

THURSDAY, SEPTEMBER 18, 1902.

PROF. LORENTZ ON THE SCOPE OF
PHYSICS.

Sichtbare und Unsichtbare Bewegungen. Vorträge gehalten von H. A. Lorentz. German Translation by G. Siebert. Pp. 123. (Brunswick: Vieweg und Sohn, 1902.) Price Mk. 3.

THESE lectures, published under the title of "Motions Visible and Invisible," were delivered at Leyden last year to what would, perhaps, be called in this country a philosophical society. The object was to present to a general audience an outline of the picture of the external world which modern physics is constructing within its own province, without going so far into detail as to lose the general outlook in the interests or difficulties of special departments of knowledge. The keynote of the book, as the title implies, is that all physical explanation rests ultimately on dynamics; and accordingly the first three out of seven lectures are devoted to an exposition of the gist of the dynamics of rectilinear, curved and vibratory motions. Not much originality is to be expected in such well-worn topics, but the freshness of some of the illustrations reveals the calibre of the author. Such, for instance, is the estimation, from Hertz's analytical theory, of the intensity of the pressures set up in the ordinary impact of small balls; when a ball of 800 grammes falls on another such from a height of 12 cm., the total pressure between them mounts up to the order of 600 kilogrammes. The results developed are applied to a brief review of the cardinal phenomena of sound and light, and to the explanation of gaseous pressure and temperature on the kinetic theory. Of personal interest is the remark, on the basis of Michelson's having found that the breadth of a spectral line of a gas approaches a definite limit as the gas is rarefied, that, according to the writer's belief, we have here as direct evidence for the motion of the gas-molecules as spectral displacements give for the motions of the heavenly bodies. We naturally turn to the sixth lecture, on electrical phenomena, in the elucidation of which the author occupies so prominent a position. At the very beginning, the conception is introduced that the ultimate atoms of matter involve positive and negative electrons, which interact through the connection between them that is afforded by the æther, and thus originate all electric phenomena. In the terms of this theory, the main electric phenomena are described, including such as cathode rays, though not much attempt is made to indicate the links of the chain of deduction that bind together the various departments of electrodynamics; finally, a rather more detailed sketch of the significance of the Zeeman effect is given. Thus one is led to see how it comes about that it is now a main effort of physicists to ascribe to these electrons a function in many types of phenomena, and to realise that there is much evidence for the view that they form a very prominent element in the constitution of matter. So far as is known, they are the sole links between ponderable matter and the æther. On them, too, a hope entertained by many is largely based, that gravitation and molecular forces will also turn out to be processes in that medium. The last lecture is an

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exposition of the principle of energy. The writer expresses his opinion that nothing short of careful experimental investigation can assure us of the impossibility of the *perpetuum mobile*, which forms the foundation of the doctrine of energy. The ramifications of that principle are illustrated from the action of a dynamo. The principle thus forms a clue that connects the most varied phenomena, even when we are ignorant of the mechanisms which produce them; we find it an unfailing guide in tracing relations, with a certainty to which no electron-theory or other special theory can pretend. But it is of limited scope; the independence *e.g.* of gaseous viscosity and density, or the effect of motion on spectra, can only be elucidated by penetrating beneath the surface of things and resolving the phenomena into their elements.

To some people, the other side of the question above referred to as to the nature of the negation of the *perpetuum mobile* will doubtless appeal more strongly. A fundamental principle in nature of simple and universal type can hardly be based exclusively on the empirical ground of experimental verification; indeed, this very principle is constantly being applied without any hesitation to considerations so delicate as to be beyond the reach of present experimental confirmation except as regards their remote results. Not the least interesting and promising topic in abstract physical science is the origin and scope of the great natural laws which transcend all distinctions between different kinds of material, and form the frame into which the science is gradually built.

The sketch here given will show that Prof. Lorentz's little book forms a welcome addition to the expositions, popular yet exact, which we possess of the current progress of physical science, even in this country which produces more than its share of such concrete and illustrative presentations; all the more so as the trend of scientific method abroad now seems to seek greater security in the purely abstract exposition of relations, between entities which appear only as pure unknowns by means of mathematical symbols, from the fear that any full-bodied analogy traced between them and other things better known may, by reason of its limitations, encourage views that may ultimately prove false.

J. L.

CELTIC MYTHOLOGY.

Cuchulain of Muirthemne: the Story of the Men of the Red Branch of Ulster. Arranged and put into English by Lady Gregory. With a Preface by W. B. Yeats. Pp. xvii + 360. (London: John Murray, 1902.) Price 6s.

