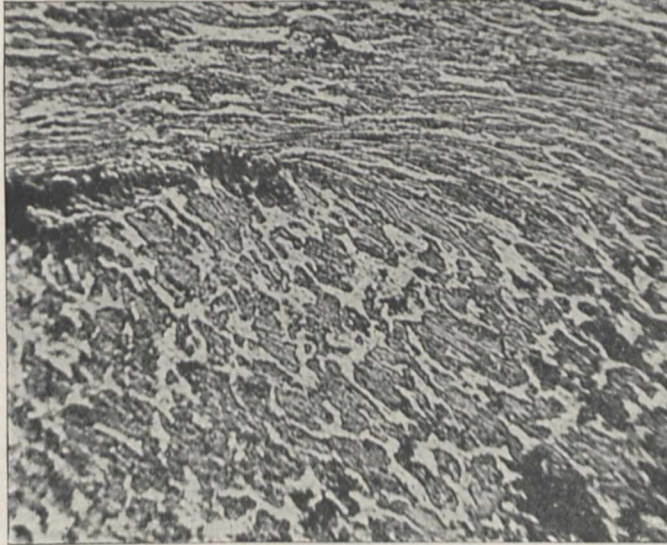


FIG. 4.—Running edge showing "flow." × 140 D.

generally break near their ends "owing to greater straining action due to discontinuity at the joint," and that the fish-joints are an unavoidable source of danger. It is also found that a rail is more liable to break when its worn head is turned down, as usually happens after a few years' use in the case of double-headed rails. Considerations of space alone prevent these points from being dealt with at greater length.

THE BRADFORD MEETING OF THE BRITISH ASSOCIATION.

THE final arrangements for the Bradford meeting of the British Association are now complete, and there is every indication that the gathering will be one of the largest that has been held in recent years. Representatives of scientific institutions are coming from nearly every country in the world; and there are delegates from the United States, Canada, the Cape, New Zealand, the West Indies, India, France, Germany, Russia, Denmark and Sweden, Spain, Italy and Greece. The Bradford people have come forward in a most willing manner to offer hospitality to the visitors, and a large proportion of the strangers will at any rate have had the opportunity of accepting private hospitality.

In our last article we dealt with the excursion programme. We propose now to say something about the various social functions which have been organised for the week.

The first social gathering will be a reception at the Municipal Technical College this afternoon (September 6). Mr. W. E. B. Priestley, the chairman of the Technical Instruction Committee, will welcome the visitors; and, after partaking of afternoon tea, they will be escorted in small bodies round the building, to see the textile exhibition, and the various processes of the textile industries. On the evening of the same day (Thursday)

a grand concert in St. George's Hall, at which Madame Ella Russell will be the *prima donna*. The Bradford Permanent Orchestra, under the conductorship of Mr. Frederick Cowen, will render a very interesting programme; and the Festival Choral Society are to perform certain celebrated items from the works of Handel, Wagner and Sullivan.

A temporary museum, illustrative of papers read before the Sections, will be provided in the Girls' Grammar School. Its primary object is to afford a space where those who read papers can deposit any specimens or apparatus which they may show, and which thus can be examined more at leisure than in the Section Room. In addition, the Bradford officials have endeavoured to get together some choice geological specimens of local interest, which will illustrate the discussions to take place in the Geological and Botanical Sections on the origin of coal; and also specimens illustrating the reef-knolls of the Craven district, which have been the subject of controversy in recent years. Further, Mr. Butler Wood, the chief librarian under the Bradford Corporation, has taken under his care a collection of local pre-historic specimens.

Amongst the readers of papers, Mr. J. J. Stead, of Middlesbrough, will exhibit specimens of metals, treated by a peculiar method which he has discovered. There will be numerous maps, principally geological—several dealing with the investigation of the underground water-courses of Malham and Ingleborough. There will also be a contribution, by Mr. A. D. Ellis, of a number of rare and valuable atlases, of the sixteenth to the eighteenth centuries; while various lantern slides used in the Sections will be shown on transparent screens. In addition, the Science and Art Department have promised the loan of the best work that was done in the recent National Competition; and the collection from South Kensington is expected to be of an exceptionally attractive character, representing, as it does, the cream of the best work of the Art Schools of the country. It is intended that the exhibits shall be largely illustrative of the products of Bradford, and that they shall also illustrate, to a certain extent, the work that is being done at the Municipal Technical College.

RAMSDEN BACCHUS.

INAUGURAL ADDRESS BY PROF. SIR WILLIAM TURNER, M.B., D.C.L., D.Sc., F.R.S., PRESIDENT OF THE ASSOCIATION.

TWENTY-SEVEN years ago the British Association met in Bradford, not at that time raised to the dignity of a City. The meeting was very successful, and was attended by about 2000 persons—a forecast, let us hope, of what we may expect at the present assembly. A distinguished chemist, Prof. A. W. Williamson, presided. On this occasion the Association has selected for the presidential chair one whose attention has been given to the study of an important department of biological science. His claim to occupy, however unworthily, the distinguished position in which he has been placed rests, doubtless, on the fact that, in the midst of engrossing duties devolving on a teacher in a great University and School of Medicine, he has endeavoured to contribute to the sum of knowledge of the science which he professes. It is a matter of satisfaction to feel that the success of a meeting of this kind does not rest upon the shoulders of the occupant of the presidential chair, but is due to the eminence and active co-operation of the men of science who either preside over or engage in the work of the nine or ten sections into which the Association is divided, and to the energy and ability for organisation displayed by the local Secretaries and Committees. The programme prepared by the general and local officers of the Association shows that no efforts have been spared to provide an ample bill of fare, both in its scientific and social aspects. Members and Associates will, I feel sure, take away from the Bradford Meeting as pleasant memories as did our colleagues of the corresponding Association Française, when, in friendly collaboration at Dover last year, they testified to the common citizenship of the

Universal Republic of Science. As befits a leading centre of industry in the great county of York, the applications of science to the industrial arts and to agriculture will form subjects of discussion in the papers to be read at the meeting.

Since the Association was at Dover a year ago, two of its former Presidents have joined the majority. The Duke of Argyll presided at the meeting in Glasgow so far back as 1855. Throughout his long and energetic life, he proved himself to be an eloquent and earnest speaker, one who gave to the consideration of public affairs a mind of singular independence, and a thinker and writer in a wide range of human knowledge. Sir J. Wm. Dawson was President at the meeting in Birmingham in 1886. Born in Nova Scotia in 1820, he devoted himself to the study of the Geology of Canada, and became the leading authority on the subject. He took also an active and influential part in promoting the spread of scientific education in the Dominion, and for a number of years he was Principal and Vice-Chancellor of the McGill University, Montreal.

Scientific Method.

Edward Gibbon has told us that diligence and accuracy are the only merits which an historical writer can ascribe to himself. Without doubt they are fundamental qualities necessary for historical research, but in order to bear fruit they require to be exercised by one whose mental qualities are such as to enable him to analyse the data brought together by his diligence, to discriminate between the false and the true, to possess an insight into the complex motives that determine human action, to be able to recognise those facts and incidents which had exercised either a primary or only a secondary influence on the affairs of nations, or on the thoughts and doings of the person whose character he is depicting.

In scientific research, also, diligence and accuracy are fundamental qualities. By their application new facts are discovered and tabulated, their order of succession is ascertained, and a wider and more intimate knowledge of the processes of nature is acquired. But to decide on their true significance a well-balanced mind and the exercise of prolonged thought and reflection are needed. William Harvey, the father of exact research in physiology, in his memorable work, "*De Motu Cordis et Sanguinis*," published more than two centuries ago, tells us of the great and daily diligence which he exercised in the course of his investigations, and the numerous observations and experiments which he collated. At the same time he refers repeatedly to his cogitations and reflections on the meaning of what he had observed, without which the complicated movements of the heart could not have been analysed, their significance determined, and the circulation of the blood in a continuous stream definitely established. Early in the present century, Carl Ernst von Baer, the father of embryological research, showed the importance which he attached to the combination of observation with meditation by placing side by side on the title page of his famous treatise, "*Ueber Entwicklungsgeschichte der Thiere*" (1828), the words *Beobachtung und Reflexion*.

Though I have drawn from biological science my illustrations of the need of this combination, it must not be inferred that it applies exclusively to one branch of scientific inquiry; the conjunction influences and determines progress in all the sciences, and when associated with a sufficient touch of imagination, when the power of seeing is conjoined with the faculty of foreseeing, of projecting the mind into the future, we may expect something more than the discovery of isolated facts; their co-ordination and the enunciation of new principles and laws will necessarily follow.

Scientific method consists, therefore, in close observation, frequently repeated so as to eliminate the possibility of erroneous seeing; in experiments checked and controlled in every direction in which fallacies might arise; in continuous reflection on the appearances and phenomena observed, and in logically reasoning out their meaning and the conclusions to be drawn from them. Were the method followed out in its integrity by all who are engaged in scientific investigations, the time and labour expended in correcting errors committed by ourselves or by other observers and experimentalists would be saved, and the volumes devoted annually to scientific literature would be materially diminished in size. Were it applied, as far as the conditions of life admit, to the conduct and management of human affairs, we should not require to be told, when critical periods in our welfare as a nation arise, that we shall muddle through somehow. Recent experience has taught us that wise

discretion and careful prevision are as necessary in the direction of public affairs as in the pursuit of science, and in both instances, when properly exercised, they enable us to reach with comparative certainty the goal which we strive to attain.

Improvements in Means of Observation.

Whilst certain principles of research are common to all the sciences, each great division requires for its investigation specialised arrangements to insure its progress. Nothing contributes so much to the advancement or knowledge as improvements in the means of observation, either by the discovery of new adjuncts to research, or by a fresh adaptation of old methods. In the industrial arts, the introduction of a new kind of raw material, the recognition that a mixture or blending is often more serviceable than when the substances employed are uncombined, the discovery of new processes of treating the articles used in manufactures, the invention of improved machinery, all lead to the expansion of trade, to the occupation of the people, and to the development of great industrial centres. In science, also, the invention and employment of new and more precise instruments and appliances enable us to appreciate more clearly the signification of facts and phenomena which were previously obscure, and to penetrate more deeply into the mysteries of nature. They mark fresh departures in the history of science, and provide a firm base of support from which a continuous advance may be made and fresh conceptions of nature can be evolved.

It is not my intention, even had I possessed the requisite knowledge, to undertake so arduous a task as to review the progress which has recently been made in the great body of sciences which lie within the domain of the British Association. As my occupation in life has required me to give attention to the science which deals with the structure and organisation of the bodies of man and animals—a science which either includes within its scope or has intimate and widespread relations to comparative anatomy, embryology, morphology, zoology, physiology and anthropology—I shall limit myself to the attempt to bring before you some of the more important observations and conclusions which have a bearing on the present position of the subject. As this is the closing year of the century it will not, I think, be out of place to refer to the changes which a hundred years have brought about in our fundamental conceptions of the structure of animals. In science, as in business, it is well from time to time to take stock of what we have been doing, so that we may realise where we stand and ascertain the balance to our credit in the scientific ledger.

So far back as the time of the ancient Greeks it was known that the human body and those of the more highly organised animals were not homogeneous, but were built up of parts, the *partes dissimilares* (τὰ ἀνόμοια μέρη) of Aristotle, which differed from each other in form, colour, texture, consistency and properties. These parts were familiarly known as the bones, muscles, sinews, blood-vessels, glands, brain, nerves and so on. As the centuries rolled on, and as observers and observations multiplied, a more and more precise knowledge of these parts throughout the Animal Kingdom was obtained, and various attempts were made to classify animals in accordance with their forms and structure. During the concluding years of the last century and the earlier part of the present, the Hunters, William and John, in our country, the Meckels in Germany, Cuvier and St. Hilaire in France, gave an enormous impetus to anatomical studies, and contributed largely to our knowledge of the construction of the bodies of animals. But whilst by these and other observers the most salient and, if I may use the expression, the grosser characters of animal organisation had been recognised, little was known of the more intimate structure or texture of the parts. So far as could be determined by the unassisted vision, and so much as could be recognised by the use of a simple lens, had indeed been ascertained, and it was known that muscles, nerves and tendons were composed of threads or fibres, that the blood- and lymph-vessels were tubes, that the parts which we call fasciæ and aponeuroses were thin membranes, and so on.

Early in the present century Xavier Bichat, one of the most brilliant men of science during the Napoleonic era in France, published his "Anatomie Générale," in which he formulated important general principles. Every animal is an assemblage of different organs, each of which discharges a function, and acting together, each in its own way, assists in the preservation of the whole. The organs are, as it were, special machines situated

in the general building which constitutes the factory or body of the individual. But, further, each organ or special machine is itself formed of tissues which possess different properties. Some, as the blood-vessels, nerves, fibrous tissues, &c., are generally distributed throughout the animal body, whilst others, as bones, muscles, cartilage, &c., are found only in certain definite localities. Whilst Bichat had acquired a definite philosophical conception of the general principles of construction and of the distribution of the tissues, neither he nor his pupil Béclard was in a position to determine the essential nature of the structural elements. The means and appliances at their disposal and at that of other observers in their generation were not sufficiently potent to complete the analysis.

Attempts were made in the third decennium of this century to improve the methods of examining minute objects by the manufacture of compound lenses, and by doing away with chromatic and spherical aberration, to obtain, in addition to magnification of the object, a relatively large flat field of vision with clearness and sharpness of definition. When in January 1830 Joseph Jackson Lister read to the Royal Society his memoir "On some properties in achromatic object-glasses applicable to the improvement of microscopes," he announced the principles on which combinations of lenses could be arranged, which would possess these qualities. By the skill of our opticians, microscopes have now for more than half a century been constructed which, in the hands of competent observers, have influenced and extended biological science with results comparable to those obtained by the astronomer through improvements in the telescope.

In the study of the minute structure of plants and animals the observer has frequently to deal with tissues and organs, most of which possess such softness and delicacy of substance and outline that, even when microscopes of the best construction are employed, the determination of the intimate nature of the tissue, and the precise relation which one element of an organ bears to the other constituent elements, is in many instances a matter of difficulty. Hence additional methods have had to be devised in order to facilitate study and to give precision and accuracy to our observations. It is difficult for one of the younger generation of biologists, with all the appliances of a well-equipped laboratory at his command, with experienced teachers to direct him in his work, and with excellent text-books, in which the modern methods are described, to realise the conditions under which his predecessors worked half a century ago. Laboratories for minute biological research had not been constructed, the practical teaching of histology and embryology had not been organised, experience in methods of work had not accumulated; each man was left to his individual efforts, and had to puzzle his way through the complications of structure to the best of his power. Staining and hardening reagents were unknown. The double-bladed knife invented by Valentin, held in the hand, was the only improvement on the scalpel or razor for cutting thin, more or less translucent slices suitable for microscopic examination; mechanical section-cutters and freezing arrangements had not been devised. The tools at the disposal of the microscopist were little more than knife, forceps, scissors, needles, with acetic acid, glycerine and Canada balsam as reagents. But in the employment of the newer methods of research, care has to be taken, more especially when hardening and staining reagents are used, to discriminate between appearances which are to be interpreted as indicating natural characters, and those which are only artificial productions.

Notwithstanding the difficulties attendant on the study of the more delicate tissues, the compound achromatic microscope provided anatomists with an instrument of great penetrative power. Between the years 1830 and 1850 a number of acute observers applied themselves with much energy and enthusiasm to the examination of the minute structure of the tissues and organs in plants and animals.

Cell Theory.

It had, indeed, long been recognised that the tissues of plants were to a large extent composed of minute vesicular bodies, technically called cells (Hooke, Malpighi, Grew). In 1831 the discovery was made by the great botanist, Robert Brown, that in many families of plants a circular spot, which he named areola or nucleus, was present in each cell; and in 1838 M. J. Schleiden published the fact that a similar spot or nucleus was a universal elementary organ in vegetables. In the tissues of animals also structures had begun to be recognised comparable with the cells and nuclei of the vegetable tissues, and in

1839 Theodore Schwann announced the important generalisation that there is one universal principle of development for the elementary part of organisms, however different they may be in appearance, and that this principle is the formation of cells. The enunciation of the fundamental principle that the elementary tissues consisted of cells constituted a step in the progress of biological science which will for ever stamp the century now drawing to a close with a character and renown equalling those which it has derived from the most brilliant discoveries in the physical sciences. It provided biologists with the visible anatomical units through which the external forces operating on, and the energy generated in, living matter come into play. It dispelled for ever the old mystical idea of the influence exercised by vapours or spirits in living organisms. It supplied the physiologist and pathologist with the specific structures through the agency of which the functions of organisms are discharged in health and disease. It exerted an enormous influence on the progress of practical medicine. A review of the progress of knowledge of the cell may appropriately enter into an address on this occasion.

Structure of Cells.

A cell is a living particle, so minute that it needs a microscope for its examination; it grows in size, maintains itself in a state of activity, responds to the action of stimuli, reproduces its kind, and in the course of time it degenerates and dies.

Let us glance at the structure of a cell to determine its constituent parts and the rôle which each plays in the function to be discharged. The original conception of a cell, based upon the study of the vegetable tissues, was a minute vesicle enclosed by a definite wall, which exercised chemical or metabolic changes on the surrounding material and secreted into the vesicle its characteristic contents. A similar conception was at first also entertained regarding the cells of animal tissues; but as observations multiplied, it was seen that numerous elementary particles, which were obviously in their nature cells, did not possess an enclosing envelope. A wall ceased to have a primary value as a constituent part of a cell, the necessary vesicular character of which therefore could no longer be entertained.

The other constituent parts of a cell are the cell plasma, which forms the body of the cell, and the nucleus embedded in its substance. Notwithstanding the very minute size of the nucleus, which even in the largest cells is not more than $1/5000$ inch in diameter, and usually is considerably smaller, its almost constant form, its well-defined sharp outline, and its power of resisting the action of strong reagents when applied to the cell have from the period of its discovery by Robert Brown caused histologists to bestow on it much attention. Its structure and chemical composition; its mode of origin; the part which it plays in the formation of new cells and its function in nutrition and secretion have been investigated.

When examined under favourable conditions in its passive or resting state, the nucleus is seen to be bounded by a membrane which separates it from the cell plasma and gives it the characteristic sharp contour. It contains an apparently structureless nuclear substance, nucleoplasm or enchylema, in which are embedded one or more extremely minute particles called nucleoli, along with a network of exceedingly fine threads or fibres, which in the active living cell play an essential part in the production of new nuclei within the cell. In its chemical composition the nuclear substance consists of albuminous plastin and globulin; and of a special material named nuclein, rich in phosphorus and with an acid reaction. The delicate network within the nucleus consists apparently of the nuclein, a substance which stains with carmine and other dyes, a property which enables the changes, which take place in the network in the production of young cells, to be more readily seen and followed out by the observer.

The mode of origin of the nucleus and the part which it plays in the production of new cells have been the subject of much discussion. Schleiden, whose observations, published in 1838, were made on the cells of plants, believed that within the cell a nucleolus first appeared, and that around it molecules aggregated to form the nucleus. Schwann again, whose observations were mostly made on the cells of animals, considered that an amorphous material existed in organised bodies, which he called cytoblastema. It formed the contents of cells, or it might be situated free or external to them. He figuratively compared it to a mother liquor in which crystals are formed. Either in the cytoblastema within the cells or in that situated external to them, the aggregation of molecules around a nucleolus to form

a nucleus might occur, and, when once the nucleus had been formed, in its turn it would serve as a centre of aggregation of additional molecules from which a new cell would be produced. He regarded therefore the formation of nuclei and cells as possible in two ways: one within pre-existing cells (endogenous cell-formation), the other in a free blastema lying external to cells (free cell-formation). In animals, he says, the endogenous method is rare, and the customary origin is in an external blastema. Both Schleiden and Schwann considered that after the cell was formed the nucleus had no permanent influence on the life of the cell, and usually disappeared.

Under the teaching principally of Henle, the famous Professor of Anatomy in Göttingen, the conception of the free formation of nuclei and cells in a more or less fluid blastema, by an aggregation of elementary granules and molecules, obtained so much credence, especially amongst those who were engaged in the study of pathological processes, that the origin of cells within pre-existing cells was to a large extent lost sight of. That a parent cell was requisite for the production of new cells seemed to many investigators to be no longer needed. Without doubt this conception of free cell-formation contributed in no small degree to the belief, entertained by various observers, that the simplest plants and animals might arise, without pre-existing parents, in organic fluids destitute of life, by a process of spontaneous generation; a belief which prevailed in many minds almost to the present day. If, as has been stated, the doctrine of abiogenesis cannot be experimentally refuted, on the other hand it has not been experimentally proved. The burden of proof lies with those who hold the doctrine, and the evidence that we possess is all the other way.

Multiplication of Cells.

Although von Mohl, the botanist, seems to have been the first to recognise (1835) in plants a multiplication of cells by division, it was not until attention was given to the study of the egg in various animals, and to the changes which take place in it, attendant on fertilisation, that in the course of time a much more correct conception of the origin of the nucleus and of the part which it plays in the formation of new cells was obtained. Before Schwann had published his classical memoir in 1839, von Baer and other observers had recognised within the animal ovum the germinal vesicle, which obviously bore to the ovum the relation of a nucleus to a cell. As the methods of observation improved, it was recognised that, within the developing egg, two vesicles appeared where one only had previously existed, to be followed by four vesicles, then eight, and so on in multiple progression until the ovum contained a multitude of vesicles, each of which possessed a nucleus. The vesicles were obviously cells which had arisen within the original germ-cell or ovum. These changes were systematically described by Martin Barry so long ago as 1839 and 1840 in two memoirs communicated to the Royal Society of London, and the appearance produced, on account of the irregularities of the surface occasioned by the production of new vesicles, was named by him the mulberry-like structure. He further pointed out that the vesicles arranged themselves as a layer within the envelope of the egg or zona pellucida, and that the whole embryo was composed of cells filled with the foundations of other cells. He recognised that the new cells were derived from the germinal vesicle or nucleus of the ovum, the contents of which entered into the formation of the first two cells, each of which had its nucleus, which in its turn resolved itself into other cells, and by a repetition of the process into a greater number. The endogenous origin of new cells within a pre-existing cell and the process which we now term the segmentation of the yolk were successfully demonstrated. In a third memoir, published in 1841, Barry definitely stated that young cells originated through division of the nucleus of the parent cell, instead of arising, as a product of crystallisation, in the fluid cytoblastema of the parent cell or in a blastema situated external to the cell.