EVEN before the appearance of this attractive volume the general reader had no valid excuse for not knowing something of the story of Cuchulain and the other heroes of Ulster; henceforward he will be still more inexcusable if he persists in ignorance. No one who cares at all for early literatures can fail to enjoy this version of these old Irish tales, so unique of their kind and so full of varied interest. The serious student, no doubt, will prefer to go direct to the originals, or to close translations like those collected in Miss Hull's "Cuchullin Saga"; but Lady Gregory's work is so different in aim from Miss Hull's that there is ample room for both. She

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has been chiefly attracted to the tales by their literary merits, and has sought with no little success to make these the prominent feature in her renderings. This at times involves the omission of details that are not without interest, but, after all, there is enough left to give a fair impression of what can be learned from the old literature of Ireland. This mass of legend, for the most part taking its final form about the twelfth century, but demonstrably far older in origin, is, in fact, a perfect mine of primitive custom and belief, and as such is full of interest for the anthropologist. Where the ordinary reader will only see something fanciful or unintelligible, the specialist will often discern an interesting survival or a striking parallel, even if it is hard at times to draw the line between Irish tradition and Irish imagination.

The peculiar character of these tales is due to a double tendency in Irish literature. On the one hand there is an exuberant imagination which recklessly transcends all limits of time and space; on the other there is a love of minute detail which constantly brings in the smallest features of everyday life and work. To the latter tendency we owe the minute descriptions of the appearance and dress of the heroes, of their horses and chariots, their arms and modes of fighting, their palaces and forts, and so on. It is a kind of Homeric life and culture that meets us here, yet with a greater admixture of primitive types, civilisation and barbarism being strangely intermingled. Nor does the Homeric Olympus lack its counterpart, for behind the real world of mortal heroes lies the realm of the Sidhe and the Tuatha De Danann, constantly reminiscent of the old Celtic mythology which Christianity has displaced. With a real and an imaginary world to move between, there is nothing that the Irish story teller will not dare to say; nothing is either too mean or too marvellous for him. Man and animal are interchangeable beings. Cuchulain himself is a reincarnation of Lugh (one of the old gods), who takes the shape of an insect and is swallowed by the sister of Conchubar. Curí makes his fort whirl round like a millstone all night, so that no one can enter it after sunset. The bridge in Scotland which Cuchulain has to cross can alter its own shape and size at pleasure. Conchubar's shield moans when he is in danger, "and all the shields of Ulster would moan in answer to it." Wells and streams have a faculty of bursting out and overflowing whole tracts of country, and it is out of two lakes that Cuchulain gets his famous pair of horses, the Grey and the Black. Charms and spells are as potent as in Africa, and satire may be so deadly as to kill its victim. Fingian the physician "could tell what a person's sickness was by looking at the smoke of the house he was in." It is three champions of the Sidhe who have to be killed three times before they are done with; but even mortal heroes have an almost feline tenacity of life. It is well for them that this is so, for their chief happiness consists in fighting; in cases of single combat the chariot-driver usually looks on and encourages his master, or goads him on to do his best by means of bitter taunts. Feats of strength and skill are naturally common, but some of those mentioned are not easy to understand. Still stranger are the distortions of Cuchulain when in a rage, for which Lady Gregory has substituted the very euphemistic statement that he assumed the appearance of a god;

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the direct opposite would not overstate the case. Contention and jealousy are rampant among the heroes, and each unblushingly sounds his own praises and states his claims to the "Champion's Portion," which after all is only a certain quantity of food and drink. Yet the spirit of chivalry is not wanting, and an adventurous quest is greatly to their minds. But while they are ready to face most dangers without shrinking, the power of *geasa* or taboo lies heavy on them. Before Conaire meets his death, he has succeeded in doing everything which he ought not to have done. Historically these *geasa* are known from the "Book of Rights," and form a curious study. Of great interest, too, is the periodic weakness of the men of Ulster, which has been the subject of much discussion among scholars.

As to the central figures in the cycle, Conchubar and Cuchulain, many difficult problems present themselves. It is possible that they take the place of older mythological personages, especially as Conchubar is actually called a god in one text and Cuchulain is the representative of Lugh. Those who are interested in this feature of early Irish literature may be referred to Prof. Rhys's Hibbert lectures, where the solar explanation of Celtic myths receives full consideration, and to Mr. Nutt's study of the "Celtic Doctrine of Rebirth" in "The Voyage of Bran." It is precisely because these Irish tales can provide materials for serious works of this kind that their perusal will be found, not only interesting, but profitable; and this new version of the Cuchulain cycle may do good service in spreading a knowledge of Celtic legend outside the small circle of scholars who have made it a subject of special study.