In a memoir published in 1842, John Goodsir advocated the view that the nucleus is the reproductive organ of the cell, and that from it, as from a germinal spot, new cells were formed. In a paper, published three years later, on nutritive centres, he described cells the nuclei of which were the permanent source of successive broods of young cells, which from time to time occupied the cavity of the parent cell. He extended also his observations on the endogenous formation of cells to the cartilage cells in the process of inflammation and to other tissues

undergoing pathological changes. Corroborative observations on endogenous formation were also given by his brother, Harry Goodsir, in 1845. These observations on the part which the nucleus plays by cleavage in the formation of young cells by endogenous development from a parent centre—that an organic continuity existed between a mother cell and its descendants through the nucleus—constituted a great step in advance of the views entertained by Schleiden and Schwann, and showed that Barry and the Goodsir had a deeper insight into the nature and functions of cells than was possessed by most of their contemporaries, and are of the highest importance when viewed in the light of recent observations.

In 1841 Robert Remak published an account of the presence of two nuclei in the blood corpuscles of the chick and the pig, which he regarded as evidence of the production of new corpuscles by division of the nucleus within a parent cell; but it was not until some years afterwards (1850 to 1855) that he recorded additional observations and recognised that division of the nucleus was the starting-point for the multiplication of cells in the ovum and in the tissues generally. Remak's view was that the process of cell-division began with the cleavage of the nucleolus, followed by that of the nucleus, and that again by cleavage of the body of the cell and of its membrane. Kölliker had previously, in 1843, described the multiplication of nuclei in the ova of parasitic worms, and drew the inference that in the formation of young cells within the egg the nucleus underwent cleavage, and that each of its divisions entered into the formation of a new cell. By these observations, and by others subsequently made, it became obvious that the multiplication of animal cells, either by division of the nucleus within the cell, or by the budding off of a part of the protoplasm of the cell, was to be regarded as a widely spread and probably a universal process, and that each new cell arose from a parent cell.

Pathological observers were, however, for the most part inclined to consider free cell-formation in a blastema or exudation by an aggregation of molecules, in accordance with the views of Henle, as a common phenomenon. This proposition was attacked with great energy by Virchow in a series of memoirs published in his "Archiv," commencing in vol. i. 1847, and finally received its death-blow in his published lectures on Cellular Pathology, 1858. He maintained that in pathological structures there was no instance of cell development *de novo*; where a cell existed, there one must have been before. Cell-formation was a continuous development by descent, which he formulated in the expression *omnis cellula e cellula*.

Karyokinesis.

Whilst the descent of cells from pre-existing cells by division of the nucleus during the development of the egg, in the embryos of plants and animals, and in adult vegetable and animal tissues, both in healthy and diseased conditions, had now become generally recognised, the mechanism of the process by which the cleavage of the nucleus took place was for a long time unknown. The discovery had to be deferred until the optician had been able to construct lenses of a higher penetrative power, and the microscopist had learned the use of colouring agents capable of dyeing the finest elements of the tissues. There was reason to believe that in some cases a direct cleavage of the nucleus, to be followed by a corresponding division of the cell into two parts, did occur. In the period between 1870 and 1880 observations were made by Schneider, Strasburger, Bütschli, Fol, van Beneden and Flemming, which showed that the division of the nucleus and the cell was due to a series of very remarkable changes, now known as indirect nuclear and cell division, or karyokinesis. The changes within the nucleus are of so complex a character that it is impossible to follow them in detail without the use of appropriate illustrations. I shall have to content myself, therefore, with an elementary sketch of the process.

I have previously stated that the nucleus in its passive or resting stage contains a very delicate network of threads or fibres. The first stage in the process of nuclear division consists in the threads arranging themselves in loops and forming a compact coil within the nucleus. The coil then becomes looser, the loops of threads shorten and thicken, and somewhat later each looped thread splits longitudinally into two portions. As the threads stain when colouring agents are applied to them, they are called chromatin fibres, and the loose coil is the chromosome (Waldayer).

As the process continues, the investing membrane of the nucleus disappears, and the loops of threads arrange themselves within the nucleus so that the closed ends of the loops are

directed to a common centre, from which the loops radiate outwards and produce a starlike figure (aster). At the same time clusters of extremely delicate lines appear both in the nucleoplasm and in the body of the cell, named the achromatic figure, which has a spindle-like form with two opposite poles, and stains much more feebly than the chromatic fibres. The loops of the chromatic star then arrange themselves in the equatorial plane of the spindle, and bending round turn their closed ends towards the periphery of the nucleus and the cell.

The next stage marks an important step in the process of division of the nucleus. The two longitudinal portions, into which each looped thread had previously split, now separate from each other, and whilst one part migrates to one pole of the spindle, the other moves to the opposite pole, and the free ends of each loop are directed towards its equator (metakinesis). By this division of the chromatin fibres, and their separation from each other to opposite poles of the spindle, two starlike chromatin figures are produced (dyaster).

Each group of fibres thickens, shortens, becomes surrounded by a membrane, and forms a new or daughter nucleus (dispirem). Two nuclei therefore have arisen within the cell by the division of that which had previously existed, and the expression formulated by Flemming—*omnis nucleus e nucleo*—is justified. Whilst this stage is in course of being completed, the body of the cell becomes constricted in the equatorial plane of the spindle, and, as the constriction deepens, it separates into two parts, each containing a daughter nucleus, so that two nucleated cells have arisen out of a pre-existing cell.

A repetition of the process in each of these cells leads to the formation of other cells, and, although modifications in details are found in different species of plants and animals, the multiplication of cells in the egg and in the tissues generally on similar lines is now a thoroughly established fact in biological science.

In the study of karyokinesis, importance has been attached to the number of chromosomes in the nucleus of the cell. Flemming had seen in the Salamander twenty-four chromosome fibres, which seems to be a constant number in the cells of epithelium and connective tissues. In other cells again, especially in the ova of certain animals, the number is smaller, and fourteen, twelve, four, and even two only have been described. The theory formulated by Boveri that the number of chromosomes is constant for each species, and that in the karyokinetic figures corresponding numbers are found in homologous cells, seems to be not improbable.

In the preceding description I have incidentally referred to the appearance in the proliferating cell of an achromatic spindle-like figure. Although this was recognised by Fol in 1873, it is only during the last ten or twelve years that attention has been paid to its more minute arrangements and possible signification in cell-division.

The pole at each end of the spindle lies in the cell plasm which surrounds the nucleus. In the centre of each pole is a somewhat opaque spot (central body) surrounded by a clear space, which, along with the spot, constitutes the centrosome or the sphere of attraction. From each centrosome extremely delicate lines may be seen to radiate in two directions. One set extends towards the pole at the opposite end of the spindle, and, meeting or coming into close proximity with radiations from it, constitutes the body of the spindle, which, like a perforated mantle, forms an imperfect envelope around the nucleus during the process of division. The other set of radiations is called the polar, and extends in the region of the pole towards the periphery of the cell.

The question has been much discussed whether any constituent part of the achromatic figure, or the entire figure, exists in the cell as a permanent structure in its resting phase; or if it is only present during the process of karyokinesis. During the development of the egg the formation of young cells, by division of the segmentation nucleus, is so rapid and continuous that the achromatic figure, with the centrosome in the pole of the spindle, is a readily recognisable object in each cell. The polar and spindle-like radiations are in evidence during karyokinesis, and have apparently a temporary endurance and function. On the other hand, van Beneden and Boveri were of opinion that the central body of the centrosome did not disappear when the division of the nucleus came to an end, but that it remained as a constituent part of a cell lying in the cell plasm near to the nucleus. Flemming has seen the central body with its sphere in leucocytes, as well as in epithelial cells and those of other

tissues. Subsequently Heidenhain and other histologists have recorded similar observations. It would seem, therefore, as if there were reason to regard the centrosome, like the nucleus, as a permanent constituent of a cell. This view, however, is not universally entertained. If not always capable of demonstration in the resting stage of a cell, it is doubtless to be regarded as potentially present, and ready to assume, along with the radiations, a characteristic appearance when the process of nuclear division is about to begin.

One can scarcely regard the presence of so remarkable an appearance as the achromatic figure without associating with it an important function in the economy of the cell. As from the centrosome at the pole of the spindle both sets of radiations diverge, it is not unlikely that it acts as a centre or sphere of energy and attraction. By some observers the radiations are regarded as substantive fibrillar structures, elastic or even contractile in their properties. Others, again, look upon them as morphological expressions of chemical and dynamical energy in the protoplasm of the cell body. On either theory we may assume that they indicate an influence, emanating, it may be, from the centrosome, and capable of being exercised both on the cell plasm and on the nucleus contained in it. On the contractile theory, the radiations which form the body of the spindle, either by actual traction of the supposed fibrillæ or by their pressure on the nucleus which they surround, might impel during karyokinesis the dividing chromosome elements towards the poles of the spindle, to form there the daughter nuclei. On the dynamical theory, the chemical and physical energy in the centrosome might influence the cell plasm and the nucleus, and attract the chromosome elements of the nucleus to the poles of the spindle. The radiated appearance would therefore be consequent and attendant on the physico-chemical activity of the centrosome. One or other of these theories may also be applied to the interpretation of the significance of the polar radiations.

Cell Plasm.

In the cells of plants, in addition to the cell wall, the cell body and the cell juice require to be examined. The material of the cell body, or the cell contents, was named by von Mohl (1846) protoplasm, and consisted of a colourless tenacious substance which partly lined the cell wall (primordial utricle), and partly traversed the interior of the cell as delicate threads enclosing spaces (vacuoles) in which the cell juice was contained. In the protoplasm the nucleus was embedded. Nägeli, about the same time, had also recognised the difference between the protoplasm and the other contents of vegetable cells, and had noticed its nitrogenous composition.

Though the analogy with a closed bladder or vesicle could no longer be sustained in the animal tissues, the name "cell" continued to be retained for descriptive purposes, and the body of the cell was spoken of as a more or less soft substance enclosing a nucleus (Leydig). In 1861 Max Schultze adopted for the substance forming the body of the animal cell the term "protoplasm." He defined a cell to be a particle of protoplasm in the substance of which a nucleus was situated. He regarded the protoplasm, as indeed had previously been pointed out by the botanist Unger, as essentially the same as the contractile sarcode which constitutes the body and pseudopodia of the *Amœba* and other Rhizopoda. As the term "protoplasm," as well as that of "bioplasm" employed by Lionel Beale in a somewhat similar though not precisely identical sense, involves certain theoretical views of the origin and function of the body of the cell, it would be better to apply to it the more purely descriptive term "cytoplasm" or "cell plasm."

Schultze defined protoplasm as a homogeneous, glassy, tenacious material, of a jelly-like or somewhat firmer consistency, in which numerous minute granules were embedded. He regarded it as the part of the cell especially endowed with vital energy, whilst the exact function of the nucleus could not be defined. Based upon this conception of the jelly-like character of protoplasm, the idea for a time prevailed that a structureless, dimly granular, jelly or slime destitute of organisation, possessed great physiological activity, and was the medium through which the phenomena of life were displayed.

More accurate conceptions of the nature of the cell plasm soon began to be entertained. Brücke recognised that the body of the cell was not simple, but had a complex organisation. Flemming observed that the cell plasm contained extremely delicate threads, which frequently formed a network, the interspaces of which were occupied by a more homogeneous substance. Where

the threads crossed each other, granular particles (mikrosomen) were situated. Bütschli considered that he could recognise in the cell plasm a honeycomb-like appearance, as if it consisted of excessively minute chambers in which a homogeneous, more or less fluid, material was contained. The polar and spindle-like radiations visible during the process of karyokinesis, which have already been referred to, and the presence of the centrosome, possibly even during the resting stage of the cell, furnished additional illustrations of differentiation within the cell plasm. In many cells there appears also to be a difference in the character of the cell plasm which immediately surrounds the nucleus and that which lies at and near the periphery of the cell. The peripheral part (ektoplasma) is more compact and gives a definite outline to the cell, although not necessarily differentiating into a cell membrane. The inner part (endoplasma) is softer, and is distinguished by a more distinct granular appearance, and by containing the products specially formed in each particular kind of cell during the nutritive process.

By the researches of numerous investigators on the internal organisation of cells in plants and animals, a large body of evidence has now been accumulated, which shows that both the nucleus and the cell plasm consist of something more than a homogeneous, more or less viscid, slimy material. Recognisable objects in the form of granules, threads or fibres can be distinguished in each. The cell plasm and the nucleus respectively are therefore not of the same constitution throughout, but possess polymorphic characters, the study of which in health and the changes produced by disease will for many years to come form important matters for investigation.

Function of Cells.

It has already been stated that, when new cells arise within pre-existing cells, division of the nucleus is associated with cleavage of the cell plasm, so that it participates in the process of new cell-formation. Undoubtedly, however, its rôle is not limited to this function. It also plays an important part in secretion, nutrition, and the special functions discharged by the cells in the tissues and organs of which they form morphological elements.

Between 1838 and 1842 observations were made which showed that cells were constituent parts of secreting glands and mucous membranes (Schwann, Henle). In 1842 John Goodsir communicated to the Royal Society of Edinburgh a memoir on secreting structures, in which he established the principle that cells are the ultimate secreting agents; he recognised in the cells of the liver, kidney, and other organs the characteristic secretion of each gland. The secretion was, he said, situated between the nucleus and the cell wall. At first he thought that, as the nucleus was the reproductive organ of the cell, the secretion was formed in the interior of the cell by the agency of the cell wall; but three years later he regarded it as a product of the nucleus. The study of the process of spermatogenesis by his brother, Harry Goodsir, in which the head of the spermatozoon was found to correspond with the nucleus of the cell in which the spermatozoon arose, gave support to the view that the nucleus played an important part in the genesis of the characteristic product of the gland cell.

The physiological activity of the cell plasm and its complex chemical constitution soon after began to be recognised. Some years before Max Schultze had published his memoirs on the characters of protoplasm, Brücke had shown that the well-known changes in tint in the skin of the *Chamæleon* were due to pigment granules situated in the cells in the skin which were sometimes diffused throughout the cells, at others concentrated in the centre. Similar observations on the skin of the frog were made in 1854 by von Wittich and Harless. The movements were regarded as due to contraction of the cell wall on its contents. In a most interesting paper on the pigmentary system in the frog, published in 1858, Lord Lister demonstrated that the pigment granules moved in the cell plasma, by forces resident within the cell itself, acting under the influence of an external stimulant, and not by contractility of the wall. Under some conditions the pigment was attracted to the centre of the cell, when the skin became pale; under other conditions the pigment was diffused throughout the body and the branches of the cell, and gave to the skin a dark colour. It was also experimentally shown that a potent influence over these movements was exercised by the nervous system.

The study of the cells of glands engaged in secretion, even when the secretion is colourless, and the comparison of their appear-

ance when secretion is going on with that seen when the cells are at rest, have shown that the cell plasm is much more granular and opaque, and contains larger particles during activity than when the cell is passive; the body of the cell swells out from an increase in the contents of its plasm, and chemical changes accompany the act of secretion. Ample evidence, therefore, is at hand to support the position taken by John Goodsir, nearly sixty years ago, that secretions are formed within cells, and lie in that part of the cell which we now say consists of the cell plasm; that each secreting cell is endowed with its own peculiar property, according to the organ in which it is situated, so that bile is formed by the cells in the liver, milk by those in the mamma, and so on.

Intimately associated with the process of secretion is that of nutrition. As the cell plasm lies at the periphery of a cell, and as it is, alike both in secretion and nutrition, brought into closest relation with the surrounding medium, from which the pabulum is derived, it is necessarily associated with the nutritive activity. Its position enables it to absorb nutritive material directly from without, and in the process of growth it increases in amount by interstitial changes and additions throughout its substance, and not by mere accretions on its surface.

Hitherto I have spoken of a cell as a unit, independent of its neighbours as regards its nutrition and the other functions which it has to discharge. The question has, however, been discussed, whether in a tissue composed of cells closely packed together cell plasm may not give origin to processes or threads which are in contact or continuous with corresponding processes of adjoining cells, and that cells may therefore, to some extent, lose their individuality in the colony of which they are members. Appearances were recognised between 1863 and 1870 by Schrön and others in the deeper cells of the epidermis and of some mucous membranes which gave sanction to this view, and it seems possible through contact or continuity of threads connecting a cell with its neighbours, that cells may exercise a direct influence on each other.

Nägeli, the botanist, as the foundation of a mechanico-physiological theory of descent, considered that in plants a network of cell plasm, named by him *idio-plasm*, extended throughout the whole of the plant, forming its specific molecular constitution, and that growth and activity were regulated by its conditions of tension and movements (1884).

The study of the structure of plants with special reference to the presence of an intercellular network has for some years been pursued by Walter Gardiner (1882-97), who has demonstrated threads of cell plasm protruding through the walls of vegetable cells and continuous with similar threads from adjoining cells. Structurally, therefore, a plant may be conceived to be built up of a nucleated cytoplasmic network, each nucleus with the branching cell plasm surrounding it being a centre of activity. On this view a cell would retain to some extent its individuality, though, as Gardiner contends, the connecting threads would be the medium for the conduction of impulses and of food from a cell to those which lie around it. For the plant cell therefore, as has long been accepted in the animal cell, the wall is reduced to a secondary position, and the active constituent is the nucleated cell plasm. It is not unlikely that the absence of a controlling nervous system in plants requires the plasm of adjoining cells to be brought into more immediate contact and continuity than is the case with the generality of animal cells, so as to provide a mechanism for harmonising the nutritive and other functional processes in the different areas in the body of the plant. In this particular, it is of interest to note that the epithelial tissues in animals, where somewhat similar connecting arrangements occur, are only indirectly associated with the nervous and vascular systems, so that, as in plants, the cells may require, for nutritive and other purposes, to act and react directly on each other.

Nerve Cells.

Of recent years great attention has been paid to the intimate structure of nerve cells, and to the appearance which they present when in the exercise of their functional activity. A nerve cell is not a secreting cell; that is, it does not derive from the blood or surrounding fluid a pabulum which it elaborates into a visible, palpable secretion characteristic of the organ of which the cell is a constituent element, to be in due course discharged into a duct which conveys the secretion out of the gland. Nerve cells, through the metabolic changes which take place in them in connection with their nutrition, are associated with the production of the form of energy specially exhibited by

animals which possess a nervous system, termed nerve energy. It has long been known that every nerve cell has a body in which a relatively large nucleus is situated. A most important discovery was the recognition that the body of every nerve cell had one or more processes growing out from it. More recently it has been proved, chiefly through the researches of Schultze, His, Golgi and Ramon y Cajal, that at least one of the processes, the axon of the nerve cell, is continued into the axial cylinder of a nerve fibre, and that in the multipolar nerve cell the other processes, or dendrites, branch and ramify for some distance away from the body. A nerve fibre is therefore an essential part of the cell with which it is continuous, and the cell, its processes, the nerve fibre and the collaterals which arise from the nerve fibre collectively form a neuron or structural nerve unit (Waldeyer). The nucleated body of the nerve cell is the physiological centre of the unit.

The cell plasm occupies both the body of the nerve cell and its processes. The intimate structure of the plasm has, by improved methods of observation introduced during the last eight years by Nissl, and conducted on similar lines by other investigators, become more definitely understood. It has been ascertained that it possesses two distinct characters which imply different structures. One of these stains deeply on the addition of certain dyes, and is named *chromophile* or *chromatic substance*; the other, which does not possess a similar property, is the *achromatic network*. The *chromophile* is found in the cell body and the dendritic processes, but not in the axon. It occurs in the form of granular particles, which may be scattered throughout the plasm, or aggregated into little heaps which are elongated or fusiform in shape and appear as distinct coloured particles or masses. The *achromatic network* is found in the cell body and the dendrites, and is continued also into the axon, where it forms the axial cylinder of the nerve fibre. It consists apparently of delicate threads or fibrillæ, in the meshes of which a homogeneous material, such as is found in the cell plasm generally, is contained. In the nerve cells, as in other cells, the plasm is without doubt concerned in the process of cell nutrition. The *achromatic fibrillæ* exercise an important influence on the axon or nerve fibre with which they are continuous, and probably they conduct the nerve impulses which manifest themselves in the form of nerve energy. The dendritic processes of a multipolar nerve cell ramify in close relation with similar processes branching from other cells in the same group. The collaterals and the free end of the axon fibre process branch and ramify in association with the body of a nerve cell or of its dendrites. We cannot say that these parts are directly continuous with each other to form an intercellular network, but they are apparently in apposition, and through contact exercise influence one on the other in the transmission of nerve impulses.

There is evidence to show that in the nerve cell the nucleus, as well as the cell plasm, is an effective agent in nutrition. When the cell is functionally active, both the cell body and the nucleus increase in size (Vas, G. Mann, Lugaro); on the other hand, when nerve cells are fatigued through excessive use, the nucleus decreases in size and shrivels; the cell plasm also shrinks, and its coloured or *chromophile* constituent becomes diminished in quantity, as if it had been consumed during the prolonged use of the cell (Hodge, Mann, Lugaro). It is interesting also to note that in hibernating animals in the winter season, when their functional activity is reduced to a minimum, the *chromophile* in the plasm of the nerve cells is much smaller in amount than when the animal is leading an active life in the spring and summer (G. Levi).

When a nerve cell has attained its normal size it does not seem to be capable of reproducing new cells in its substance by a process of karyokinesis, such as takes place when young cells arise in the egg and in the tissues generally. It would appear that nerve cells are so highly specialised in their association with the evolution of nerve energy, that they have ceased to have the power of reproducing their kind, and the metabolic changes both in cell plasm and nucleus are needed to enable them to discharge their very peculiar function. Hence it follows that when a portion of the brain or other nerve-centre is destroyed, the injury is not repaired by the production of fresh specimens or their characteristic cells, as would be the case in injuries to bones and tendons.

In our endeavours to differentiate the function of the nucleus from that of the cell plasm, we should not regard the former as concerned only in the production of young cells, and the latter as the exclusive agent in growth, nutrition, and, where gland

cells are concerned, in the formation of their characteristic products. As regards cell reproduction also, though the process of division begins in the nucleus in its chromosome constituents, the achromatic figure in the cell plasm undoubtedly plays a part, and the cell plasm itself ultimately undergoes cleavage.

A few years ago the tendency amongst biologists was to ignore or attach but little importance to the physiological use of the nucleus in the nucleated cell, and to regard the protoplasm as the essential and active constituent of living matter; so much so, indeed, was this the case that independent organisms regarded as distinct species were described as consisting of protoplasm destitute of a nucleus; also that scraps of protoplasm separated from larger nucleated masses could, when isolated, exhibit vital phenomena. There is reason to believe that a fragment of protoplasm, when isolated from the nucleus of a cell, though retaining its contractility and capable of nourishing itself for a short time, cannot increase in amount, act as a secreting structure, or reproduce its kind: it soon loses its activity, withers, and dies. In order that these qualities of living matter should be retained, a nucleus is by most observers regarded as necessary (Nussbaum, Gruber, Haberlandt, Korschelt), and for the complete manifestation of vital activity both nucleus and cell plasm are required.

Bacteria.

The observations of Cohn, made about thirty years ago, and those of De Bary shortly afterwards, brought into notice a group of organisms to which the name "bacterium" or "microbe" is given. They were seen to vary in shape: some were rounded specks called cocci, others were straight rods called bacilli, others were curved or spiral rods, vibrios or spirillæ. All were characterised by their extreme minuteness, and required for their examination the highest powers of the best microscopes. Many bacteria measure in their least diameter not more than $1/25000$ th of an inch, $1/10$ th the diameter of a human white blood corpuscle. Through the researches of Pasteur, Lord Lister, Koch, and other observers, bacteria have been shown to play an important part in nature. They exercise a very remarkable power over organic substances, especially those which are complex in chemical constitution, and can resolve them into simpler combinations. Owing to this property, some bacteria are of great economic value, and without their agency many of our industries could not be pursued; others again, and these are the most talked of, exercise a malign influence in the production of the most deadly diseases which afflict man and the domestic animals.

Great attention has been given to the structure of bacteria and to their mode of propagation. When examined in the living state and magnified about 2000 times, a bacterium appears as a homogeneous particle, with a sharp definite outline, though a membranous envelope or wall, distinct from the body of the bacterium, cannot at first be recognised; but when treated with reagents a membranous envelope appears, the presence of which, without doubt, gives precision of form to the bacterium. The substance within the membrane contains granules which can be dyed with colouring agents. Owing to their extreme minuteness it is difficult to pronounce an opinion on the nature of the chromatine granules and the substance in which they lie. Some observers regard them as nuclear material, invested by only a thin layer of protoplasm, on which view a bacterium would be a nucleated cell. Others consider the bacterium as formed of protoplasm containing granules capable of being coloured, which are a part of the protoplasm itself, and not a nuclear substance. On the latter view, bacteria would consist of cell plasm inclosed in a membrane and destitute of a nucleus. Whatever be the nature of the granule-containing material, each bacterium is regarded as a cell, the minutest and simplest living particle capable of an independent existence that has not yet been discovered.

Bacteria cells, like cells generally, can reproduce their kind. They multiply by simple fission, probably with an ingrowth of the cell wall, but without the karyokinetic phenomena observed in nucleated cells. Each cell gives rise to two daughter cells, which may for a time remain attached to each other and form a cluster or a chain, or they may separate and become independent isolated cells. The multiplication, under favourable conditions of light, air, temperature, moisture and food, goes on with extraordinary rapidity, so that in a few hours many thousand new individuals may arise from a parent bacterium.

Connected with the life-history of a bacterium cell is the

formation in its substance, in many species and under certain conditions, of a highly refractile shiny particle called a spore. At first sight a spore seems as if it were the nucleus of the bacterium cell, but it is not always present when multiplication by cleavage is taking place, and when present it does not appear to take part in the fission. On the other hand, a spore, from the character of its envelope, possesses great power of resistance, so that dried bacteria, when placed in conditions favourable to germination, can through their spores germinate and resume an active existence. Spore formation seems, therefore, to be a provision for continuing the life of the bacterium under conditions which, if spores had not formed, would have been the cause of its death.

The time has gone by to search for the origin of living organisms by a spontaneous aggregation of molecules in vegetable or other infusions, or from a layer of formless primordial slime diffused over the bed of the ocean. Living matter during our epoch has been, and continues to be, derived from pre-existing living matter, even when it possesses the simplicity of structure of a bacterium, and the morphological unit is the cell.

Development of the Egg.

As the future of the entire organism lies in the fertilised egg cell, we may now briefly review the arrangements, consequent on the process of segmentation, which lead to the formation, let us say in the egg of a bird, of the embryo of the young chick.

In the latter part of the last century, C. F. Wolff observed that the beginning of the embryo was associated with the formation of layers, and in 1817 Pander demonstrated that in the hen's egg at first one layer, called mucous, appeared, then a second or serous layer, to be followed by a third, intermediate or vascular layer. In 1828 von Baer amplified our knowledge in his famous treatise, which from its grasp of the subject created a new epoch in the science of embryology. It was not, however, until the discovery by Schwann of cells as constant factors in the structure of animals and in their relation to development that the true nature of these layers was determined. We now know that each layer consists of cells, and that all the tissues and organs of the body are derived from them. Numerous observers have devoted themselves for many years to the study of each layer, with the view of determining the part which it takes in the formation of the constituent parts of the body, more especially in the higher animals, and the important conclusion has been arrived at that each kind of tissue invariably arises from one of these layers and from no other.

The layer of cells which contributes, both as regards the number and variety of the tissues derived from it, most largely to the formation of the body is the middle layer or mesoblast. From it the skeleton, the muscles, and other locomotor organs, the true skin, the vascular system, including the blood and other structures which I need not detail, take their rise. From the inner layer of cells or hypoblast, the principal derivatives are the epithelial lining of the alimentary canal and of the glands which open into it, and the epithelial lining of the air-passages. The outer or epiblast layer of cells gives origin to the epidermis or scarf skin and to the nervous system. It is interesting to note that from the same layer of the embryo arise parts so different in importance as the cuticle—a mere protecting structure, which is constantly being shed when the skin is subjected to the friction of a towel or the clothes—and the nervous system, including the brain, the most highly differentiated system in the animal body. How completely the cells from which they are derived had diverged from each other in the course of their differentiation in structure and properties is shown by the fact that the cells of the epidermis are continually engaged in reproducing new cells to replace those which are shed, whilst the cells of the nervous system have apparently lost the power of reproducing their kind.

In the early stage of the development of the egg, the cells in a given layer resemble each other in form, and, as far as can be judged from their appearance, are alike in structure and properties. As the development proceeds, the cells begin to show differences in character, and in the course of time the tissues which arise in each layer differentiate from each other and can be readily recognised by the observer. To use the language of von Baer, a generalised structure has become specialised, and each of the special tissues produced exhibits its own structure and properties. These changes are coincident with a rapid

multiplication of the cells by cleavage, and thus increase in size of the embryo accompanies specialisation of structure. As the process continues, the embryo gradually assumes the shape characteristic of the species to which its parents belonged, until at length it is fit to be born and to assume a separate existence.

The conversion of cells, at first uniform in character, into tissues of a diverse kind is due to forces inherent in the cells in each layer. The cell plasma plays an active though not an exclusive part in the specialisation; for as the nucleus influences nutrition and secretion, it acts as a factor in the differentiation of the tissues. When tissues so diverse in character as muscular fibre, cartilage, fibrous tissues, and bone arise from the cells of the middle or mesoblast layer, it is obvious that, in addition to the morphological differentiation affecting form and structure, a chemical differentiation affecting composition also occurs, as the result of which a physiological differentiation takes place. The tissues and organs become fitted to transform the energy derived from the food into muscular energy, nerve energy, and other forms of vital activity. Corresponding differentiations also modify the cells of the outer and inner layers. Hence the study of the development of the generalised cell layers in the young embryo enables us to realise how all the complex constituent parts of the body in the higher animals and in man are evolved by the process of differentiation from a simple nucleated cell—the fertilised ovum. A knowledge of the cell and of its life-history is therefore the foundation-stone on which biological science in all its departments is based.

If we are to understand by an organ in the biological sense a complex body capable of carrying on a natural process, a nucleated cell is an organ in its simplest form. In a unicellular animal or plant such an organ exists in its most primitive stage. The higher plants and animals again are built up of multitudes of these organs, each of which, whilst having its independent life, is associated with the others, so that the whole may act in unison for a common purpose. As in one of your great factories each spindle is engaged in twisting and winding its own thread, it is at the same time intimately associated with the hundreds of other spindles in its immediate proximity, in the manufacture of the yarn from which the web of cloth is ultimately to be woven.

It has taken more than fifty years of hard and continuous work to bring our knowledge of the structure and development of the tissues and organs of plants and animals up to the level of the present day. Amidst the host of names of investigators, both at home and abroad, who have contributed to its progress, it may seem invidious to particularise individuals. There are, however, a few that I cannot forbear to mention, whose claim to be named on such an occasion as this will be generally conceded.

Botanists will, I think, acknowledge Wilhelm Hofmeister as a master in morphology and embryology, Julius von Sachs as the most important investigator in vegetable physiology during the last quarter of a century, and Strasburger as a leader in the study of the phenomena of nuclear division.

The researches of the veteran Professor of Anatomy in Würzburg, Albert von Kölliker, have covered the entire field of animal histology. His first paper, published fifty-nine years ago, was followed by a succession of memoirs and books on human and comparative histology and embryology, and culminated in his great treatise on the structure of the brain, published in 1896. Notwithstanding the weight of more than eighty years, he continues to prosecute histological research, and has published the results of his latest, though let us hope not his last, work during the present year.

Amongst our own countrymen, and belonging to the generation which has almost passed away, was William Bowman. His investigations between 1840 and 1850 on the mucous membranes, muscular fibre, and the structure of the kidney, together with his researches on the organs of sense, were characterised by a power of observation and of interpreting difficult and complicated appearances which has made his memoirs on these subjects landmarks in the history of histological inquiry.

Of the younger generation of biologists, Francis Maitland Balfour, whose early death is deeply deplored as a loss to British science, was one of the most distinguished. His powers of observation and philosophic perception gave him a high place as an original inquirer, and the charm of his personality—for charm is not the exclusive possession of the fairer sex—endured him to his friends.

General Morphology.

Along with the study of the origin and structure of the tissues of organised bodies, much attention has been given during the century to the parts or organs in plants and animals, with the view of determining where and how they take their rise, the order of their formation, the changes which they pass through in the early stages of development, and their relative positions in the organism to which they belong. Investigations on these lines are spoken of as morphological, and are to be distinguished from the study of their physiological or functional relations, though both are necessary for the full comprehension of the living organism.

The first to recognise that morphological relations might exist between the organs of a plant, dissimilar as regards their function, was the poet Goethe, whose observations, guided by his imaginative faculty, led him to declare that the calyx, corolla, and other parts of a flower, the scales of a bulb, &c., were metamorphosed leaves, a principle generally accepted by botanists, and indeed extended to other parts of a plant, which are referred to certain common morphological forms although they exercise different functions. Goethe also applied the same principle in the study of the skeletons of vertebrate animals, and he formed the opinion that the spinal column and the skull were essentially alike in construction, and consisted of vertebrae, an idea which was also independently conceived and advocated by Oken.

The anatomist who in our country most strenuously applied himself to the morphological study of the skeleton was Richard Owen, whose knowledge of animal structure, based upon his own dissections, was unrivalled in range and variety. He elaborated the conception of an ideal, archetype vertebrate form which had no existence in nature, and to which, subject to modifications in various directions, he considered all vertebrate skeletons might be referred. Owen's observations were conducted to a large extent on the skeletons of adult animals, of the knowledge of which he was a master. As in the course of development modifications in shape and in the relative position of parts not unfrequently occur and their original character and place of origin become obscured, it is difficult, from the study only of adults, to arrive at a correct interpretation of their morphological significance. When the changes which take place in the skull during its development, as worked out by Reichert and Rathke, became known and their value had become appreciated, many of the conclusions arrived at by Owen were challenged and ceased to be accepted. It is, however, due to that eminent anatomist to state from my personal knowledge of the condition of anatomical science in this country fifty years ago, that an enormous impulse was given to the study of comparative morphology by his writings, and by the criticisms to which they were subjected.

There can be no doubt that generalised arrangements do exist in the early embryo which, up to a certain stage, are common to animals that in their adult condition present diverse characters, and out of which the forms special to different groups are evolved. As an illustration of this principle, I may refer to the stages of development of the great arteries in the bodies of vertebrate animals. Originally, as the observations of Rathke have taught us, the main arteries are represented by pairs of symmetrically arranged vascular arches, some of which enlarge and constitute the permanent arteries in the adult, whilst others disappear. The increase in size of some of these arches, and the atrophy of others, are so constant for different groups that they constitute anatomical features as distinctive as the modifications in the skeleton itself. Thus in mammals the fourth vascular arch on the left side persists, and forms the arch of the aorta; in birds the corresponding part of the aorta is an enlargement of the fourth right arch, and in reptiles both arches persist to form the great artery. That this original symmetry exists also in man we know from the fact that now and again his body, instead of corresponding with the mammalian type, has an aortic arch like that which is natural to the bird, and in rarer cases even to the reptile. A type form common to the vertebrata does therefore in such cases exist, capable of evolution in more than one direction.

The reputation of Thomas Henry Huxley as a philosophic comparative anatomist rests largely on his early perception of, and insistence on, the necessity of testing morphological conclusions by a reference to the development of parts and organs, and by applying this principle in his own investigations. The principle is now so generally accepted by both botanists and

anatomists that morphological definitions are regarded as depending essentially on the successive phases of the development of the parts under consideration.

The morphological characters exhibited by a plant or animal tend to be hereditarily transmitted from parents to offspring, and the species is perpetuated. In each species the evolution of an individual, through the developmental changes in the egg, follows the same lines in all the individuals of the same species, which possess therefore in common the features called specific characters. The transmission of these characters is due, according to the theory of Weismann, to certain properties possessed by the chromosome constituents of the segmentation nucleus in the fertilised ovum, named by him the germ plasma, which is continued from one generation to another, and impresses its specific character on the egg and on the plant or animal developed from it.

As has already been stated, the special tissues which build up the bodies of the more complex organisms are evolved out of cells which are at first simple in form and appearance. During the evolution of the individual, cells become modified or differentiated in structure and function, and so long as the differentiation follows certain prescribed lines the morphological characters of the species are preserved. We can readily conceive that, as the process of specialisation is going on, modifications or variations in groups of cells and the tissues derived from them, notwithstanding the influence of heredity, may in an individual diverge so far from that which is characteristic of the species as to assume the arrangements found in another species, or even in another order. Anatomists had indeed long recognised that variations from the customary arrangement of parts occasionally appeared, and they described such deviations from the current descriptions as irregularities.

Darwinian Theory.

The signification of the variations which arise in plants and animals had not been apprehended until a flood of light was thrown on the entire subject by the genius of Charles Darwin, who formulated the wide-reaching theory that variations could be transmitted by heredity to younger generations. In this manner he conceived new characters would arise, accumulate, and be perpetuated, which would in the course of time assume specific importance. New species might thus be evolved out of organisms originally distinct from them, and their specific characters would in turn be transmitted to their descendants. By a continuance of this process new species would multiply in many directions, until at length from one or more originally simple forms the earth would become peopled by the infinite varieties of plant and animal organisms which have in past ages inhabited, or do at present inhabit, our globe. The Darwinian theory may therefore be defined as Heredity modified and influenced by Variability. It assumes that there is an heredity quality in the egg, which, if we take the common fowl for an example, shall continue to produce similar fowls. Under conditions, of which we are ignorant, which occasion molecular changes in the cells and tissues of the developing egg, variations might arise in the first instance probably slight, but becoming intensified in successive generations, until at length the descendants would have lost the characters of the fowl and have become another species. No precise estimate has been arrived at, and indeed one does not see how it is possible to obtain it, of the length of years which might be required to convert a variation, capable of being transmitted, into a new and definite specific character.

The circumstances which, according to the Darwinian theory, determined the perpetuation by hereditary transmission of a variety and its assumption of a specific character depended, it was argued, on whether it possessed such properties as enabled the plant or animal in which it appeared to adapt itself more readily to its environment, *i.e.* to the surrounding conditions. If it were to be of use the organism in so far became better adapted to hold its own in the struggle for existence with its fellows and with the forces of nature operating on it. Through the accumulation of useful characters the specific variety was perpetuated by natural selection, so long as the conditions were favourable for its existence, and it survived as being the best fitted to live. In the study of the transmission of variations which may arise in the course of development it should not be too exclusively thought that only those variations are likely to be preserved which can be of service during the life of the individual, or in the perpetuation of the species, and possibly available for the evolution of new

species. It should also be kept in mind that morphological characters can be transmitted by hereditary descent, which, though doubtless of service in some bygone ancestor, are in the new conditions of life of the species of no physiological value. Our knowledge of the structural and functional modifications to be found in the human body, in connection with abnormalities and with tendencies or predisposition to diseases of various kinds, teaches us that characters which are of no use, and indeed detrimental to the individual, may be hereditarily transmitted from parents to offspring through a succession of generations.

Since the conception of the possibility of the evolution of new species from pre-existing forms took possession of the minds of naturalists, attempts have been made to trace out the lines on which it has proceeded. The first to give a systematic account of what he conceived to be the order of succession in the evolution of animals was Ernst Haeckel, of Jena, in a well-known treatise. Memoirs on special departments of the subject, too numerous to particularise, have subsequently appeared. The problem has been attacked along two different lines: the one by embryologists, of whom may be named Kowalewsky, Gegenbaur, Dohrn, Ray Lankester, Balfour and Gaskell, who with many others have conducted careful and methodical inquiries into the stages of development of numerous forms belonging to the two great divisions of the animal kingdom. Invertebrates, as well as vertebrates, have been carefully compared with each other in the bearing of their development and structure on their affinities and descent, and the possible sequence in the evolution of the Vertebrata from the Invertebrata has been discussed. The other method pursued by paleontologists, of whom Huxley, Marsh, Cope, Osborne and Traquair are prominent authorities, has been the study of the extinct forms preserved in the rocks and the comparison of their structure with each other and with that of existing organisms. In the attempts to trace the line of descent the imagination has not unfrequently been called into play in constructing various conflicting hypotheses. Though from the nature of things the order of descent is, and without doubt will continue to be, ever a matter of speculation and not of demonstration, the study of the subject has been a valuable intellectual exercise and a powerful stimulant to research.

We know not as regards time when the fiat went forth, "Let there be Life, and there was Life." All we can say is that it must have been in the far-distant past, at a period so remote from the present that the mind fails to grasp the duration of the interval. Prior to its genesis our earth consisted of barren rock and desolate ocean. When matter became endowed with Life, with the capacity of self-maintenance and of resisting external disintegrating forces, the face of nature began to undergo a momentous change. Living organisms multiplied, the land became covered with vegetation, and multitudinous varieties of plants, from the humble fungus and moss to the stately palm and oak, beautified its surface and fitted it to sustain higher kinds of living beings. Animal forms appeared, in the first instance simple in structure, to be followed by others more complex, until the mammalian type was produced. The ocean also became peopled with plant and animal organisms, from the microscopic diatom to the huge leviathan. Plants and animals acted and reacted on each other, on the atmosphere which surrounded them and on the earth on which they dwelt, the surface of which became modified in character and aspect. At last Man came into existence. His nerve-energy, in addition to regulating the processes in his economy which he possesses in common with animals, was endowed with higher powers. When translated into psychical activity it has enabled him throughout the ages to progress from the condition of a rude savage to an advanced stage of civilisation; to produce works in literature, art, and the moral sciences which have exerted, and must continue to exert, a lasting influence on the development of his higher Being; to make discoveries in physical science; to acquire a knowledge of the structure of the earth, of the ocean in its changing aspects, of the atmosphere and the stellar universe, of the chemical composition and physical properties of matter in its various forms, and to analyse, comprehend, and subdue the forces of nature.

By the application of these discoveries to his own purposes Man has, to a large extent, overcome time and space; he has studded the ocean with steamships, girdled the earth with electric wire, tunnelled the lofty Alps, spanned the Forth with a bridge of steel, invented machines and founded industries of

all kinds for the promotion of his material welfare, elaborated systems of government fitted for the management of great communities, formulated economic principles, obtained an insight into the laws of health, the causes of infective diseases, and the means of controlling and preventing them.