OUR BOOK SHELF.

Flora Arctica. Part i. By C. H. Ostenfeld. Pp. xi + 136. (Copenhagen: Det Nordiske Forlag, 1902.)

THE records of plants collected in the Arctic regions are for the most part scattered through numerous papers and written in various languages. At the request of Prof. Warming, Mr. O. Gelert in 1898 undertook to work up, revise and combine the accumulated data, basing his investigations on the collections belonging to the Copenhagen Museum. The work promised to be so extensive that he requested Mr. C. H. Ostenfeld to cooperate with him. This cooperation was cut short in 1899 by Mr. Gelert's premature death, and since that time Mr. Ostenfeld has continued the work alone. The limits of the Arctic territory as here interpreted coincide fairly nearly with the limits of the wood-boundary. This has its anomalies, for, as shown by the map provided, all Greenland is included almost to the 60th parallel, while Iceland in longitude 65° N. and Norway which extends higher than the 70th parallel are excluded. This the first volume contains the Pteridophyta, Gymnospermæ and Monocotyledons. The Pteridophytes are very few in number, the large group of Filices being limited to ten species. The Gymnosperms included are but three, this being the result of the boundary adopted. Amongst the Monocotyledons the most extensive orders are the Gramineæ, with twenty-four genera and sixty-one species, and the Cyperaceæ, including six genera, of which *Carex*, the most important, is subdivided into fifty-four species. In dealing with this genus the author has had the benefit of Mr. C. B. Clarke's valuable assistance. The Gramineæ were undertaken by Mr. Gelert, and the arrangement given is that left by him. The larger proportion of the illustrations refer to the Carices;

the figures of the general appearance are good, but the sketches of details, as, for instance, the utricles, are too small to help much in determination of species. They would be more satisfactory if they were drawn natural size or larger. The book is written in English.

An Arithmetic for Schools. By J. P. Kirkman, M.A., and A. E. Field, M.A. Pp. lxxvi + 492. (London: Edward Arnold, n.d.) Price 3s. 6d.

The distinguishing characteristics of this book are simplicity and great clearness of exposition. The first two chapters deal mainly with our terrible English system of weights and measures, and in this lawless region no skill on the part of an author can be of service to the beginner. Once this tangled wilderness is passed, however, the skill of the authors in exposition comes into play. The treatment of common measures and multiples and the various rules for ascertaining rapidly whether a given number is or is not divisible by specified numbers are very clearly and successfully explained. The philosophy of the rules for the division and multiplication of vulgar fractions is very plainly set forth, and the rules for the contracted multiplication and division of decimals are well explained and illustrated near the end of the book. We have also an account of the metric system, followed by numerous examples of "practice." After this we have the calculation of areas and volumes, and an adequate exposition of the method of extracting square and cube roots. This is followed by the treatment of interest, stocks, and the various branches of the subject which are found in all arithmetical treatises, and then comes an enormous collection of examples. An appendix explaining and illustrating the use of squared paper for the comparison of scales and other kinds of calculation forms a useful and interesting conclusion.

The work is one which can be very confidently recommended to all teachers and students of arithmetic.

A First Step in Arithmetic. By J. G. Bradshaw, B.A. Pp. vi + 166. (London: Macmillan and Co., Ltd., 1902.) Price 2s.

ONLY the first four rules, simple and compound, are covered by this book, but the exercises upon them have been so carefully selected and arranged that children who receive instruction through them will acquire an intelligent and working knowledge of simple arithmetic. The exercises are arranged for both oral and paper work, and there is no doubt that the combination of the two methods of teaching the subject gives the best educational result. In most text-books of arithmetic, the pupils are discouraged at the outset by exercises and problems beyond their comprehension, but Mr. Bradshaw deals with amounts which beginners will have no difficulty in grasping and will work out successfully. An essay containing hints on methods of presenting the early rules of arithmetic, which occupies the first twenty-nine pages, contains some notes of service to inexperienced teachers of children; but they are out of place in a pupil's book, and belong rather to a volume on the practice of teaching.

The Real Origin of Religion. By Jabelon. Pp. 48. (London: Simpkin, Marshall and Co., Ltd., 1902.)