When we reflect that many of the most important discoveries in abstract science and in its applications have been made during the present century, and indeed since the British Association held its first meeting in the ancient capital of your county sixty-nine years ago, we may look forward with confidence to the future. Every advance in science provides a fresh platform from which a new start can be made. The human intellect is still in process of evolution. The power of application and of concentration of thought for the elucidation of scientific problems is by no means exhausted. In science is no hereditary aristocracy. The army of workers is recruited from all classes. The natural ambition of even the private in the ranks to maintain and increase the reputation of the branch of knowledge which he cultivates affords an ample guarantee that the march of science is ever onwards, and justifies us in proclaiming for the next century, as in the one fast ebbing to a close, that Great is Science, and it will prevail.

SECTION A.

MATHEMATICS AND PHYSICS.

OPENING ADDRESS BY JOSEPH LARMOR, M.A., D.Sc., F.R.S., PRES. C.P.S., PRESIDENT OF THE SECTION.

IT is fitting that before entering upon the business of the Section we should pause to take note of the losses which our department of science has recently sustained. The fame of Bertrand, apart from his official position as Secretary of the French Academy of Sciences, was long ago universally established by his classical treatise on the Infinitesimal Calculus: it has been of late years sustained by the luminous exposition and searching criticism of his books on the Theory of Probability and Thermodynamics and Electricity. The debt which we owe to that other veteran, G. Wiedemann, both on account of his own researches, which take us back to the modern revival of experimental physics, and for his great and indispensable thesaurus of the science of electricity, cannot easily be overstated. By the death of Sophus Lie, following soon after his return to a chair in his native country Norway, we have lost one of the great constructive mathematicians of the century, who has in various directions fundamentally expanded the methods and conceptions of analysis by reverting to the fountain of direct geometrical intuition. In Italy the death of Beltrami has removed an investigator whose influence has been equally marked on the theories of transcendental geometry and on the progress of mathematical physics. In our own country we have lost in D. E. Hughes one of the great scientific inventors of the age; while we specially deplore the removal, in his early prime, of one who has recently been well known at these meetings, Thomas Preston, whose experimental investigations on the relations between magnetism and light, combined with his great powers of lucid exposition, marked out for him a brilliant future.

Perhaps the most important event of general scientific interest during the past year has been the definite undertaking of the great task of the international co-ordination of scientific literature; and it may be in some measure in the prolonged conferences that were necessitated by that object that the recently announced international federation of scientific academies has had its origin. In the important task of rendering accessible the stores of scientific knowledge, the British Association, and in particular this Section of it, has played the part of pioneer. Our annual volumes have long been classical, through the splendid reports of the progress of the different branches of knowledge that have been from time to time contributed to them by the foremost British men of science; and our work in this direction has received the compliment of successful imitation by the sister Associations on the Continent.

The usual conferences connected with our department of scientific activity have been this year notably augmented by the very successful international congresses of mathematicians and of physicists which met a few weeks ago in Paris. The three volumes of reports on the progress of physical science during the last ten years, for which we are indebted to the initiative of the French Physical Society, will provide an admirable conspectus

of the present trend of activity, and form a permanent record for the history of our subject.

Another very powerful auxiliary to progress is now being rapidly provided by the republication, in suitable form and within reasonable time, of the collected works of the masters of our science. We have quite recently received, in a large quarto volume, the mass of most important unpublished work that was left behind him by the late Prof. J. C. Adams; the zealous care of Prof. Sampson has worked up into order the more purely astronomical part of the volume; while the great undertaking, spread over many years, of the complete determination of the secular change of the magnetic condition of the earth, for which the practical preparations had been set on foot by Gauss himself, has been prepared for the press by Prof. W. G. Adams. By the publication of the first volume of Lord Rayleigh's papers a series of memoirs which have formed a main stimulus to the progress of mathematical physics in this country during the past twenty years has become generally accessible. The completed series will form a landmark for the end of the century that may be compared with Young's "Lectures on Natural Philosophy" for its beginning.

The recent reconstruction of the University of London, and the foundation of the University of Birmingham, will, it is to be hoped, give greater freedom to the work of our University Colleges. The system of examinations has formed an admirable stimulus to the effective acquisition of that general knowledge which is a necessary part of all education. So long as the examiner recognises that his function is a responsible and influential one, which is to be taken seriously from the point of view of moulding the teaching in places where external guidance is helpful, test by examination will remain a most valuable means of extending the area of higher education. Except for workers in rapidly progressive branches of technical science, a broad education seems better adapted to the purposes of life than special training over a narrow range; and it is difficult to see how a reasonably elastic examination test can be considered as a hardship. But the case is changed when preparation for a specialised scientific profession, or mastery of the lines of attack in an unsolved problem, is the object. The general education has then been presumably finished; in expanding departments of knowledge, variety rather than uniformity of training should be the aim, and the genius of a great teacher should be allowed free play without external trammels. It would appear that in this country we have recently been liable to unduly mix up two methods. We have been starting students on the special and lengthy, though very instructive, processes which are known as original research at an age when their time would be more profitably employed in rapidly acquiring a broad basis of knowledge. As a result, we have been extending the examination test from the general knowledge to which it is admirably suited into the specialised activity which is best left to the stimulus of personal interest. Informal contact with competent advisers, themselves imbued with the scientific spirit, who can point the way towards direct appreciation of the works of the masters of the science, is far more effective than detailed instruction at second hand, as regards growing subjects that have not yet taken on an authoritative form of exposition. Fortunately there seems to be now no lack of such teachers to meet the requirements of the technical colleges that are being established throughout the country.

The famous treatise which opened the modern era by treating magnetism and electricity on a scientific basis appeared just 300 years ago. The author, William Gilbert, M.D., of Colchester, passed from the Grammar School of his native town to St. John's College, Cambridge; soon after taking his first degree, in 1560, he became a Fellow of the College, and seems to have remained in residence, and taken part in its affairs, for about ten years. All through his subsequent career, both at Colchester and afterwards at London, where he attained the highest position in his profession, he was an exact and diligent explorer, first of chemical and then of magnetic and electric phenomena. In the words of the historian Hallam, writing in 1839, "in his Latin treatise on the Magnet he not only collected all the knowledge which others had possessed, but he became at once the father of experimental philosophy in this island"; and no demur would be raised if Hallam's restriction to this country were removed. Working nearly a century before the time when the astronomical discoveries of Newton had originated the idea of attraction at a distance, he established a complete formulation of the interaction of magnets by what we now call the exploration of their

fields of force. His analysis of the facts of magnetic influence, and incidentally of the points in which it differs from electric influence, is virtually the one which Faraday re-introduced. A cardinal advance was achieved, at a time when the Copernican Astronomy had still largely to make its way, by assigning the behaviour of the compass and the dip needle to the fact that the earth itself is a great magnet, by whose field of influence they are controlled. His book passed through many editions on the Continent within forty years; it won the high praise of Galileo. Gilbert has been called "the father of modern electricity" by Priestley, and "the Galileo of magnetism" by Poggenдорff.

When the British Association last met at Bradford in 1873 the modern theory which largely reverts to Gilbert's way of formulation, and refers electric and magnetic phenomena to the activity of the æther instead of attractions at a distance, was of recent growth; it had received its classical exposition only two years before the publication of Clerk Maxwell's treatise. The new doctrine was already widely received in England on its own independent merits. On the Continent it was engaging the strenuous attention of Helmholtz, whose series of memoirs, deeply probing the new ideas in their relation to the prevalent and fairly successful theories of direct action across space, had begun to appear in 1870. During many years the search for crucial experiments that would go beyond the results equally explained by both views met with small success; it was not until 1887 that Hertz, by the discovery of the æthereal radiation of long wave-length emitted from electric oscillators, verified the hypothesis of Faraday and Maxwell and initiated a new era in the practical development of physical science. The experimental field thus opened up was soon fully occupied both in this country and abroad; and the borderland between the sciences of optics and electricity is now being rapidly explored. The extension of experimental knowledge was simultaneous with increased attention to directness of explanation; the expositions of Heaviside and Hertz and other writers fixed attention, in a manner already briefly exemplified by Maxwell himself, on the inherent simplicity of the completed æthereal scheme, when once the theoretical scaffolding employed in its construction and dynamical consolidation is removed; while Poynting's beautiful corollary specifying the path of the transmission of energy through the æther has brought the theory into simple relations with the applications of electrodynamics.

Equally striking has been the great mastery obtained during the last twenty years over the practical manipulation of electric power. The installation of electric wires as the nerves connecting different regions of the earth had attained the rank of accomplished fact so long ago as 1857, when the first Atlantic cable was laid. It was largely the theoretical and practical difficulties, many of them unforeseen, encountered in carrying that great undertaking to a successful issue, that necessitated the elaboration by Lord Kelvin and his coadjutors of convenient methods and instruments for the exact measurement of electric quantities, and thus prepared the foundation for the more recent practical developments in other directions. On the other hand, the methods of theoretical explanation have been in turn improved and simplified through the new ways of considering the phenomena which have been evolved in the course of practical advances on a large scale, such as the improvement of dynamo armatures, the conception and utilisation of magnetic circuits, and the transmission of power by alternating currents. In our time the relations of civilised life have been already perhaps more profoundly altered than ever before, owing to the establishment of practically instantaneous electric communication between all parts of the world. The employment of the same subtle agency is now rapidly superseding the artificial reciprocating engines and other contrivances for the manipulation of mechanical power that were introduced with the employment of steam. The possibilities of transmitting power to great distances at enormous tension, and therefore with very slight waste, along lines merely suspended in the air, are being practically realised; and the advantages thence derived are increased manifold by the almost automatic manner in which the electric power can be transformed into mechanical rotation at the very point where it is desired to apply it. The energy is transmitted at such lightning speed that at a given instant only an exceedingly minute portion of it is in actual transit. When the tension of the alternations is high, the amount of electricity that has to oscillate backwards and forwards on the guiding wires is proportionately diminished, and the frictional waste reduced. At the terminals the direct transmission from one armature of the motor to the other, across the

intervening empty space, at once takes us beyond the province of the pushing and rubbing contacts that are unavoidable in mechanical transmission; while the perfect symmetry and reversibility of the arrangement by which power is delivered from a rotary alternator at one end, guided by the wires to another place many miles away, where it is absorbed by another alternator with precise reversal of the initial stages, makes this process of distribution of energy resemble the automatic operations of nature rather than the imperfect material connections previously in use. We are here dealing primarily with the flawless continuous medium which is the transmitter of radiant energy across the celestial spaces; the part played by the coarsely constituted material conductor is only that of a more or less imperfect guide which directs the current of æthereal energy. The wonderful nature of this theoretically perfect, though of course practically only approximate, method of abolishing limitations of locality with regard to mechanical power is not diminished by the circumstance that its principle must have been in some manner present to the mind of the first person who fully realised the character of the reversibility of a gramme armature.

In theoretical knowledge a new domain, to which the theory as expounded twenty years ago had little to say, has recently been acquired through the experimental scrutiny of the electric discharge in rarefied gaseous media. The very varied electric phenomena of vacuum tubes, whose electrolytic character was first practically established by Schuster, have been largely reduced to order through the employment of the high exhaustions introduced and first utilised by Crookes. Their study under these circumstances, in which the material molecules are so sparsely distributed as but rarely to interfere with each other, has conduced to enlarged knowledge and verification of the fundamental relations in which the individual molecules stand to all electric phenomena, culminating recently in the actual determination, by J. J. Thomson and others following in his track, of the masses and velocities of the particles that carry the electric discharge across the exhausted space. The recent investigations of the circumstances of the electric dissociation produced in the atmosphere and in other gases by ultra-violet light, the Röntgen radiation, and other agencies, constitute one of the most striking developments in experimental molecular physics since Graham determined the molecular relations of gaseous diffusion and transpiration more than half a century ago. This advance in experimental knowledge of molecular phenomena, assisted by the discovery of the precise and rational effect of magnetism on the spectrum, has brought into prominence a modification or rather development of Maxwell's exposition of electric theory, which was dictated primarily by the requirements of the abstract theory itself; the atoms or ions are now definitely introduced as the carriers of those electric charges which interact across the æther, and so produce the electric fields whose transformations were the main subject of the original theory.

We are thus inevitably led, in electric and æthereal theory, as in the chemistry and dynamics of the gaseous state which is the department of abstract physics next in order of simplicity, to the consideration of the individual molecules of matter. The theoretical problems which had come clearly into view a quarter of a century ago, under Maxwell's lead, whether in the exact dynamical relations of æthereal transmission or in the more fruituous domain of the statistics of interacting molecules, are those around which attention is still mainly concentrated; but as the result of the progress in each, they are now tending towards consolidation into one subject. I propose—leaving further review of the scientific aspect of the recent enormous development of the applications of physical science for hands more competent to deal with the practical side of that subject—to offer some remarks on the scope and validity of this molecular order of ideas, to which the trend of physical explanation and development is now setting in so pronounced a manner.

If it is necessary to offer an apology for detaining the attention of the Section on so abstract a topic, I can plead its intrinsic philosophical importance. The hesitation so long felt on the Continent in regard to discarding the highly-developed theories which analysed all physical actions into direct attractions between the separate elements of the bodies concerned, in favour of a new method in which our ideas are carried into regions deeper than the phenomena, has now given place to eager discussion of the potentialities of the new standpoint. There has even appeared a disposition to consider that the Newtonian dynamical principles, which have formed the basis of physical explanation for nearly two centuries, must be replaced in these

deeper subjects by a method of direct description of the mere course of phenomena, apart from any attempt to establish causal relations; the initiation of this method being traced, like that of the Newtonian dynamics itself, to this country. The question has arisen as to how far the new methods of æthereal physics are to be considered as an independent departure, how far they form the natural development of existing dynamical science. In England, whence the innovation came, it is the more conservative position that has all along been occupied. Maxwell was himself trained in the school of physics established in this country by Sir George Stokes and Lord Kelvin, in which the dominating idea has been that of the strictly dynamical foundation of all physical action. Although the pupil's imagination bridged over dynamical chasms, across which the master was not always able to follow, yet the most striking feature of Maxwell's scheme was still the dynamical framework into which it was built. The more advanced reformers have now thrown overboard the apparatus of potential functions which Maxwell found necessary for the dynamical consolidation of his theory, retaining only the final result as a verified descriptive basis for the phenomena. In this way all difficulties relating to dynamical development and indeed consistency are avoided, but the question remains as to how much is thereby lost. In practical electro-magnetics the transmission of power is now the most prominent phenomenon; if formal dynamics is put aside in the general theory, its guidance must here be replaced by some more empirical and tentative method of describing the course of the transmission and transformation of mechanical energy in the system.

The direct recognition in some form, either explicitly or tacitly, of the part played by the æther, has become indispensable to the development and exposition of general physics ever since the discoveries of Hertz left no further room for doubt that this physical scheme of Maxwell was not merely a brilliant speculation, but constituted, in spite of outstanding gaps and difficulties, a real formulation of the underlying unity in physical dynamics. The domain of abstract physics is in fact roughly divisible into two regions. In one of them we are mainly concerned with interactions between one portion of matter and another portion occupying a different position in space; such interactions have very uniform and comparatively simple relations; and the reason is traceable to the simple and uniform constitution of the intervening medium in which they have their seat. The other province is that in which the distribution of the material molecules comes into account. Setting aside the ordinary dynamics of matter in bulk, which is founded on the uniformity of the properties of the bodies concerned and their experimental determination, we must assign to this region all phenomena which are concerned with the unco-ordinated motions of the molecules, including the range of thermal and in part of radiant actions; the only possible basis for detailed theory is the statistical dynamics of the distribution of the molecules. The far more deep-seated and mysterious processes which are involved in changes in the constitution of the individual molecules themselves are mainly outside the province of physics, which is competent to reason only about permanent material systems; they must be left to the sciences of chemistry and physiology. Yet the chemist proclaims that he can determine only the results of his reactions and the physical conditions under which they occur; the character of the bonds which hold atoms in their chemical combinations is at present unknown, although a large domain of very precise knowledge relating, in some diagrammatic manner, to the topography of the more complex molecules has been attained. The vast structure which chemical science has in this way raised on the narrow foundation of the atomic theory is perhaps the most wonderful existing illustration both of the rationality of natural processes and of the analytical powers of the human mind. In a word, the complication of the material world is referable to the vast range of structure and of states of aggregation in the material atoms; while the possibility of a science of physics is largely due to the simplicity of constitution of the universal medium through which the individual atoms interact on each other.

The reference of the uniformity in the interactions at a distance between material bodies to the part played by the æther is a step towards the elimination of extraneous and random hypotheses about laws of attraction between atoms. It also places that medium on a different basis from matter, in that its mode of activity is simple and regular, whereas intimate material interactions must be of illimitable complexity. This gives strong ground for the view that we should not be tempted towards ex-

plaining the simple group of relations which have been found to define the activity of the æther, by treating them as mechanical consequences of concealed structure in that medium; we should rather rest satisfied with having attained to their exact dynamical correlation, just as geometry explores or correlates, without explaining, the descriptive and metric properties of space. On the other hand, a view is upheld which considers the pressures and thrusts of the engineer, and the strains and stresses in the material structures by which he transmits them from one place to another, to be the archetype of the processes by which all mechanical effect is transmitted in nature. This doctrine implies an expectation that we may ultimately discover something analogous to structure in the celestial spaces, by means of which the transmission of physical effect will be brought into line with the transmission of mechanical effect by material framework.

At a time when the only definitely ascertained function of the æther was the undulatory propagation of radiant energy across space, Lord Kelvin pointed out that, by reason of the very great velocity of propagation, the density of the radiant energy in the medium at any place must be extremely small in comparison with the amount of energy that is transmitted in a second of time: this easily led him to the very striking conclusion that, on the hypothesis that the æther is like material elastic media, it is not necessary to assume its density to be more than 10^{-18} of that of water, or its optical rigidity to be more than ten 10^{-8} of that of steel or glass. Thus far the æther would be merely an impalpable material atmosphere for the transference of energy by radiation, at extremely small densities but with very great speed, while ordinary matter would be the seat of practically all this energy. But this way of explaining the absence of sensible influence of the æther on the phenomena of material dynamics lost much of its basis as soon as it was recognised that the same medium must be the receptacle of very high densities of energy in the electric fields around currents and magnets.¹ The other mode of explanation is to consider the æther to be of the very essence of all physical actions, and to correlate the absence of obvious mechanical evidence of its intervention with its regularity and universality.

On this plan of making the æther the essential factor in the transformation of energy as well as its transmission across space, the material atom must be some kind of permanent nucleus that retains around itself an æthereal field of physical influence, such as, for example, a field of strain. We can recognise the atom only through its interactions with other atoms that are so far away from it as to be practically independent systems; thus our direct knowledge of the atom will be confined to this field of force which belongs to it. Just as the exploration of the distant field of magnetic influence of a steel magnet, itself concealed from view, cannot tell us anything about the magnet except the amount and direction of its moment, so a practically complete knowledge of the field of physical influence of an atom might be expressible in terms of the numerical values of a limited number of physical moments associated with it, without any revelation as to its essential structure or constitution being involved. This will at any rate be the case for ultimate atoms if, as is most likely, the distances at which they are kept apart are large compared with the diameters of the atomic nuclei; it in fact forms our only chance for penetrating to definite dynamical views of molecular structure. So long as we cannot isolate a single molecule, but must deal observationally with an innumerable distribution of them, even this kind of knowledge will be largely confined to average values. But the last half-century has witnessed the successful application of a new instrument of research, which has removed in various directions the limitations that had previously been placed on the knowledge to which it was possible for human effort to look forward. The spectroscope has created a new astronomy by revealing the constitutions and the unseen internal motions of the stars. Its power lies in the fact that it does take hold of the internal relations of the individual molecule of matter, and provide a very definite and

¹ We can here only allude to Lord Kelvin's recent most interesting mechanical illustrations of a solid æther interacting with material molecules and with itself by attraction at a distance; unlike the generalised dynamical methods expounded in the text, which can leave the intimate structure of the material molecule outside the problem, a definite working constitution is there assigned to the molecular nucleus. It is pointed out in a continuation that is to appear in the *Phil. Mag.* for September, that a density of æther of the order of only 10^{-9} , which would not appreciably affect the inertia of matter, would involve rigidity comparable with that of steel, and thus permit transmission of magnetic forces by stress; this solid æther is, however, as usual, taken to be freely permeable to the molecules of matter.

detailed, though far from complete, analysis of the vibratory motions that are going on in it; these vibrations being in their normal state characteristic of its dynamical constitution, and in their deviations from the normal giving indications of the velocity of its movement and the physical state of its environment. Maxwell long ago laid emphasis on the fact that a physical atomic theory is not competent even to contemplate the vast mass of potentialities and correlations of the past and the future, that biological theory has to consider as latent in a single organic germ containing at most only a few million molecules. On our present view we can accept his position that the properties of such a body cannot be those of a "purely material system," provided, however, we restrict this phrase to apply to physical properties as here defined. But an exhaustive discovery of the intimate nature of the atom is beyond the scope of physics; questions as to whether it must not necessarily involve in itself some image of the complexity of the organic structures of which it can form a correlated part must remain a subject of speculation outside the domain of that science. It might be held that this conception of discrete atoms and continuous æther really stands, like those of space and time, in intimate relation with our modes of mental apprehension, into which any consistent picture of the external world must of necessity be fitted. In any case it would involve abandonment of all the successful traditions of our subject if we ceased to hold that our analysis can be formulated in a consistent and complete manner, so far as it goes, without being necessarily an exhaustive account of phenomena that are beyond our range of experiment. Such phenomena may be more closely defined as those connected with the processes of intimate combination of the molecules: they include the activities of organic beings which all seem to depend on change of molecular structure.

If, then, we have so small a hold on the intimate nature of matter, it will appear all the more striking that physicists have been able precisely to divine the mode of operation of the intangible æther, and to some extent explore in it the fields of physical influence of the molecules. On consideration we recognise that this knowledge of fundamental physical interaction has been reached by a comparative process. The mechanism of the propagation of light could never have been studied in the free æther of space alone. It was possible, however, to determine the way in which the characteristics of optical propagation are modified, but not wholly transformed, when it takes place in a transparent material body instead of empty space. The change in fact arises on account of the æther being entangled with the network of material molecules; but inasmuch as the length of a single wave of radiation covers thousands of these molecules the wave-motion still remains uniform and does not lose its general type. A wider variation of the experimental conditions has been provided for our examination in the case of those substances in which the phenomenon of double refraction pointed to a change of the æthereal properties which varied in different directions; and minute study of this modification has proved sufficient to guide to a consistent appreciation of the nature of this change, and therefore of the mode of æthereal propagation that is thus altered. In the same way, it was the study and development of the manner in which the laws of electric phenomena in material bodies had been unravelled by Ampère and Faraday that guided Faraday himself and Maxwell—who were impressed with the view that the æther was at the bottom of it all—in their progress towards an application of similar laws to æther devoid of matter, such as would complete a scheme of continuous action by consistently interconnecting the material bodies and banishing all untraced interaction across empty space. Maxwell in fact chose to finally expound the theory by ascribing to the æther of free space a dielectric constant and a magnetic constant of the same types as had been found to express the properties of material media, thus extending the seat of the phenomena to all space on the plan of describing the activity of the æther in terms of the ordinary electric ideas. The converse mode of development, starting with the free æther under the directly dynamical form which has been usual in physical optics, and introducing the influence of the material atoms through the electric charges which are involved in their constitution,¹ was hardly employed by him;

¹ In 1870 Maxwell, while admiring the breadth of the theory of Weber, which is virtually based on atomic charges combined with action at a distance, still regarded it as irreconcilable with his own theory, and left to the future the question as to why "theories apparently so fundamentally opposed should have so large a field of truth common to both."—"Scientific Papers," ii. p. 228.

in part, perhaps, because, owing to the necessity of correlating his theory with existing electric knowledge and the mode of its expression, he seems never to have reached the stage of moulding it into a completely deductive form.

The dynamics of the æther, in fact the recognition of the existence of an æther, has thus, as a matter of history, been reached through study of the dynamical phenomena of matter. When the dynamics of a material system is worked up to its purest and most general form, it becomes a formulation of the relations between the succession of the configurations and states of motion of the system, the assistance of an independent idea of force not being usually required. We can, however, only attain to such a compact statement when the system is self-contained, when its motion is not being dissipated by agencies of frictional type, and when its connections can be directly specified by purely geometrical relations between the co-ordinates, thus excluding such mechanisms as rolling contacts. The course of the system is then in all cases determined by some form or other of a single fundamental property, that any alteration in any small portion of its actual course must produce an increase in the total "Action" of the motion. It is to be observed that in employing this law of minimum as regards the Action expressed as an integral over the whole time of the motion, we no more introduce the future course as a determining influence on the present state of motion than we do in drawing a straight line from any point in any direction, although the length of the line is the minimum distance between its ends. In drawing the line piece by piece we have to make tentative excursions into the immediate future in order to adjust each element into straightness with the previous element; so in tracing the next stage of the motion of a material system we have similarly to secure that it is not given any such directions as would unduly increase the Action. But whatever views may be held as to the ultimate significance of this principle of Action, its importance, not only for mathematical analysis, but as a guide to physical exploration, remains fundamental. When the principles of the dynamics of material systems are refined down to their ultimate common basis, this principle of minimum is what remains. Hertz preferred to express its contents in the form of a principle of straightness of course or path. It will be recognised, on the lines already indicated, that this is another mode of statement of the same fundamental idea; and the general equivalence is worked out by Hertz on the basis of Hamilton's development of the principles of dynamics. The latter mode of statement may be adaptable so as to avoid the limitations which restrict the connections of the system, at the expense, however, of introducing new variables; if, indeed, it does not introduce gratuitous complexity for purposes of physics to attempt to do this. However these questions may stand, this principle of straightness or directness of path forms, wherever it applies, the most general and comprehensive formulation of purely dynamical action: it involves in itself the complete course of events. In so far as we are given the algebraic formula for the time-integral which constitutes the Action, expressed in terms of any suitable co-ordinates, we know implicitly the whole dynamical constitution and history of the system to which it applies. Two systems in which the Action is expressed by the same formula are mathematically identical, are physically precisely correlated, so that they have all dynamical properties in common. When the structure of a dynamical system is largely concealed from view, the safest and most direct way towards an exploration of its essential relations and connections, and in fact towards answering the prior question as to whether it is a purely dynamical system at all, is through this order of ideas. The ultimate test that a system is a dynamical one is not that we shall be able to trace mechanical stresses throughout it, but that its relations can be in some way or other consolidated into accordance with this principle of minimum Action. This definition of a dynamical system in terms of the simple principle of directness of path may conceivably be subject to objection as too wide; it is certainly not too narrow; and it is the conception which has naturally been evolved from two centuries of study of the dynamics of material bodies. Its very great generality may lead to the objection that we might completely formulate the future course of a system in its terms, without having obtained a working familiarity with its details, of the kind to which we have become accustomed in the analysis of simple material systems; but our choice is at present between this kind of formulation, which is a real and essential one, and an empirical description of the course of phenomena combined with explan-

ations relating to more or less isolated groups. The list of great names, including Kelvin, Maxwell, Helmholtz, that have been associated with the employment of the principle for the elucidation of the relations of deep-seated dynamical phenomena is a strong guarantee that we shall do well by making the most of this clue.

Are we then justified in treating the material molecule, so far as revealed by the spectroscope, as a dynamical system coming under this specification? Its intrinsic energy is certainly permanent and not subject to dissipation; otherwise the molecule would gradually fade out of existence. The extreme precision and regularity of detail in the spectrum shows that the vibrations which produce it are exactly synchronous, whatever be their amplitude, and in so far resemble the vibrations of small amplitude in material systems. As all indications point to the molecule being a system in a state of intrinsic motion, like a vortex ring, or a stellar system in astronomy, we must consider these radiating vibrations to take place around a steady state of motion which does not itself radiate, not around a state of rest. Now not the least of the advantages possessed by the Action principle, as a foundation for theoretical physics, is the fact that its statement can be adapted to systems involving in their constitution permanent steady motions of this kind, in such a way that only the variable motions superposed on them come into consideration. The possibilities as regards physical correlation of thus introducing permanent motional states as well as permanent structure into the constitution of our dynamical systems have long been emphasised by Lord Kelvin;¹ the effective adaptation of abstract dynamics to such systems was made independently by Kelvin and Routh about 1877; the more recent exposition of the theory by Helmholtz has directed general attention to what is undoubtedly the most significant extension of dynamical analysis which has taken place since the time of Lagrange.

Returning to the molecules, it is now verified that the Action principle forms a valid foundation throughout electrodynamics and optics; the introduction of the æther into the system has not affected its application. It is therefore a reasonable hypothesis that the principle forms an allowable foundation for the dynamical analysis of the radiant vibrations in the system formed by a single molecule and surrounding æther; and the knowledge which is now accumulating, both of the orderly grouping of the lines of the spectrum and of the modifications impressed on these lines by a magnetic field or by the density of the matter immediately surrounding the vibrating molecule, can hardly fail to be fruitful for the dynamical analysis of its constitution. But let it be repeated that this analysis would be complete when a formula for the dynamical energy of the molecule is obtained, and would go no deeper. Starting from our definitely limited definition of the nature of a dynamical system, the problem is merely to correlate the observed relations of the periods of vibration in a molecule, when it has come into a steady state as regards constitution and is not under the influence of intimate encounter with other molecules.

It may be recalled incidentally that the generalised Maxwell-Boltzmann principle of the equable distribution of the acquired store of kinetic energy of the molecule, among its various possible independent types of motion, is based directly on the validity of the Action principle for its dynamics. In the demonstrations usually offered the molecule is considered to have no permanent or constitutive energy of internal motion. It can, however, be shown, by use of the generalisation aforesaid of the Action principle, that no discrepancy will arise on that account. Such intrinsic kinetic energy virtually adds on to the potential energy of the system; and the remaining or acquired part of the kinetic energy of the molecule may be made the subject of the same train of reasoning as before.

Let us now return to the general question whether our definition of a dynamical system may not be too wide. As a case in point, the single principle of Action has been shown to provide a definite and sufficient basis for electrodynamics; yet when, for example, one armature of an electric motor pulls the other after it without material contact, and so transmits mechanical power, no connection between them is indicated by the principle such as could by virtue of internal stress transmit the pull. The essential feature of the transmission of a pull by stress across a medium is that each element of volume of the medium

acts by itself, independently of the other elements. The stress excited in any element depends on the strain or other displacement occurring in that element alone; and the mechanical effect that is transmitted is considered as an extraneous force applied at one place in the medium, and passed on from element to element through these internal pressures and tractions until it reaches another place. We have, however, to consider two atomic electric charges as being themselves some kind of strain configurations in the æther; each of them already involves an atmosphere of strain in the surrounding æther which is part of its essence, and cannot be considered apart from it; each of them essentially pervades the entire space, though on account of its invariable character we consider it as a unit. Thus we appear to be debarred from imagining the æther to act as an elastic connection which is merely the agent of transmission of a pull from the one nucleus to the other, because there are already stresses belonging to and constituting an intrinsic part of the terminal electrons, which are distributed all along the medium. Our Action criterion of a dynamical system, in fact, allows us to reason about an electron as a single thing, notwithstanding that its field of energy is spread over the whole medium; it is only in material solid bodies, and in problems in which the actual sphere of physical action of the molecule is small compared with the smallest element of volume that our analysis considers, that the familiar idea of transmission of force by simple stress can apply. Whatever view may ultimately commend itself, this question is one that urgently demands decision. A very large amount of effort has been expended by Maxwell, Helmholtz, Heaviside, Hertz, and other authorities in the attempt to express the mechanical phenomena of electrical action in terms of a transmitting stress. The analytical results up to a certain point have been promising, most strikingly so at the beginning, when Maxwell established the mathematical validity of the way in which Faraday was accustomed to represent to himself the mechanical interactions across space, in terms of a tension along the lines of force equilibrated by an equal pressure preventing their expansion sideways. According to the views here developed, that ideal is an impossible one; if this could be established to general satisfaction the field of theoretical discussion would be much simplified.

This view that the atom of matter is, so far as regards physical actions, of the nature of a structure in the æther involving an atmosphere of æthereal strain all around it, not a small body which exerts direct actions at a distance on other atoms according to extraneous laws of force, was practically foreign to the eighteenth century, when mathematical physics was modelled on the Newtonian astronomy and dominated by its splendid success. The scheme of material dynamics, as finally compactly systematised by Lagrange, had therefore no direct relation to such a view, although it has proved wide enough to include it. The remark has often been made that it is probably owing to Faraday's mathematical instinct, combined with his want of acquaintance with the existing analysis, that the modern theory of the æther obtained a start from the electric side. Through his teaching and the weight of his authority, the notion of two electric currents exerting their mutual forces by means of an intervening medium, instead of by direct attraction across space, was at an early period firmly grasped in this country. In 1845 Lord Kelvin was already mathematically formulating, with most suggestive success, continuous elastic connections, by whose strain the fields of activity of electric currents or of electric distributions could be illustrated; while the exposition of Maxwell's interconnected scheme, in the earlier form in which it relied on concrete models of the electric action, goes back almost to 1860. Corresponding to the two physical ideals of isolated atoms exerting attraction at a distance, and atoms operating by atmospheres of æthereal strain, there are, as already indicated, two different developments of dynamical theory. The original Newtonian equations of motion determined the course of a system by expressing the rates at which the velocity of each of its small parts or elements is changing. This method is still fully applicable to those problems of gravitational astronomy in which dynamical explanation was first successful on a grand scale, the planets being treated as point-masses, each subject to the gravitational attraction of the other bodies. But the more recent development of the dynamics of complex systems depends on the fact that analysis has been able to reduce within manageable limits the number of varying quantities whose course is to be explicitly traced, through taking advantage of those internal relations of the parts of the system that are invariable, either geometrically

¹ For a classical exposition see his Brit. Assoc. Address of 1884 on "Steps towards a Kinetic Theory of Matter," reprinted in "Popular Lectures and Addresses," vol. i.

or dynamically. Thus, to take the simplest case, the dynamics of a solid body can be confined to a discussion of its three components of translation and its three components of rotation, instead of the motion of each element of its mass. With the number of independent co-ordinates thus diminished, when the initial state of the motion is specified the subsequent course of the complete system can be traced; but the course of the changes in any part of it can only be treated in relation to the motion of the system as a whole. It is just this mode of treatment of a system as a whole that is the main characteristic of modern physical analysis. The way in which Maxwell analysed the interactions of a system of linear electric currents, previously treated as if each were made up of small independent pieces or elements, and accumulated the evidence that they formed a single dynamical system, is a trenchant example. The interactions of vortices in fluid form a very similar problem, which is of special note in that the constitution of the system is there completely known in advance, so that the two modes of dynamical exposition can be compared. In this case the older method forms independent equations for the motion of each material element of the fluid, and so requires the introduction of the stress—here the fluid pressure—by which dynamical effect is passed on to it from the surrounding elements: it corresponds to a method of contact action. But Helmholtz opened up new ground in the abstract dynamics of continuous media when he recognised (after Stokes) that, if the distribution of the velocity of spin at those places in the fluid where the motion is vortical be assigned, the motion in every part of the fluid is therein kinematically involved. This, combined with the theorem of Lagrange and Cauchy, that the spin is always confined to the same portions of the fluid, formed a starting-point for his theory of vortices, which showed how the subsequent course of the motion can be ascertained without consideration of pressure or other stress.

The recognition of the permanent state of motion constituting a vortex ring as a determining agent as regards the future course of the system was in fact justly considered by Helmholtz as one of his greatest achievements. The principle had entirely eluded the attention of Lagrange and Cauchy and Stokes, who were the pioneers in this fundamental branch of dynamics, and had virtually prepared all the necessary analytical material for Helmholtz's use. The main import of this advance lay, not in the assistance which it afforded to the development of the complete solution of special problems in fluid motion, but in the fact that it constituted the discovery of the types of permanent motion of the system, which could combine and interact with each other without losing their individuality,¹ though each of them pervaded the whole field. This rendered possible an entirely new mode of treatment; and mathematicians who were accustomed, as in astronomy, to aim directly at the determination of all the details of the special case of motion, were occasionally slow to apprehend the advantages of a procedure which stopped at formulating a description of the nature of the interaction between various typical groups of motions into which the whole disturbance could be resolved.

The new train of ideas introduced into physics by Faraday was thus consolidated and emphasised by Helmholtz's investigations of 1858 in the special domain of hydrodynamics. In illustration let us consider the fluid medium to be pervaded by permanent vortices circulating round solid rings as cores: the older method of analysis would form equations of motion for each element of the fluid, involving the fluid pressure, and by their integration would determine the distribution of pressure on each solid ring, and thence the way it moves. This method is hardly feasible even in the simplest cases. The natural plan is to make use of existing simplifications by regarding each vortex as a permanent reality, and directly attacking the problem of its interactions with the other vortices. The energy of the fluid arising from the vortex motion can be expressed in terms of the positions and strengths of the vortices alone; and then the principle of Action, in the generalised form which includes steady motional configurations as well as constant material configurations, affords a method of deducing the motions of the cores and the interactions between them. If the cores are thin they in fact interact mechanically, as Lord Kelvin and Kirchhoff proved, in the same manner as linear electric currents would do; though the impulse thence derived towards a direct hydrokinetic explanation of electro-magnetics was damped by the fact

¹ We may compare G. W. Hill's more recent introduction of the idea of permanent orbits into physical astronomy.

that repulsion and attraction have to be interchanged in the analogy. The conception of vortices, once it has been arrived at, forms the natural physical basis of investigation, although the older method of determining a distribution of pressure-stress throughout the fluid and examining how it affects the cores is still possible; that stress, however, is not simply transmitted, as it has to maintain the changes of velocity of the various portions of the fluid. But if the vortices have no solid cores we are at a loss to know where even this pressure can be considered as applied to them; if we follow up the stress, we lose the vortex; yet a fluid vortex can nevertheless illustrate an atom of matter, and we can consider such atoms as exerting mutual forces, only these forces cannot be considered as transmitted through the agency of fluid pressure. The reason is that the vortex cannot now be identified with a mere core bounded by a definite surface, but is essentially a configuration of motion extending throughout the medium.

Thus we are again in face of the fundamental question whether all attempts to represent the mechanical interactions of electro-dynamic systems, as transmitted from point to point by means of simple stress, are not doomed to failure; whether they do not, in fact, introduce unnecessary and insurmountable difficulty into the theory. The idea of identifying an atom with a state of strain or motion, pervading the region of the æther around its nucleus, appears to demand wider views as to what constitutes dynamical transmission. The idea that any small portion of the primordial medium can be isolated, by merely introducing tractions acting over its surface and transmitted from the surrounding parts, is no longer appropriate or consistent: a part of the dynamical disturbance in that element of the medium is on this hypothesis already classified as belonging to, and carried along with, atoms that are outside it but in its neighbourhood—and this part must not be counted twice over. The law of Poynting relating to the paths of the transmission of energy is known to hold in its simple form only when the electric charges or currents are in a steady state; when they are changing their positions or configurations their own fields of intrinsic energy are carried along with them.

It is not surprising, considering the previous British familiarity with this order of ideas, that the significance for general physics of Helmholtz's doctrine of vortices was eagerly developed in this country, in the form in which it became embodied through Lord Kelvin's famous illustration of the constitution of the matter, as consisting of atoms with separate existence and mutual interactions. This vortex-atom theory has been a main source of physical suggestion because it presents, on a simple basis, a dynamical picture of an ideal material system, atomically constituted, which could go on automatically without extraneous support. The value of such a picture may be held to lie, not in any supposition that this is the mechanism of the actual world laid bare, but in the vivid illustration it affords of the fundamental postulate of physical science, that mechanical phenomena are not parts of a scheme too involved for us to explore, but rather present themselves in definite and consistent correlations, which we are able to disentangle and apprehend with continually increasing precision.

It would be an interesting question to trace the origin of our preference for a theory of transmission of physical action over one of direct action at a distance. It may be held that it rests on the same order of ideas as supplies our conception of force; that the notion of effort which we associate with change of the motion of a body involves the idea of a mechanical connection through which that effort is applied. The mere idea of a transmitting medium would then be no more an ultimate foundation for physical explanation than that of force itself. Our choice between direct distance action and mediate transmission would thus be dictated by the relative simplicity and coherence of the accounts they give of the phenomena: this is, in fact, the basis on which Maxwell's theory had to be judged until Hertz detected the actual working of the medium. Instantaneous transmission is to all intents action at a distance, except in so far as the law of action may be more easily formulated in terms of the medium than in a direct geometrical statement.

In connection with these questions it may be permitted to refer to the eloquent and weighty address recently delivered by M. Poincaré to the International Congress of Physics. M. Poincaré accepts the principle of Least Action as a trustworthy basis for the formulation of physical theory, but he imposes the condition that the results must satisfy the Newtonian law of equality of action and reaction between each pair of bodies

concerned, considered by themselves; this, however, he would allow to be satisfied indirectly, if the effects could be traced across the intervening æther by stress, so that the tractions on the two sides of each ideal interface are equal and opposite.¹ As above argued, this view appears to exclude *ab initio* all atomic theories of the general type of vortex atoms, in which the energy of the atom is distributed throughout the medium instead of being concentrated in a nucleus; and this remark seems to go to the root of the question. On the other hand, the position here asserted is that recent dynamical developments have permitted the extension of the principle of Action to systems involving permanent motions, whether obvious or latent, as part of their constitution; that on this wider basis the atom may itself involve a state of steady disturbance extending through the medium, instead of being only a local structure acting by push and pull. The possibilities of dynamical explanation are thus enlarged. The most definite type of model yet imagined of the physical interaction of atoms through the æther is, perhaps, that which takes the æther to be a rotationally elastic medium after the manner of MacCullagh and Rankine, and makes the ultimate atom include the nucleus of a permanent rotational strain-configuration, which as a whole may be called an electron. The question how far this is a legitimate and effective model stands by itself, apart from the dynamics which it illustrates; like all representations it can only cover a limited ground. For instance, it cannot claim to include the internal structure of the nucleus of an atom or even of an electron; for purposes of physical theory that problem can be put aside, it may even be treated as inscrutable. All that is needed is a postulate of free mobility of this nucleus through the æther. This is definitely hypothetical, but it is not an unreasonable postulate because a rotational æther has the properties of a perfect fluid medium except where differentially rotational motions are concerned, and so would not react on the motion of any structure moving through it except after the manner of an apparent change of inertia. It thus seems possible to hold that such a model forms an allowable representation of the dynamical activity of the æther, as distinguished from the complete constitution of the material nuclei between which that medium establishes connection.