THE object of this pamphlet is to establish the not very novel or fortunate hypothesis of the phallic origin of all religious symbolism. The proofs offered are of three kinds, none of which possesses any real cogency. Certain savage tribes attach great importance to circumcision and other mutilations of the sexual organs, the reason for which is unknown. Therefore, the author argues, all primitive ceremonialism must be of sexual significance. This conclusion is supported by a number of etymologies, all unscientific and demonstrably false, and by an obscurely worded attempt to interpret the vision of Ezekiel as an account of the anatomical structure of the brain. The scientific value of the farrago is precisely *nil*.

LETTERS TO THE EDITOR.

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Re Vegetable Electricity.

I AM reluctantly obliged to traverse a statement made by Prof. J. C. Bose (in the *Journal* of the Linnean Society of July 21, p. 304, footnote) to the effect that "Dr. Waller has subsequently been able to confirm the results which he (Dr. W.) heard me describe on the occasions referred to (Royal Institution, May 10, 1901; Royal Society, June 6, 1901).

I am compelled to state that Prof. Bose, previously to these dates, visited my laboratory on several occasions, received every facility that I was able to afford him as regards the methods by which I was and am investigating the physiological properties of animal and vegetable protoplasm, and *inter alia* heard from me, and has doubtless forgotten, the statement that the electrical response of plants is a general property of vegetable protoplasm, and not confined to such plants (dionæa, mimosa, &c.) as exhibit obvious movements.

Prof. Bose obtained (with my full approval) from my laboratory-mechanic the principal instruments used by me in such investigations, has imitated some of my experiments, and has gradually adopted their guiding theory. He is not entitled to make the statement quoted above.

AUGUSTUS D. WALLER.

P.S.—In connection with this subject of vegetable electricity I may take this opportunity of commenting upon two series of observations that have been made in Germany in contradiction of some of my principal conclusions.

Prof. Adami, of Hof, quotes from the German translation of 1899 of my "Lectures on Animal Electricity," published in 1898, the following passage:—"Verbindet man zwei Punkte A und B der unverletzten Kartoffel mit dem Galvanometer, so lässt sich kein merklicher Strom nachweisen; sobald aber die Kartoffel an einem Punkte B durch einen Messerschnitt verletzt wird, schlägt der Lichtfleck nach rechts aus, infolge der chemischen Thätigkeit und elektromotorischen Kraft, die durch den Schnitt erregt worden sind. Man beachte, dass dieser Versuch, im strengsten Sinne des Wortes, eine Vivisektion ist. Für unseren Zweck muss die Kartoffel lebendig sein. Die Wirkung bleibt vollständig aus, wenn die Kartoffel durch kochen getötet worden ist."¹

He then proceeds to give an account of a considerable number of experiments contradictory of the above statement. Prof. Adami, of Hof, did not use unpolarisable electrodes, but copper pins. It is not surprising that he should have failed to observe any signs of vegetable electricity.

Dr. Arthur Tompa, working in the Botanical and Physiological Institutes of the University of Halle, under the direction of Prof. Bernstein and Prof. Klebs, and with the advantage of the knowledge and experience of Dr. Tschermak, quotes on p. 100² the ten headings of my communication at the Turin Congress on Vegetable Electricity, and quite correctly selects for reinvestigation as being the general and most important topic, paragraph 5, "The Electrical Response as a Measure of 'Vitality.'" He devotes much time and care to this reinvestigation, and somewhat reluctantly comes to the conclusion that Waller's blaze reaction is a fallacy arising from the fact that Waller has followed erroneously the direction of current. He devotes a diagram and a page of description, p. 104,³ to his hypothesis in explanation of this imaginary blunder. I do not think that I have mistaken the direction of current, or that Dr. Tompa could have supposed that I was liable to do this if he had been at the pains to look at any of the diagrams in any of the papers of mine that he quotes.

Dr. Tompa should also have noticed in any of these papers that I have always spoken of excitation by induction currents and by condenser discharges. He has used the direct current of one or more Daniell cells. I have never done this for the reason that such currents give predominant polarisation counter-currents on living and on dead tissues alike. The blaze

¹ Sonderabdruck aus dem ii. Bericht des nordoberfränkischen Vereins für Natur-Geschichts- und Landeskunde.

² A. Tompa, Beiträge zur Pflanzlichen Elektrizität ("Botanisch-Beihften," original arbeiten).

³ Idem *Ibid*.

reaction, whether unequivocal (homodrome) or equivocal (anti-drome) requires short strong currents for its manifestation. I have therefore always used induction shocks and condenser discharges, as stated even in the extremely brief Turin abstract quoted by Dr. Tompa.