At any rate, models of this nature have certainly been most helpful in Maxwell's hands towards the effective intuitive grasp of a scheme of relations as a whole, which might have proved too complex for abstract unravelment in detail. When a physical model of concealed dynamical processes has served this kind of purpose, when its content has been explored and estimated, and has become familiar through the introduction of new terms and ideas, then the ladder by which we have ascended may be kicked away, and the scheme of relations which the model embodied can stand forth in severely abstract form. Indeed, many of the most fruitful branches of abstract mathematical analysis itself have owed their start in this way to concrete physical conceptions. This gradual transition into abstract statement of physical relations in fact amounts to retaining the essentials of our working models while eliminating the accidental elements involved in them; elements of the latter kind must always be present because otherwise the model would be identical with the thing which it represents, whereas we cannot expect to mentally grasp all aspects of the content of even the simplest phenomena. Yet the abstract standpoint is always attained through the concrete; and for purposes of instruction such models, properly guarded, do not perhaps ever lose their value: they are just as legitimate aids as geometrical diagrams, and they have the same kind of limitations. In Maxwell's words, "for the sake of persons of these different types scientific truth should be presented in different forms, and should be regarded as equally scientific whether it appear in the robust form and the vivid colouring of a physical illustration, or in the tenuity and paleness of a symbolical expression." The other side of the picture, the necessary incompleteness of even our legitimate images and modes of representation, comes out in the despairing opinion of Young ("Chromatics," 1817), at a time when his faith in the undulatory theory of light had been eclipsed by Malus's discovery of the phenomena of polarisation by reflection, that this difficulty "will probably long remain, to mortify the vanity of an

ambitious philosophy, completely unresolved by any theory": not many years afterwards the mystery was solved by Fresnel.

This process of removing the intellectual scaffolding by which our knowledge is reached, and preserving only the final formulae which express the correlations of the directly observable things, may moreover readily be pushed too far. It asserts the conception that the universe is like an enclosed clock that is wound up to go, and that accordingly we can observe that it is going, and can see some of its more superficial movements, but not much of them; that thus, by patient observation and use of analogy, we can compile, in merely tabular form, information as to the manner in which it works and is likely to go on working, at any rate for some time to come; but that any attempt to probe the underlying connection is illusory or illegitimate. As a theoretical precept this is admirable. It minimises the danger of our ignoring or forgetting the limitations of human faculty, which can only utilise the imperfect representations that the external world impresses on our senses. On the other hand such a remainder has rarely been required by the master minds of modern science, from Descartes and Newton onwards, whatever their theories may have been. Its danger as a dogma lies in its application. Who is to decide, without risk of error, what is essential fact and what is intellectual scaffolding? To which class does the atomic theory of matter belong? That is, indeed, one of the intangible things which it is suggested may be thrown overboard, in sorting out and classifying our scientific possessions. Is the mental idea or image, which suggests, and alone can suggest, the experiment that adds to our concrete knowledge, less real than the bare phenomenal uniformity which it has revealed? Is it not, perhaps, more real in that the uniformities might not have been there in the absence of the mind to perceive them?

No time is now left for review of the methods of molecular dynamics. Here our knowledge is entirely confined to steady states of the molecular system: it is purely statical. In ordinary statics and the dynamics of undisturbed steady notions, the form of the energy function is the sufficient basis of the whole subject. This method is extended to thermodynamics by making use of the mechanically available energy of Rankine and Kelvin, which is a function of the bodily configuration and chemical constitution and temperature of the system, whose value cannot under any circumstances spontaneously increase, while it will diminish in any operation which is not reversible. In the statics of systems in equilibrium or in steady motion, this method of energy is a particular case of the method of Action; but in its extension to thermal statics it is made to include chemical as well as configurational changes, and a new point appears to arise. Whether we do or do not take it to be possible to trace the application of the principle of Action throughout the process of chemical combination of two molecules, we certainly here postulate that the static case of that principle, which applies to steady systems, can be extended across chemical combinations. The question is suggested whether extension would also be valid to transformations which involve vital processes. This seems to be still considered an open question by the best authorities. If it be decided in the negative a distinction is involved between vital and merely chemical processes.

It is now taken as established that vital activity cannot create energy, at any rate in the long run, which is all that can from the nature of the case be tested. It seems not unreasonable to follow the analogy of chemical actions, and assert that it cannot in the long run increase the mechanical availability of energy—that is, considering the organism as an apparatus for transforming energy without being itself in the long run changed. But we cannot establish a Carnot cycle for a portion of an organism, nor can we do so for a limited period of time; there might be creation of availability accompanied by changes in the organism itself, but compensated by destruction and the inverse changes a long time afterwards. This amounts to asserting that where, as in a vital system or even in a simple molecular combination, we are unable to trace or even assert complete dynamical sequence, exact thermodynamic statements should be mainly confined to the activity of the existing organism as a whole; it may transform inorganic material without change of energy and without gain of availability, although any such statements would be inappropriate and unmeaning as regards the details of the processes that take place inside the organism itself.

In any case it would appear that there is small chance of reducing these questions to direct dynamics; we should rather

¹ Cf. also Hertz on the electro-magnetic equations, § 12, *Wied. Ann.*, 1899. The problem of merely replacing a system of forces by a statical stress is widely indeterminate, and therefore by itself unreal; the actual question is whether any such representation can be co-ordinated with existing dynamics.

regard Carnot's principle, which includes the law of uniformity of temperature and is the basis of the whole theory, as a property of statistical type confined to stable or permanent aggregations of matter. Thus no dynamical proof from molecular considerations could be regarded as valid unless it explicitly restricted the argument to permanent systems; yet the conditions of permanency are unknown except in the simpler cases. The only mode of discussion that is yet possible is the method of dynamical statistics of molecules introduced by Maxwell. Now statistics is a method of arrangement rather than of demonstration. Every statistical argument requires to be verified by comparison with the facts, because it is of the essence of this method to take things as fortuitously distributed except in so far as we know the contrary; and we simply may not know essential facts to the contrary. For example, if the interaction of the æther or other cause produces no influence to the contrary, the presumption would be that the kinetic energy acquired by a molecule is, on the average, equally distributed among its various independent modes of motion, whether vibrational or translational. Assuming this type of distribution to be once established in a gaseous system, the dynamics of Boltzmann and Maxwell show that it must be permanent. But its assumption in the first instance is a result rather of the absence than of the presence of knowledge of the circumstances, and can be accepted only so far as it agrees with the facts; our knowledge of the facts of specific heat shows that it must be restricted to modes of motion that are homologous. In the words of Maxwell, when he first discovered in 1860, to his great surprise, that in a system of colliding rigid atoms the energy would always be equally divided between translatory and rotatory motions, it is only necessary to assume, in order to evade this unwelcome conclusion, that "something essential to the complete statement of the physical theory of molecular encounters must have hitherto escaped us."

Our survey thus tends to the result, that as regards the simple and uniform phenomena which involve activity of finite regions of the universal æther, theoretical physics can lay claim to constructive functions, and can build up a definite scheme; but in the domain of matter the most that it can do is to accept the existence of such permanent molecular systems as present themselves to our notice, and fit together an outline plan of the more general and universal features in their activity. Our well-founded belief in the rationality of natural processes asserts the possibility of this, while admitting that the intimate details of atomic constitution are beyond our scrutiny and provide plenty of room for processes that transcend finite dynamical correlation.

NOTES.

M. FAYE has been elected a Foreign Member of the Reale Accademia dei Lincei of Rome.

DR. OUSTALET has been appointed professor of zoology in the Paris Natural History Museum, in succession to the late Prof. Milne-Edwards.

WE regret to see the announcement of the death of Mr. Henry Sidgwick, late professor of moral philosophy at Cambridge.

SIR JOHN B. LAWES, BART., F.R.S., whose agricultural experiments at Rothamsted are of world-wide renown, died on Friday last, at eighty-six years of age.

THE announcement in *Science* that Prof. J. E. Keeler, director of the Lick Observatory, and the author of many important papers on astrophysics, died in San Francisco on August 12, from the effects of heart disease, will be received by astronomers with much regret. Prof. Keeler was only forty-three years of age.

IT has been officially notified that a death which occurred in hospital at Glasgow on Monday in last week was due to true bubonic plague. The presence of the disease is suspected in several cases of illness under treatment.

THE Committee on Water-tube Boilers in the Navy has now been completed by the selection of Dr. John Inglis, lately

president of the Institution of Engineers and Shipbuilders in Scotland, and vice-president of the Institution of Naval Architects.

THE Melbourne correspondent of the *Times* states that, in compliance with a request of the Royal Geographical Society and other British scientific bodies, Prof. Baldwin Spencer has received leave of absence from the Melbourne University for one year, to enable him to study the customs and beliefs of the natives of the northern portion of South Australia.

THE Berlin Academy of Sciences has made the following grants, in addition to those already announced (p. 394): Dr. Holtermann, Berlin, for a botanical expedition to Ceylon, 4000 marks; Prof. Ludolf Krehl, Greifswald, for experiments on respiration, 1500 marks; Prof. Julius Tafel, Würzburg, for the continuation of his work on electrolysis, 100 marks; Dr. Benno Wandolleck, Dresden, for the investigation of the morphology of diptera, 800 marks.

THE names of one hundred eminent Americans no longer living are to be engraved in the Hall of Fame of the New York University. *Science* states that the following names of men of science have been proposed: John Adams Audubon, Spencer F. Baird, Alexander D. Bache, Nathaniel Bowditch, William Chauvenet, Henry Draper, James P. Espy, Asa Gray, Robert Hare, Joseph Henry, Edward Hitchcock, Isaac Lea, Matthew Fontaine Maury, Marie Mitchell, Benjamin Peirce, David Rittenhouse, Benjamin Silliman, Benjamin Thompson, John Torrey.

THE Marconi Wireless Telegraph Company have contracted to supply the Admiralty with Marconi apparatus for thirty-two ships and stations. The test of efficiency which has to be satisfied is that the instruments shall enable communication to be carried on between a fitted ship in Portsmouth Harbour and a fitted ship at Portland, a distance of about sixty-five miles, with a good deal of land between, including the Dorsetshire Hills, making it about ninety miles by sea. A trial set of the apparatus successfully fulfilled the conditions a few days ago.

THE death is announced of Dr. W. H. Lowe, formerly president of the Royal College of Physicians of Edinburgh. Dr. Lowe held several important positions in Edinburgh, among others those of president of the Royal Medical Society, and vice-president, subsequently president, of the Royal Botanic Society. He was elected a Fellow of the Royal College of Physicians of Edinburgh in 1846, and president of that college in 1873. At the meeting of the British Medical Association in Edinburgh in 1875 he presided over the section of psychology, and delivered the address before that section.

THE eleventh annual general meeting of the members of the Institution of Mining Engineers will be held at Bristol on Tuesday, September 18. Among the papers to be read, or taken as read, are the following:—The geological features of the Somerset and Bristol coal-field, with special reference to the physical geology of the Somersetshire Basin, by Mr. James McMurtrie; methods of working the thin coal-seams of the Bristol and Somerset coal-field, by Mr. George E. J. McMurtrie; the analogy between the gold "cintas" of Columbia and the auriferous gravels of California, by Mr. Edward Gledhill; the theory of the equivalent orifice treated graphically, by Mr. H. W. Halbaum; development and working of minerals in the Leon district, Spain, by Mr. J. A. Jones; and the geological age of the gold-deposits of Victoria, Australia, by Mr. James Stirling.

THE programme of the meeting of the Iron and Steel Institute, to be held in Paris on September 18–21, under the presidency of Sir William Roberts-Austen, has just been issued.

The following are subjects of papers to be brought before the meeting:—The development of the iron and steel industries in France since 1889, by H. Pinget; iron and steel from the point of view of the "phase-doctrine," by Prof. Bakhuis-Roozeboom; iron and steel at the Paris Exhibition, by Prof. H. Bauerman; American methods of testing iron and steel, by Mr. Albert Ladd Colby; rolling-mills, by Mr. Louis Katona; the constitution of slags, by Baron H. von Jüptner; a new method of producing high temperatures, by Mr. Ernest F. Lange; the action of aluminium on the carbon of cast iron, by Messrs. Godfrey Melland and H. W. Waldron; the present position of the solution theory of carburised iron, by Dr. A. Stansfield; iron and phosphorus, with appendixes on (1) eutectics, (2) solid solutions, (3) method of determining free phosphide of iron in iron and steel, and (4) heat-tinting metal sections for microscopic examination, by Mr. J. E. Stead.

WE learn from the *Forres, Elgin and Nairn Gazette* of August 29 that a serious flood, due to the bursting of the Sanquhar reservoir on the morning of August 23, wrought great havoc over the western part of Forres. Since the great Moray floods of 1829, described by Sir Thomas Dick Lauder, the district has not suffered such a disaster. In that year the Findhorn was the main cause of flooding; in the present case injury was done by the breaking down of the embankment which dammed up the waters in a valley on the Sanquhar estate to the east of the Findhorn and a little south of Forres. The dam formed a reservoir of from eight to twelve acres. On Wednesday morning, August 22, the area was only partially covered with water, from eight to ten feet below the level of the overflow. Within twelve hours an inch and a half of rain fell. The reservoir filled rapidly, and by 3 a.m. on Thursday the water was rushing down the overflow, which was only thirty feet wide. Shortly before 5 a.m. the immense breastwork burst outwards from top to bottom in one mass, about twenty feet wide, close to the overflow, and the waters rushed wildly out. Near by an iron bridge with a concrete pier, 30 feet broad and 4 feet thick, were carried away, an ash tree was uprooted, and the waters spread rapidly over the low grounds in a wave that gathered to a height of three or four feet. Sheaves of barley and oats were carried off, wooden outhouses were torn away, stone walls, iron railings, gates and glasshouses were broken down, doors were driven in and a number of villas and cottages were submerged for some time to a depth of from three to five feet. Fortunately no lives were lost.

WITH reference to the inquiry as to the functions of the protruding filaments of the caterpillar of the Puss Moth (p. 385), we have received communications from several correspondents, who all agree with Mr. W. F. Kirby (p. 413) in regarding the appendages as chiefly intended for driving away Ichneumon Flies.

A NOTE in the *Electrician* refers to a curious effect produced by severe thunderstorms upon the glow lamps on the circuits of the Calcutta Electric Supply Co. It appears that immediately following each lightning flash the brightness of the glowing lamps has been observed to increase suddenly, gradually returning to the normal incandescence. This phenomenon has so frequently been observed that the engineers of the company have sought every possible explanation of the curious phenomenon, but have been unable to find any defect in their circuits—which are on the overhead wire system—that might offer an explanation. Indeed, the only conceivable explanation is one which appears so extraordinary that many may find considerable difficulty in accepting it. It is well known that carbon, acting as a coherer in a wireless telegraph apparatus, undergoes the usual sudden decrease in resistance when subjected to electric radiation. It is suggested that the carbon filaments

of a glowing lamp may undergo a similar change when exposed to the influence of a tropical thunderstorm in its immediate vicinity. This sudden decrease in the resistance of the filament would, of course, produce a correspondingly rapid increase in its candle-power, after which the gradual self-decoherence of the carbon would account for the return of the lamp to its normal incandescence.

WE have received an interesting account of the climate of Norway, by Mr. A. S. Steen, being a reprint from the Official Publication for the Paris Exhibition, 1900. As that country stretches through more than 13 degrees of latitude and extends nearly 300 miles beyond the Arctic Circle, the most varied shades of continental and maritime climates are represented within its confines. Mr. Steen has divided the country into south-east, west and north sections, this being in fact in accordance with nature's own division. In the inland districts of south-east Norway and Finmark we have examples of the most typical inland climate, viz. severe winter and relatively high temperature maxima in summer, and small rainfall; while along the whole length of coast-line the winter is unusually mild, the summer cool, and rain falls in abundance. The influence of the Gulf Stream can be traced all over the country, and it is one of the chief agencies to which Norway owes its condition as a civilised inhabited State to its farthest bounds on the shores of the Polar Sea. The following are quoted as some of the highest summer temperatures: in the south-east 86° and upwards, and 93° at Christiania (once only); on the south coast no higher temperature than 80°·5 has ever been recorded. In the west, temperatures of 88°·5, and once 93° at Vossevangen, have been recorded. In the northern section temperatures of 85° to 88° have been recorded, but in the most southern of the Lofoten Isles (in the middle of the ocean) the thermometer has never risen above 68°.

A PAPER, by Mr. A. E. Sunderland, on applications of electrochemistry in dye and print works, is published in the *Society of Arts Journal* (August 24). The requirements which should be fulfilled by a machine for electrical dyeing are considered to be as follows:—(1) The poles must not be of metal, but of carbon or biscuit porcelain, which conduct by becoming saturated with the electrolyte. (2) They must be as near to one another as possible. (3) The cloth must pass between the poles in the open width. (4) The poles may be perfectly smooth, and preferably cylindrical, revolving freely. These particulars are necessary, because in the ordinary passage of the electric current across any dye solution, the tendency of the dye is to concentrate itself around the negative pole, and not to circulate freely in the whole dye vessel; there is thus always a great danger of unevenness. In the finishing of goods the peculiar effect which is produced by calendering a piece in two different directions, one impression upon another, is well known. This is technically termed water-marking or moire, and is due to the irregular reflection from the surface of the material, one part of the light being totally reflected, and the other part dispersed. The effect can be introduced in several ways, one of which depends upon electricity. This process, Mr. Sunderland remarks, resolves itself practically into the local application of electrolysis. A platinum plate of suitable size is connected with the positive pole of the source of current. On this conducting surface is placed some absorbent material saturated with a solution of common salt. On this pad is placed the fabric to be water-marked, and the plate engraved with the water-mark connected with the negative terminal is pressed down upon it. The salt solution is decomposed, and a facsimile of the water-mark is printed on the cloth. To produce opaque designs, the absorbent material is saturated with a solution of barium chloride, which is decomposed on passing the current.

IN the *Atti dei Lincei*, ix. 2, Dr. A. Campetti describes experiments made with common salt and copper sulphate tending to prove that there exists a difference of potential between a solid salt and its unsaturated solution, this difference of potential being of the same order of magnitude and sign as the difference of potential between a more concentrated and a less concentrated solution of the same salt.

THE question as to whether evaporation from the surface of an electrified liquid produces a loss of electricity is one of considerable interest in connection with theories of atmospheric electricity. An investigation of this point is given by Signori A. Pochettino and A. Sella in the *Atti dei Lincei*, ix. 1. The method employed was to examine the rate at which an electrified plate lost its charge under the varying conditions when its surface was dry or was covered with a layer of water, and when it was exposed to a current of dry air or air saturated with watery vapour. The results tabulated show that the loss is more rapid in dry air than in saturated air, that with saturated air the presence or absence of the layer of water makes no practical difference, but that with dry air the discharge is actually slightly less rapid when the plate is wet than when it is dry. It is inferred that evaporation does not produce loss of charge, that the difference between dry air and saturated air is due to the fact that the dry air was ionised, while all trace of ionisation had been removed from the saturated air, and that the greater insulation obtained with dry air by wetting the plate was due to the ionisation being partially removed by the evaporation from the plate.

IN a paper published in the *Proceedings* of the Cambridge Philosophical Society, Mr. Barrett-Hamilton suggests that the (pathological) changes of colour and form which occur in certain Salmonoids during the breeding season may afford a clue to the origin of secondary sexual characters in animals in general. "Once," writes the author, "the existence of such a primitive state of things characterised by growth or discoloration of the whole or part of the body is admitted, we have therein the starting-point whence natural selection by alteration, suppression or accentuation of the details might easily produce many or all the nuptial changes of animals as we now see them, evolving in each a structure suitable to its own particular need, whether in eye, as in the Eel, in snout, as in the Salmon, or in hind-limb, as in Lepidosiren.

Indian Museum Notes (vol. v. No. 1) contains an interesting paper, by Mr. E. E. Green, on Indian Scale-insects (Coccidæ), showing the great increase which has recently taken place in our knowledge of their various groups. So late as 1886 only seven Indian representatives of the family were recorded, the well-known Wax-insect (*Ceroplastes ceriferus*) being one. Now thirty-seven species, distributed among fourteen genera, are known from Continental India, although this represents only a very small proportion of the real number. Not only are these insects interesting from their structure and their beauty of form and colour, but some are of commercial importance. The remainder of the number treats of various insect pests, notably those infesting tea and coffee plants, and those destructive to cereals and crops.

THE distribution of the Ruff in Ireland forms the subject of an interesting paper, by Mr. C. L. Patten, in the *Irish Naturalist* for August.

THE July number of the *Agricultural Gazette* of New South Wales maintains the usual high and useful character of this journal, an article on the important part played by bacteria in soil being of especial interest to the scientific agriculturist.

FROM the Indian Museum we have received "Illustrations of the Shallow-Water Ophiuroidea collected by the *Investigator*," by Dr. K. Koehler, published by the trustees. The specimens described are figured in eight plates.

TO the last issue of the *Journal* of the Asiatic Society of Bengal for 1899, Mr. F. Finn contributes a paper on Indian Weaver Finches (Ploceidæ), in the course of which he shows how a supposed new species has been named on a specimen of a well-known bird in its summer plumage.

MALACOLOGISTS will find much to interest them in the sheets of the *Proceedings* of the Philadelphia Academy last to hand, Mr. H. A. Pilsbry communicating four papers dealing respectively with the land snails of Japan, South America, Australia and Polynesia, and India.

Science Gossip for September contains an interesting article, by Mr. R. J. Hughes, on the colouring of shells, in which he demonstrates that the most common pigment among those of northern Europe is the sesquioxide of iron. Another paper in the same number forms the continuation of "Geological Notes in the Orange River Colony," by Major Skinner, R.A.M.G.

IN the July number of the *American Naturalist*, Prof. H. L. Osborn describes a remarkable Axolotl from Dakota, which appears different from any named form, and may indicate a new type. In the course of his paper the author raises the question whether we yet know the adult of the true Mexican Axolotl, the specimens that have developed into Salamanders being from the United States and perhaps specifically distinct.

WE have received three fascicules of the "Results of the Branner-Agassiz Expedition to Brazil," in course of publication in the *Proceedings* of the Washington Academy. Two of these, written by ladies, are devoted to Crustacea, while the third, by Mr. C. H. Gilbert, deals with the fishes. When ladies appear as authors of papers, it is much to be desired that they should prefix "Mrs." or "Miss" to their names, as it is otherwise often difficult to ascertain their proper titles.

MENTION in these columns has already been made of Mr. G. S. Miller's work on Old World mammals, and we have now received a paper, communicated by that naturalist to the *Proceedings* of the Washington Academy of Sciences (vol. ii. pp. 203-246), in which he describes a very large number of new species, mainly Rodents, collected by Dr. W. L. Abbott on islands in the North China Sea. Many of these are rats and mice.

THE publication of Prof. E. Morselli's free course of lectures on man from an evolutionary point of view is still proceeding, and the fascicules when bound together will form an interesting volume on physical anthropology, or, as the author terms it, *Antropologia générale*. The last number to hand (No. 45) concludes the section on the brain, and commences an account of the progenitors of man.

THERE is always something of interest in our well illustrated contemporary, *The Reliquary and Illustrated Archaeologist*. The July number contains some architectural notes from Monmouthshire, by Mr. J. Russell Larkby, illustrated by numerous sketches, and a short paper, by Mr. R. E. Head, on lace bobbins; these are often decorated in various ways, and different parts of the country furnish local types.

THOSE who are interested in criminal anthropology will find in a recent number of the *Bulletin de la Société d'Anthropologie de Paris* (Tome x. 4^e série, p. 453) a psycho-physiological, medico-legal, and anatomical study of an atrocious criminal named Vacher, by MM. J.-V. Laborde, Manouvrier, Papillaut and Gellé. It is strange that studies of this kind are never made in this country. It is quite time that physical anthropology and psychology were more directly recognised by persons interested in criminology.

SIR ARCHIBALD GEIKIE'S "Outlines of Field Geology" (Macmillan) has been the counsellor and friend of many young geologists and intelligent observers of the earth's features. A

new edition—containing numerous alterations and additions, while retaining the original form—has just been published, and it should be possessed by every lover of country rambles or teacher of earth-knowledge.

A BULKY volume, containing "Agricultural Statistics of British India for the years 1894-95 to 1898-99," has just been distributed by the Department of Revenue and Agriculture of the Government of India. The tables show (1) total average, classification of areas, irrigation, fallow land, area under crops, and stock; (2) prices of produce; (3) incidence of the land revenue on area and population; (4) varieties of tenure held direct from Government; (5) register of transfers of landed property; and (6) yields of principal crops.

THE additions to the Zoological Society's Gardens during the past week include a Green Monkey (*Cercopithecus callitrichus*, ♂) from West Africa, presented by Mr. C. A. Gilbert; two Boschboks (*Tragelaphus sylvaticus*) from South Africa, presented by Dr. A. MacCarthy Morrourh; a Rufous-necked Wallaby (*Macropus ruficollis*) from New South Wales, presented by Miss Seymour; a Germain's Peacock Pheasant (*Polyplectron germaini*) from Cochín China, presented by Mr. Arthur Yates; a Common Boa (*Boa constrictor*) from South America, presented by Mr. G. R. Fairbanks; two Red-bellied Squirrels (*Sciurus variegatus*) from South America, a Yellow-fronted Amazon (*Chrysotis ochrocephala*) from Guiana, ten Roofed Terrapins (*Kachuga tectum*) from India, deposited; (4) a Wapiti Deer (*Cervus canadensis*), two Collared Fruit Bats (*Cynonycteris collaris*), born in the Gardens; two White Ibises (*Endocimus albus*), bred in the Gardens.

OUR ASTRONOMICAL COLUMN.

EPHEMERIS FOR OBSERVATIONS OF EROS.—In the last issue of the *Astronomische Nachrichten* (Bd. 153, No. 3660), Signor E. Millosevich gives a revised ephemeris of this asteroid for the next few weeks:—

Ephemeris for 12h. Berlin Mean Time.

1900.	R.A.	Decl.
	h. m. s.	° ' "
Sept. 6 ...	2 27 24.16	+ 35 29 53.7
7 ...	28 28.18	35 52 13.0
8 ...	29 30.73	36 14 36.1
9 ...	30 31.77	36 37 2.8
10 ...	31 31.22	36 59 33.0
11 ...	32 29.03	37 22 6.8
12 ...	33 25.13	37 44 43.9
13 ...	2 34 19.43	+ 38 7 24.2

COMET SWIFT (1894 IV).—Mr. F. H. Seares has calculated the osculating elements, and from them computed a finding ephemeris for this comet, which may possibly have some connection with the lost comet of De Vico. As it is important, however, that the comet should again be observed before any further attempt is made to establish such connection, he hopes that all possessing the necessary optical power will prosecute the search for it (*Astronomische Nachrichten*, Bd. 153, No. 3656).

Osculating Elements.

Epoch and Osculation 1900 July 23^o Berlin Mean Time.

$$\begin{aligned} M &= 317^{\circ} 16' 15'' \\ \pi &= 348^{\circ} 56' 56'' \\ \Omega &= 24^{\circ} 50' 38'' \\ i &= 3^{\circ} 35' 17'' \\ \phi &= 31^{\circ} 2' 30'' \\ \mu &= 554'' \cdot 3823 \end{aligned} \quad 1900^{\circ}$$

Ephemeris for Berlin Mean Midnight.

1900.	R.A.	Decl.
	h. m. s.	° ' "
Sept. 9 ...	16 27 21	- 25 21.9
13 ...	32 57	25 30.5
17 ...	38 55	25 39.1
21 ...	45 15	25 47.5
25 ...	51 56	25 55.6
29 ...	16 58 57	- 26 3.1

THE NEW SPECTROGRAPHS FOR THE POTSDAM GREAT REFRACTOR.—In the *Astrophysical Journal*, vol. xi. pp. 393-399, Prof. H. C. Vogel describes the two new spectrographs which have recently been completed for the great Potsdam refractor of 80 cm. aperture.

(a) *Three-prism spectrograph*.—This is designed so that the combined deviations of the three prisms shall be nearly 180°, thus bringing the collimator and camera almost parallel. These are then mounted on a massive steel plate 78 cm. long, 41 cm. broad, and 7 mm. thick, which in its turn is firmly attached to the tail-piece of the telescope by an elliptical base plate 10 mm. thick, lateral flexure being guarded against by several intermediate metal ribs. The slit has only one movable jaw, and the whole can be rotated round the telescope axis, and the position angle recorded to 1' of arc. For comparison spectra the arc light has been found most convenient, the difficulty of spectral displacement of comparison lines due to imperfect adjustment of source having been overcome by interposing a translucent diffusing screen between the light and slit. The collimator lens (Steinheil) has an aperture of 3.2 cm.; focal length, 48 cm. One of the camera objectives is a Zeiss anastigmat of 56 cm. focus; the other a triple cemented lens by Steinheil of 4.1 cm. aperture; focus, 41 cm. The prisms are of very white Jena glass, and with the Zeiss camera lens a spectrum of uniform focus from b to K is obtained. Delicate arrangements have been made for securing constant temperature conditions, &c. The weight of the complete spectrograph is 31 kilog.

(b) *Single-prism spectrograph*.—In this instrument the collimator lens is 3.5 cm. aperture, focus 53 cm.; the camera lens, 4 cm. aperture, focus 72 cm., both being triple cemented objectives by Steinheil. The prism is by Zeiss, and has a refracting angle of 60°, with faces 61 mm. long and 45 mm. high. The spectrum is uniformly sharp from D to N. The whole instrument weighs 20 kilograms.

Prof. Vogel gives the results of the application of tests instituted by Prof. W. W. Campbell for the Mills' spectrograph of the Lick Observatory, showing that the performance of both instruments is very trustworthy. Three plates are given showing the instruments in position as attached to the telescope.

STRUCTURE AND CONSTITUTION OF TWO NEW METEORITES.—Messrs. G. P. Merrill and H. N. Stokes recently communicated a paper to the Washington Academy of Sciences (*Proceedings*, vol. ii. pp. 41-68, July 1900), describing the results of their examination of two fragments of newly-fallen meteorites. One, a stony meteorite, fell on July 10, 1899, in Allegan, Michigan, U.S.A., the largest fragment weighing 62½ lbs. To the unaided eye this stone shows on the broken surface a quite even granular structure of grey colour, and, on closer examination, numerous beautifully spherulitic chondrules, averaging not more than one or two millimetres in diameter. In some cases these chondrules have pitted surfaces. More critical inspection indicates that they are composed of enstatite and olivine. Numerous brilliant metallic points of a silver-white colour indicate the presence of disseminated iron, so that the stone may be said to be made up of the chondrules, iron and dark grey silicate minerals, imbedded in a light ashy grey matrix. This Allegan stone is exceedingly friable. Microscopically, the ground mass of the stone is seen to be made up of a confused agglomerate of olivine and enstatite particles with interspersed metallic iron, iron sulphide and chromic iron. An important feature is that in no cases do the silicates occur with perfect crystallographic outlines, both olivine and enstatite being fragmental. The presence of alumina and alkalis suggested a search for feldspar, but it was decided that this mineral was not present. A considerable proportion of the ground mass was found microscopically to be composed of a black glassy material. Careful chemical analysis showed that 77 per cent. of the meteorite was of non-metallic origin, the remainder being chiefly iron and nickel. The second meteorite examined is known as the Mart Iron, having been found early in 1898 near Mart, in Texas. This originally weighed 15½ lbs., from which a slice weighing 456 grams was presented to the National Museum at Washington. The etched surface shows the iron to belong to the octahedral variety, and is of moderately coarse crystallisation. Chemical analysis showed that 98.3 per cent. of the meteorite was composed of the metals iron, nickel, copper, cobalt, the remainder being made up of schreibersite and a small quantity of troilite.

Photographs of both meteorites in their present condition are given, and numerous drawings indicating the microscopical structure.

LATITUDE-VARIATION, EARTH-MAGNETISM AND SOLAR ACTIVITY.

IN the *Astronomische Nachrichten* (No. 3619) I have published the results of an investigation dealing with the effects of periodic changes in solar activity on the motion of our planet. It is there shown that these changes, as indicated by the frequency of sun-spots, exert a subtle but pregnant influence on the secular variations of the earth's elements; and, moreover, that disturbances precisely similar to those which appear in the observations of the obliquity and of the sun's longitude are distinctly exhibited in the variation of terrestrial latitude.

In the further pursuit of these researches I have been led to

magnetic strain in iron rods, it seems reasonable to believe that something similar to the molecular displacement in the rod may take place in a magnetic body like our earth with respect to its magnetic axis. As has long been known, this axis is by no means coincident with the earth's axis of figure, but is inclined to it, according to Gauss, at an angle of about 12° . It is therefore not unnatural to conclude that a molecular strain in the direction of the magnetic axis will occasion an asymmetric change of the earth's figure, and will thereby produce a displacement of the axis of figure relative to the instantaneous axis of rotation. Such a displacement could remain constant only so long as the total magnetic potential of the earth was not subject to alteration, in which case the pole of rotation would describe a circle of constant radius round the pole of figure as centre. But, as already stated, various facts compel us to believe that the magnetic potential of the earth does alter, and, indeed, changes synchronously with the state of solar activity—the most striking instance being the regular increase of aurora and of magnetic disturbances with the increasing frequency of sun-spots. Now, if we consider aurora as discharges of the earth's electric force, it follows that the strain in the direction of the magnetic axis should abate after an auroral display, and the pole of figure should therefore approach the pole of instantaneous rotation.

The outcome of this hypothesis would be that changes in the state of solar activity, since they produce a measurable effect on the terrestrial magnetic forces, should also be accompanied by corresponding changes in the motion of the earth's axis. In *A.N.* 3649 I have endeavoured to test this theory by such facts as have up to the present been discovered regarding the complex phenomenon of latitude-variation, and I shall here briefly describe the results there obtained.

In the first place, from the material afforded by the investigations of Loomis and Fritz, and from observations made in Scotland during the past thirty years, I constructed curves exhibiting the frequency of auroral displays from 1812 to 1899. (Fig. 1, curves A and C.) In these the influence of the eleven-years solar period is most conspicuous, but there is also exhibited an intimate connection with the "great" cycle of sun-spots. In contrast with the spot-curve, minima of aurora are found to be of unequal heights. Accordingly, if a second curve $ss's'$ be drawn through the aurora-curve A in such a way as to bisect as nearly as possible every wave appearing in it, this new curve will be seen to attain its maxima and minima simultaneously with the "great" spot period. It is therefore beyond dispute, as already proved by Wolf and Fritz, that the existence of this "great" period of solar activity is an established fact, and that it is clearly brought out by the curve of aurora.

In the next place, curves were formed to show the variations in the frequency of terrestrial magnetic disturbances. For this

purpose I took the annual number of days on which such disturbances were observed at Greenwich, as recorded by Mr. Ellis in *Monthly Notices* 60, December 1899. (Fig. 1, curve B₁.)

Mr. Ellis subdivides his records according to the intensity of the disturbance, but only three of his subdivisions were taken into account; those, namely, showing the frequency of moderate, active, and great disturbances respectively. For the satisfactory combination of these different sets, the principle was adopted that the weight assigned to each set should be inversely proportional to the mean frequency—unit weight being given to the "active" disturbances—on the ground that the small frequency of "great" disturbances is probably compensated for by

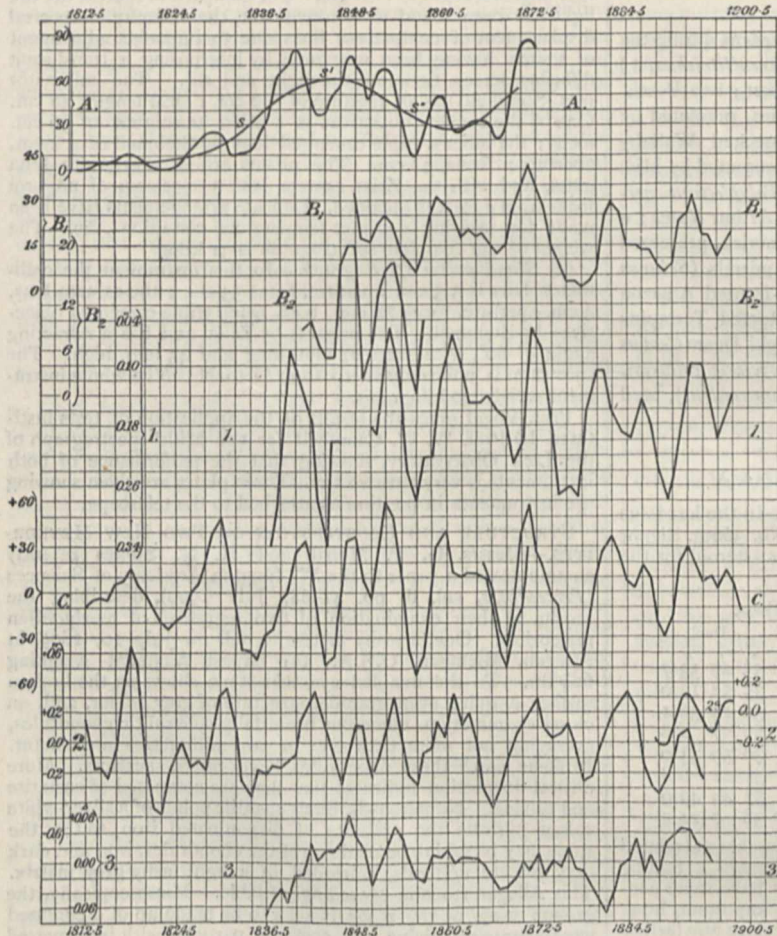


Fig. 1. (from *Ast. Nach.* 3649)
 A, frequency of aurora (Loomis); B₁, frequency of magnetic disturbances at Greenwich (Ellis); B₂, frequency of magnetic disturbances at Greenwich (Airy); C, frequency of aurora (Europe, south of Arctic Circle) from 1812-1871 (Fritz), and in Scotland from 1865-1899. The "great" period has been eliminated in both curves in order to exhibit more clearly the eleven-years' fluctuations. 1, semi-amplitudes of latitude-variation (Chandler, Nyren and Albrecht); 2, residuals of obliquity (Fig. C in *A.N.* 3619); 3, Greenwich corrections to the R.A. of stars derived from observations of the sun (Thackeray).

conclude that the anomalies existing in the observations of the sun's right-ascensions and declinations are to be attributed exclusively to changes in the position of the earth's axis of rotation with regard to the axis of maximum moment of inertia, and that these changes in their turn are intimately connected with the varying display of forces on the solar surface. In a subsequent article which appeared in *NATURE* (No. 1584, March 8) I made a suggestion as to the nature of this connection, and advanced the hypothesis that the magnetism of the earth is probably the medium through which the changes of solar energy react upon the motion of the earth's pole.

In view of the results of Joule's experiments regarding

their much more energetic character. In order to extend the record as far back as possible, a similar curve (Fig. 1, B₂) was constructed, based on Airy's statistics from 1841-1857 (*Trans. Roy. Soc.*, vol. cliii.).

These magnetic curves are in perfect harmony with those of the auroræ, and both sets bring out a remarkable and, for our purpose, eminently important fact, namely, that although for the most part they correspond closely with the eleven-years spot period, there nevertheless appear waves which at first sight seem to have nothing to do with the display of solar activity. Most noticeable in this respect are the maxima of 1852 and 1864, of which the former especially seems almost to contradict the existence of a connection between sun-spots and auroræ. A closer examination of the spot-curves, however, reveals the fact that in these two instances there occurred, at exactly the same times, peculiar disturbances or irregularities in the exhibition of spots on the solar surface, so that, after all, the waves exhibited at these points in the magnetic and auroral curves may be supposed to have been caused by solar influence, although they appear for some reason or other on a greatly exaggerated scale. This is decidedly the opinion of Prof. Fritz and of Mr. Ellis, both of whom expressly mention instances of this character, the latest having occurred in 1898 following the spot-maximum of 1894.

The succeeding part of this research may be conveniently divided into two parts. In the first, the earth-magnetic variations are compared and contrasted, in relation to the eleven-years period of sun-spots, with certain phenomena associated more or less directly with latitude-variation; and in the second with similar phenomena relative to the "great" sun-spot and aurora period.

These phenomena are:—

I. With regard to the eleven-years period—

- i. The semi-amplitudes of latitude-variation.
- ii. The periods of latitude-variation.
- iii. The changes in the values of the obliquity as observed at Greenwich from 1812-1896.
- iv. Mr. Thackeray's corrections to the right-ascensions of stars derived from observations of the sun during the years 1836-1895.

II. With regard to the "great" period—

- v. Dr. Chandler's long period inequality in the latitude-variation.
- vi. The observed residuals of the obliquity from 1753-1896 as compared with Leverrier's tabular values.
- vii. The Greenwich corrections to the sun's right-ascensions relative to a fundamental system of fixed stars, according to Prof. Newcomb.

The data requisite for the formation of the curve of semi-amplitudes (Fig. 1, curve 1) was taken from Dr. Chandler's paper in *A.J.* No. 277, and from the publications of Dr. Nyrén (*A.N.* 3166), Mr. Wanach (*A.N.* 3112) and Prof. Albrecht ("Berichte über den Stand der Erforschung der Breitenvariation"). It has to be borne in mind, as pointed out in my previous papers, that the latitude phenomenon lags behind the comparison magnetic curves by about 15 years. Such a lag appears indeed to be a characteristic feature common to most terrestrial phenomena which have hitherto been found to be influenced by solar activity. In this connection I must refer to the highly important and interesting discovery made by Sir Norman Lockyer some years ago, that the curve representing the frequency of the "unknown" lines widened in sun-spot spectra during a cycle of solar activity follows the spot-curve by exactly the same interval, viz. 15 years. I have received a

communication from Sir Norman, stating that this curve of "unknown" lines goes excellently with my curve 1 of Fig. 1. the maxima and minima of the spectroscopic curves showing a perfect synchronism with those of the curve of latitude-variation. I take this opportunity of expressing my indebtedness to Sir Norman Lockyer for drawing my attention to this most significant and singular fact.

The lag in the case of curve 1 has been allowed for by shifting this curve one and a half years in the backward direction. When it has thus been made to coincide with the comparison curves, their correspondence becomes most striking—a remarkable feature being the exactness with which certain secondary maxima in 1865, 1887 and 1898 are represented in each case.

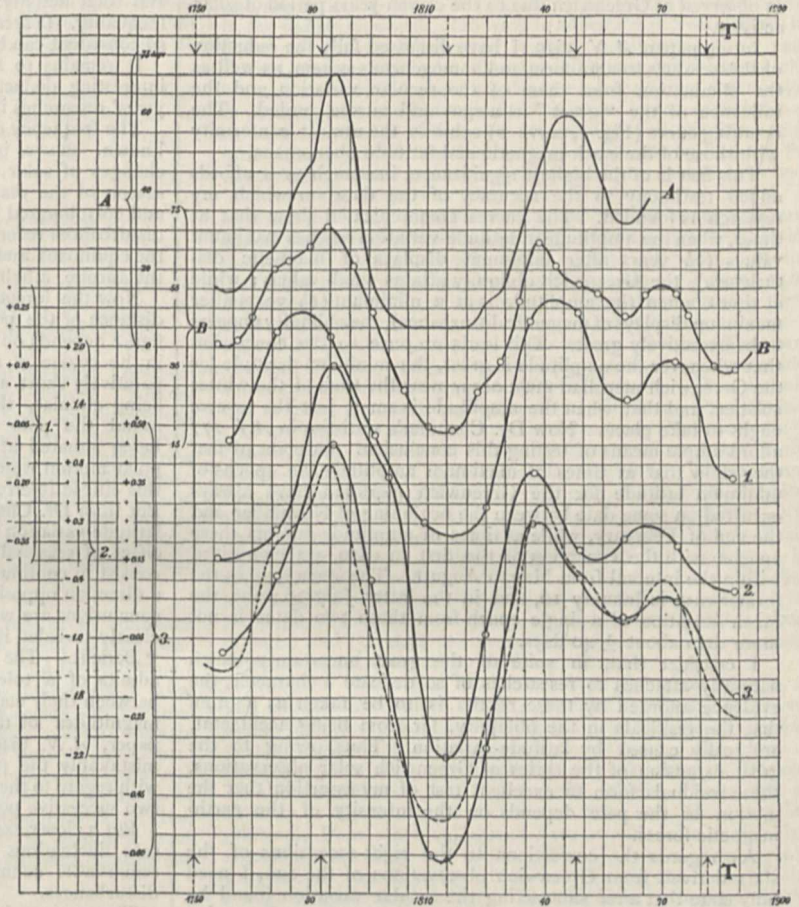


Fig. II.
(From *Ast. Nach.*
3649.)