I shall be surprised if Dr. Tompa does not repeat the experiments, and from the courteous tone of his account of the matter I think it probable that he will withdraw his stricture on my work when he has witnessed for himself the clear and indubitable results of the experiments.

Can Carbon Dioxide be "Vitalised"?

THERE has long been present in my mind an idea to which I have hitherto hardly dared give expression. The query forming the above heading amounts to the raising of the question whether the carbon dioxide which is exhaled as a product of animal or vegetable vital processes differs in any way from the carbon dioxide of "inorganic" origin formed, let us say, from carbon by combustion in oxygen. The answer will probably be in the negative, since, on theoretical (stereochemical) grounds, an asymmetric structure is not possible in the case of this molecule. Nevertheless, it might be worth while to cross-examine nature on this point. It is, in fact, possible that the experiment may have been already tried with negative results, and that is why I venture into print, since I have been unable to find any record. Two ways occur to me for submitting the question to the test of experiment. Calling the carbon dioxide from the two sources "inorganic" and "organic" respectively for the sake of brevity, the "organic" gas might be obtained either from the brewer's vat or from a carbonate formed from the carbon dioxide of animal respiration. The rate of absorption of this gas might be carefully compared with the rate of absorption of a specimen of "inorganic" gas by a growing plant. This is a method which appeals to vegetable physiologists. The other method, which is more purely chemical, depends upon our being able to obtain some optically active compound sufficiently basic to absorb carbon dioxide. I cannot call to mind any such compound at the present moment, and from where I am writing I have no access to the usual sources of information. Given, however, an optically active base capable of forming a carbonate, would the gases from the two sources be absorbed at equal rates? Perhaps some of your readers may be able to dispose of these queries offhand.

R. MELDOLA.

Easton Park Cottage, Dunmow, September 13.

Effect of a Lightning Flash.

DURING the storm on Wednesday, September 10, a house opposite my rooms in Fulham was struck by lightning at 4.40 p.m. Curiously enough, at the moment of the occurrence I was looking at the exact spot, and it may be of interest to record what occurred. A stack of brickwork about ten feet high capped with two red-pot chimneys about three feet high was struck, and a hole was made in the slates of the roof on the south side of the stack. One chimney was shattered. The flash was extremely brilliant and left a perfectly straight line of light on the retina; the length of the flash appeared to be twenty feet, but its upper part was lost in the diffused daylight. The flash was of several seconds' duration and was followed by a thin column of smoke; both these facts are due in my opinion to the fusion of the soot in the chimney. The flash itself was a mere line, otherwise the appearance of the whole strongly reminded me of a cordite discharge from a big gun. There was a loud report, and the circumstances left little doubt in my mind that the electrical discharge was upwards in direction.

C. DAVIES SHERBORN.

Bipedal Locomotion of a Ceylonese Lizard.

I HAVE frequently observed with interest the erect attitude assumed by the small Agamid lizard *Otocryptis bivittata*, Wieg., when running rapidly, and have long suspected that the short front legs were not used at such times. But the rapidity with which the animal runs, and the nature of the ground which it usually frequents, have prevented very close observation. I have, however, recently fully satisfied myself that its action is truly bipedal. The lizard happens to be common in the Botanic Gardens here, and on several occasions one of them has crossed a smooth sanded road immediately in

front of me. I have thus been able to see clearly that the anterior limbs are carried quite free from the ground, progress being effected solely by the long hind limbs.

It seems possible that the closely allied and similarly built lizard *Sitana ponticeriana*, Cuv., may have the same habit. Does the Indian species of *Otocryptis* (*O. beddomii*) progress in the same fashion?

At present the habit has been recorded only of one or more Australian lizards, notably the "frilled lizard" (*Chlamydosaurus kingi*), which has been very cleverly photographed in the erect attitude by Mr. Saville Kent.

E. ERNEST GREEN.

Peradeniya, Ceylon, August.

A Series Related to Bernoulli's Numbers.