T, turning points of Dr. Chandler's long period inequality of latitude-variation; A, great period of auroræ (Loomis). (The ordinates represent eleven-years' means of Loomis' annual aurora-numbers.) B, great period of sun-spots (Wolf); 1, twelve-years' means of residuals of obliquity (Greenwich observations) after elimination of purely secular change; 2, twelve-years' means of corrections to the sun's R. A. relative to a system of fixed stars (Greenwich observations) after elimination of purely secular change; 3, combined curve of obliquity and sun's R.A., the dotted curve representing Wolf's great period of sun-spots on a somewhat different scale.

Indeed, so accurately are the motions of the amplitude-curve shadowed in those of the magnetic variations, that to any unprejudiced astronomer this fact in itself must indicate with sufficient force the existence of a *vera causa*.

The periods of latitude-variation afford a new and almost as certain proof of the existence of an intimate connection between the polar motion and earth-magnetic phenomena.

Dr. Chandler has already shown that a small amplitude corresponds to a great period and *vice versa* (*A.J.* 277, p. 98). How well this influence is borne out may be seen from the following analysis of the average values of r according to the lengths of the period:—

Period in days.	Observed ϵ .	Computed ϵ .
Under 390	0.20	0.20
390-420	0.18	0.19
420-450	0.15	0.13
Over 450	0.10	0.08

This statement in itself constitutes a proof of my assertion, and renders it unnecessary for me to add anything further on this point. Any one who cares to plot down the values for the periods given by Dr. Chandler must arrive at the conclusion that the comparison of the curve so obtained, with the magnetic and auroral curves, gives indeed a convincing argument in favour of the earth-magnetic hypothesis.

I have next to consider the changes in the values of the obliquity as observed at Greenwich due to the eleven-years period of solar activity.

In my paper, *A.N.* 3619, I have discussed fully the reduction of these values to a uniform and homogeneous system, as well as the elimination from them of the secular variation and the influence of the "great" sun-spot and aurora period. The resulting curve (Fig. 1, curve 2) exhibits the utmost conformity with those of the earth-magnetic and latitude phenomena.

This fact is of the highest significance, inasmuch as it affords added testimony to the accuracy of the data on which my research is founded. The curves communicated show that at times, when the amplitude of latitude-variation reaches maximum values ($1\frac{1}{2}$ years after minimum displays of magnetic disturbance), the Greenwich obliquity attains small values; while at times, when the amplitude is at a minimum ($1\frac{1}{2}$ years after maximum displays of magnetic disturbance), the obliquity appears to be excessively great. This leads at once to the conclusion that whenever the amplitude is great, the minimum latitude for the Greenwich meridian must occur near the time of the winter solstice, and that when the amplitude is small just the reverse ought to take place. Now Dr. Chandler's statistics in *A.J.* 277 afford ample means of testing this conclusion. In point of fact they show that at times of maximum amplitude the epochs of minimum latitude for the Greenwich meridian have always occurred on some date between the beginning of November and the end of February, while at times of amplitude-minima these epochs, with the exception of the first in 1840, are comprised within the interval from May to August. The mean date in the former case is January 10, and in the latter July 16; and the mean deviation of a single epoch from these two dates is not more than about ± 40 days.

I consider that, in spite of the great uncertainty which naturally attaches to researches of so delicate a character, the evidence afforded by these results is to be taken as a proof that the residuals in the obliquity, far from being accidental, are really caused by latitude-variation. Thus, owing to the great extension of the series of Greenwich solar observations, these residuals form an excellent test of my assertion that the motion of the pole depends on the intensity of the earth-magnetic forces.

As regards the corrections to the right-ascensions of the stars derived from Greenwich observations of the sun, I need only state that after subtracting the secular variation found by Mr. Thackeray (*M.N.* June 1896), the resulting values give curve 3 of Fig. 1, which, in spite of somewhat large accidental discrepancies, is in general agreement with all the others, especially with that of the obliquity.

Having thus shown that my contention with regard to a connection between the eleven-years period of auroral displays and magnetic disturbances and the motion of the earth's pole of rotation appears to be borne out by all the facts which constitute the sum of our present knowledge of the peculiar phenomena relating to latitude-variation, I next consider the "great" period of auroræ, which, as already stated, is synchronous with the great period of solar activity.

For this purpose I exhibit in Fig. 2 curves showing the great aurora-period according to Loomis' annual numbers, and the great spot-period in Wolf's relative numbers.

The interval comprised by this great period is according to Wolf equal to six small cycles, *i.e.* sixty-six years. Now this is exactly the period of Dr. Chandler's long inequality of latitude-variation. The smallest amplitudes and greatest periods of latitude-variation, according to Chandler's formula, fell in 1782 and 1848, almost exactly at the times of greatest auroral displays; whereas the greatest amplitudes and smallest periods

occurred in 1815 and 1881, *i.e.* just at the times when the display of auroræ reached a minimum.

But in addition to this there are other facts which point to an influence on the earth's motion exercised by some force varying with the great period of solar activity. In my previous papers I have discussed at some length the evidence afforded by the curves representing the observed residuals of the obliquity, and Prof. Newcomb's corrections to the right-ascension of the sun relative to a fundamental system of fixed stars. I therefore need not here dwell upon their importance as strongly supporting my hypothesis.

A reference to curves 1, 2 and 3 of Fig. 2 will show how exquisitely parallel are their courses, and how complete is their agreement, not only with the changes in the displays of auroræ and solar activity, but also with Dr. Chandler's long period inequality. It seems utterly inconceivable that a correspondence so consistent can be attributed merely to accident.

It remains to state briefly one or two very important and interesting deductions made from the results of the last ten years' researches into the phenomena of latitude-variation.

The frequency of auroræ and magnetic disturbances, as is well known, shows, in addition to the variations associated with changes of solar activity, other fluctuations depending on the season of the year—a fact which has been closely investigated and corroborated by Mr. Ellis. It appears that the magnetic disturbances recorded at Greenwich reveal decided maxima at the equinoxes and minima at the solstices, thus betraying, like the auroræ, a half-yearly period.

Now the foregoing results point to the conclusion that the distance of the pole of instantaneous rotation from the pole of figure depends on the display of earth-magnetic forces. Hence in the course of a year this distance must become twice comparatively short and twice comparatively long; *i.e.* instead of being circular, the path described by the pole of rotation round the pole of figure must be elliptical—the mean pole being situated at the centre of the ellipse. If the period of polar motion were exactly one year, the position of the axes of this ellipse referred to a fixed meridian would remain unaltered. But from Dr. Chandler's investigations we know the period of latitude-variation to be on the average 428 days. Hence the effect of seasonal change in the earth-magnetic forces must consist in continuously rotating the axes of the polar ellipse in a direction opposite to that of the motion of the pole. These conclusions are well corroborated by the observed facts, and are clearly revealed in the plate appended to Prof. Albrecht's latest "Bericht." The comparatively great eccentricity of the ellipses admits of a tolerably accurate determination of the angles between their major axes and the Greenwich meridian. If the magnitudes of these angles be computed (Table vi. of my paper, *A.N.* 3649), it will be found that they exhibit quite unmistakably the progressive change of position of the ellipse with regard to the meridian, the average angular distance between two successive positions of the major axes being about 33° .

But a closer examination of these figures shows that they indicate fluctuations in this average amount which stand in a remarkable connection with the varying display of magnetic disturbances.

The motion of the ellipse appears to have been largely progressive in 1892, 1894 and 1898; while it has been very slight, and at times even retrograde, in 1890, 1893 and 1896. In the first-mentioned years the ellipses are also more irregular and distorted than in the others, indicating a more vehement and spontaneous character of the forces acting on the motion of the pole. Now, according to Mr. Ellis, these years were the *only ones* in which magnetic disturbances of the character "great" occurred at Greenwich, while in the last-named years his statistics show that there prevailed a decided magnetic calm. While leaving the final confirmation of this interesting fact to future observations, it does not seem too much to say that in the face of existing evidence it is difficult to retain the idea that a coincidence so peculiar can possibly be ascribed to mere accident.

The results of my researches may be thus shortly summarised:—

- i. The changes in the motion of the pole of rotation round the pole of figure are in an intimate connection with the variations of the earth-magnetic forces.
- ii. Inasmuch as the latter phenomena are in a close relation with the state of solar activity, the motion of the pole is also

indirectly dependent on the dynamical changes taking place at the sun's surface.

iii. The distance between the instantaneous and mean poles decreases with increasing intensity of earth-magnetic disturbance.

iv. The length of the period of latitude-variation increases with increasing intensity of earth-magnetic disturbance.

v. In strict analogy with the phenomena of auroræ and of magnetic disturbance, the influence of the eleven-years period of sun-spots, as well as of the "great" period, is clearly exhibited in the phenomenon of latitude-variation; and the same deviations from the solar curve as are manifested by the auroræ are also evident in the motion of the pole.

vi. The half-yearly period of the earth-magnetic phenomena influences the motion of the pole of rotation in such a way that its path, instead of being circular, assumes the form of an ellipse, having the mean pole at its centre.

vii. The half-yearly period also explains the conspicuous fact of a rotation of the axes of the ellipse in a direction opposite to that of the motion of the pole.

J. HALM.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

PROF. J. G. MACGREGOR, of Dalhousie University, Halifax, Nova Scotia, has been appointed professor of physics in University College, Liverpool, in succession to Prof. Lodge.

THE Calendar of the Glasgow and West of Scotland Technical College, for the session 1900-1901, has been received. Among the contents of the volume we are glad to notice schemes of courses of study, extending over three years, for students who intend to take up some branch of applied science or engineering as a profession. Students are permitted to attend single classes, but they are encouraged to follow one of the regular courses in the several departments of study. This is the only way to derive any real advantage from a Technical College, desultory attendance at classes without any definite object being of little value.

AT a special meeting of the University Court of St. Andrews, held on Saturday last, the proposal of the Marquis of Bute, who offered a sum of 20,000*l.* to be held as a fund for endowing a chair of anatomy in the University, was considered. After deliberation, the Court resolved cordially to accept the proposed gift on the conditions as stipulated by his lordship, and to request the Lord Rector to inform Lord Bute of the Court's decision. The Court further resolved to proceed at once with the creation of a professorship of anatomy at St. Andrews, to be endowed by Lord Bute's gift, the first presentation to the chair being Dr. Musgrove, the present lecturer in anatomy, such presentation to be made as soon as the ordinance creating the chair is approved by her Majesty in Council.

THE mission of science in education was recently considered in some detail by Prof. J. M. Coulter in an address delivered at the University of Michigan, and published in *Science*. The claims set forth in the paper are formulated as follows:—The introduction of science among the subjects used in education has revolutionised the methods of teaching, and all subjects have felt the impulse of a new life; it has developed the scientific spirit, which prompts to investigation, which demands that belief shall rest upon a foundation of adequate demonstration, which recognises that the sphere of influence surrounding facts may be speedily traversed and that everything beyond is as uncertain as if there were no facts; it has introduced a training peculiar to itself, in that it teaches the attitude of self-elimination, an attitude necessary in order to reach ultimate truth, and thus supplements and steadies the other half of life, which is to appreciate. To obtain these results, there must be teachers who can teach, whose background and source of supply is the investigator. Moreover, the results are immensely desirable, inasmuch as they do not interfere with anything that is fine and uplifting in the old education, but simply mean that the possibilities of high attainment and high usefulness are open to a far greater number.

MESSRS. S. Z. DE FERRANTI, the electrical engineers at Hollinwood, near Oldham, have just adopted an educational scheme for their apprentices. Success at evening classes, combined with steady work, are to be the chief recommendations for promotion from one department to another. And the apprentice who obtains the highest position in the South Kensington Examinations in subjects of importance to the theoretical training of an engineer will be awarded a scholarship tenable in the day engineering department of the Manchester Municipal Technical School. His fees will be paid by Messrs. Ferranti, and also the wages he would receive if working in their shops. Mr. F. Brocklehurst takes this generous scheme as the text of a pamphlet upon "Technical Education," issued by the Technical Instruction Committee of Manchester, and he hangs upon it some instructive remarks as to the responsibilities of manufacturers and the nation at large, if England is to maintain her position in the industrial world. Referring to education in Switzerland, he points out that at Winterthur, a small engineering town near Zurich, the technical school is attended by 400 day students who have voluntarily left their employment (sacrificing their wages in so doing) for one or two sessions in order to devote themselves to technical study. The town, the canton and the State combine to assist the realisation of their ambitions by bearing the burden of cost, and in keeping the fees of the technical school low. In the same way the great Polytechnic of Zurich is crowded in its day department with hundreds of young men preparing themselves for the engineering, electrical and chemical industries. Germany provides many similar examples. In the Technical High School of Darmstadt there are to be found 1100 day students, all of them over eighteen years of age, many of them graduates of universities, and the remainder having received a splendid high-class education in secondary schools. These are engaged in the study of electrical, chemical or mechanical science directly bearing upon industrial pursuits. This is only one of many technical high schools in Germany, the culmination of which is seen in the Charlottenberg Technical High School, near Berlin—the finest institution of its kind in the world—with its more than 2000 day students. These young men are being prepared for the highest positions, as technical chemists, mechanical, naval, civil and railway engineers, ship-builders and architects. There are now in the German Technical High Schools no fewer than 11,000 day students. In connection with the figures given it must be noted that (1) they are exclusive of science students taking university courses; (2) the pupils are without exception youths of over eighteen years of age; and (3) each technical high school insists upon an entrance examination of an exacting character.

The great advance of the United States in engineering is, as Mr. Brocklehurst remarks in his pamphlet referred to above, largely due to the fact that during the last forty years very important engineering schools have been founded. The chief of these is the Massachusetts Institute of Technology at Boston. This is attended by 1171 day students, whose average age at entrance is eighteen years and nine months, and who are either graduates from other colleges or have attended the public high schools for at least four years. The Worcester Engineering Polytechnic has 823 day students. Nearly 1000 are in the Lehigh Engineering College. The Stevens Institute of Technology, New Jersey, has 214; and the Case School of Applied Science in Cleveland, Ohio, 218. Five hundred and ninety-seven day students attend the classes of the Sheffield Scientific School in Connecticut, while the Sibley College of Engineering—part of Cornell University, New York—has 492 day students. There are 242 day students in the Engineering Department of the University of Michigan. A recent report shows that in the Engineering Colleges of the United States the number of day-students enrolled is 9659, and that their growth since 1878 is 516 per cent. ! Fifty-one per cent. of these students have had a three-year high school course, which would bring them to seventeen years of age. The number of engineering students graduated in 1899 was 1413, and the number of institutions providing an education in this branch of technical instruction (engineering) is 89. This is exclusive of evening work altogether. It is also exclusive of what America is doing in the fields of chemistry and textiles. Little wonder is it that this wealth of educational opportunity is producing its crop of skilled craftsmen trained to compete on more than equal terms with the Briton. The Manchester Technical Institution Committee is doing a service to the nation by placing these facts prominently before the manufacturers of the district.

SOCIETIES AND ACADEMIES.

PARIS.

Academy of Sciences, August 27.—M. Faye in the chair.—On Egyptian gold, by M. Berthelot. Analyses of specimens of gold of different epochs show that at the time of the sixth and twelfth Egyptian dynasties the art of separating the silver from native gold was not known. Some gold leaf of the Persian epoch was pure, the silver having been separated. As, however, there is a period of about twelve centuries between the dates of the last two specimens analysed, specimens of intermediate dates must be examined if the date of this metallurgical discovery is to be fixed.—Observations of the comet 1900 *b* (Borelly-Brooks) made with the large equatorial of the Observatory of Bordeaux, by MM. G. Rayet and A. Férand. The nucleus of the comet on July 31 was of about the 9th or 10th magnitude, the head having a diameter of 3' to 4' of arc.—The apparent semi-diameter of the sun and its position relative to the moon, deduced from the eclipse of May 28, by MM. Ch. André and Ph. Lagrula. The final result for the apparent semi-diameter of the sun is given as $15' 59'' 24 \pm 0'' 30$.—On an anomaly of the dichotomous phase of the planet Venus, by M. E. Antoniadi. The edge of the planet is always more brilliant than the central regions; thence irradiation ought to produce the prolongations actually observed. The phenomenon would thus appear to be of purely physiological origin.—Dielectric cohesion and explosive fields, by M. E. Bouty. The term explosive field is applied to the minimum strength of field between two nearly plane electrodes required to produce sparking. The curves relating to critical fields, as described in a preceding note, show many analogies with those of explosive fields. Thus both the critical and explosive fields are linear functions of the pressure of the gas, and the constants for the gases hydrogen, air and carbonic acid are arranged in the same order of magnitude.—On the composition of the combinations obtained with fuchsine and the sulphonated azo-colouring matters, by M. Seyewetz.—On lighting by the cold physiological light called living light, by M. Raphael Dubois. By the growth of certain micro-organisms in suitable media, details of which are given, a room may be illuminated with an intensity about equal to moonlight.—Action of the total pressure upon the assimilation by chlorophyll, by M. Jean Friedel. Although the influence of the partial pressure of the carbon dioxide in the atmosphere upon chlorophyll assimilation has been well investigated, the effect of changing the total pressure of the air has not yet been examined. It was found that the lowering of the total pressure, even to $\frac{1}{2}$ atmosphere, does not modify the nature of the chlorophyll assimilation, but that its intensity diminishes in a regular manner with the pressure. Four species of plants were used, and the numbers obtained for the variations were of the same order in all of them.—On the ancient extent of the glaciers in the region discovered by the Belgian Antarctic Expedition, by M. Henryk Arctowski.

CAPE TOWN.

South African Philosophical Society, August 1.—L. Péringuey, President, in the chair.—The secretary read a second report on the mud island which appeared off Pelican Point at the beginning of June, from Mr. Cleverly, R.M., Walfish Bay, and showed the photographs taken by Mr. Waldron, Public Works Department. Mr. Cleverly reported that the island no longer existed on June 7, it having then entirely subsided, as, on steaming over the site, soundings of six and seven fathoms were obtained. The sea was much discoloured, and a distinct odour of sulphur was still to be distinguished. Small quantities of dead fish were found on Pelican Point, but this is a not unusual occurrence. About the time of the island's appearance heavy rollers set in along the coast, and though these did not affect Walfish Bay, thirty yards of the new breakwater at Swakop Mouth were totally destroyed, a derrick carried away, and two men drowned. Though these rollers are usually experienced on this coast in the winter months, Mr. Cleverly understands that the engineer in charge at Swakop Mouth had set up a theory that the damage to his works resulted from an earthquake wave, and that he pointed to the appearance of the mud island at Walfish Bay in support of his theory, but in Mr. Cleverly's opinion the cause of the upheaval must have been extremely local as no disturbance whatsoever was felt at the settlement or in the confined waters of Walfish Bay. Mr. Waldron, on the invitation of the president, gave an account of

his visits to the island. It was visited on June 1, 2 and 4. At the next visit, on June 7, there was no island. On June 1 one member of the party landed and noticed a small basin-shaped hollow containing water and emitting gas bubbles. The odour was distinctly that of sulphuretted hydrogen. Dr. Corstophine agreed with Dr. Marloth as to there being no need for volcanic activity to explain the phenomenon; nor was there any evidence of such. He compared the appearance of the island at Walfish Bay with the "mud lumps" known to arise in the Gulf of Mexico, and quoted Sir Charles Lyell's account of these. The Walfish Bay island was evidently a quite similar phenomenon. As to the gas, the Gulf of Mexico "mud lumps" usually gave off marsh-gas, and the sulphuretted hydrogen perceived as being emitted at Walfish Bay, was probably due to the decomposition of animal as against plant material. The fine mud from Walfish Bay, under the microscope, was found to contain diatoms, fish scales, bones, and other remnants of animal matter.—Notes on stone implements of paleolithic type found at Stellenbosch and the vicinity, by L. Péringuey and G. S. Corstophine. The discovery of stone implements of a particularly ancient type at Bosman's Crossing, Paarl and Malmesbury, was described. From the rude character of the chipped stones, Mr. Péringuey was disposed to regard them as being equal in age to the paleolithic implements of Europe, but Dr. Corstophine had shown him the difficulty of accepting this theory owing to the geological deposits in or on which the stones are found. So far no implements have been found in any deposit that can be regarded as of great antiquity. In the Stellenbosch district the implements are found imbedded either in the rain-wash of weathered granite or in the laterite, or simply on the surface, so that no geological evidence has yet been discovered as to the presumable antiquity of the implements. One feature of this occurrence, which Dr. Corstophine pointed out, is that as yet no implements have been found on the recent alluvial terraces of the Eerste River, but only on the hill slopes round about. The implements are formed from water-worn boulders of Table Mountain Sandstone, and often retain a considerable portion of the water-worn surface.

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