THE following seems to be a useful and interesting series :-

$$\frac{r}{r+1} = \frac{D_1}{r+1} + \frac{D_2}{2} + \frac{rD_3}{3} + \frac{r(r-1)D_4}{4} + \dots + \frac{r(r-1) \dots (r-\rho+3)D_\rho}{\rho} + \dots + \frac{r(r-1)D_{r-2}}{4} + \frac{rD_{r-1}}{3} + \frac{D_r}{2}$$

where

$$\begin{aligned} D_r &= 1; \\ D_{r-1} &= \frac{1}{2} = 3B_1; \\ D_{r-3} &= -\frac{1}{6} = 5B_2; \\ D_{r-5} &= \frac{1}{8} = 7B_3; \text{ \&c.}, \end{aligned}$$

and generally for all odd values of $\rho > 1$,

$$D_{r-\rho} = - \left\{ (-1)^{\frac{\rho+1}{2}} \right\} (\rho+2) B_{\frac{\rho+1}{2}}$$

B_1, B_2, \dots being the numbers of Bernoulli.

Also

$$D_{r-2} = D_{r-4} = D_{r-6} = \dots = 0.$$

I have been trying since last year, without success, to ascertain whether this is a known series previously published. If it is, perhaps some of your readers will be good enough to supply a reference.

J. R. SUTTON.

Kenilworth, Kimberley, August 7.

FREDERICK AUGUSTUS ABEL.

THE death of Sir Frederick Abel on Saturday, September 6, at the age of seventy-five, removes a conspicuous figure from the world of science and technology and brings to a close a long and useful public career. For some years he had been in failing health, but his sudden death, which came painlessly from cardiac failure following one of those attacks of shivering and rigor to which he had long been subject, was quite unexpected.

Frederick Augustus Abel was born in 1827, being the son of Mr. J. L. Abel, of Woolwich. The family, which appears to have been of Swedish origin, had already produced men notable in science, music and painting. Abel has given in the Hofmann memorial lecture, which he delivered to the Chemical Society in 1893, an amusing account of his unsuccessful attempts in the early 'forties to learn chemistry at the Polytechnic Institution of those days; and these recollections perhaps impelled him in the efforts he subsequently made to improve the quality of technical education in this country. In 1845, he entered the Royal College of Chemistry as one of Hofmann's first pupils, and was soon promoted to be an assistant, which he remained until 1851, when he was appointed professor of chemistry at the Royal Military Academy at Woolwich, succeeding Faraday in this position. In 1854, he became chemist to the War Office, a post which he held until 1888, when he retired under the regulations of the Civil Service. It was during this period of thirty-four years that he made his

most important contributions to chemistry in its applications to explosives and to metallurgy. Foremost among these are his researches into the preparation and uses of gun-cotton as an explosive, which were summarised in a paper printed in the *Philosophical Transactions* of 1866 and in the Bakerian lecture which appeared in the *Philosophical Transactions* of the following year. Gun-cotton was already known at that time, but it was generally regarded, at any rate in this country, as a dangerous and probably inefficient substitute for gun-powder. Abel showed, as the result of a long series of carefully chosen and elaborate experiments, how the material may be safely prepared of constant composition, how it should be stored, and also indicated its value as an explosive agent. These papers are eminently characteristic of the practical bent of Abel's mind. Though interested in the progress of pure science, his own inclinations were in the direction of its applications. With the exception of a few of his early papers, written whilst he was Hofmann's assistant, nearly all his contributions have been to the applications of chemical science, and have been made with the express purpose of solving practical problems.

In connection with his other work on explosives, the researches, carried on in conjunction with Sir Andrew Noble, on the chemical changes resulting from firing gunpowder under various conditions and those on the detonation of explosives may be specially mentioned. In 1888, Abel was appointed chairman of the Government Committee on Explosives, and as a result of a series of experiments conducted under its auspices, the smokeless explosive known as "cordite," containing both gun-cotton and nitroglycerine, was patented by Abel and Dewar, and became the standard explosive of this country.

The influence of composition on the properties of steel and its analysis and the testing of petroleum also engaged his attention. The apparatus known by his name which he devised in connection with the Petroleum Acts of 1868 and 1879 for determining the temperature at which petroleum gives off inflammable vapour is still in general use, and he became a recognised authority on petroleum and its employment as an illuminating agent.

As a member of the Royal Commission on Accidents in Mines, he investigated the cause of the explosion at the Seaham Colliery in 1881, and its connection with the presence of coal dust in the air.

No account of Abel's career can be complete without some reference to what he regarded as the most important work of his life. From the first he took a leading and responsible part in the movement which led to the foundation of the Imperial Institute. He was the secretary to the first organising committee, and in a lecture delivered at the Royal Institution in 1887 he gave an account of the work which the Institute proposed to accomplish. It is noteworthy that the need for further provision in this country for scientific research in connection with art and manufactures was one of the principal points in this lecture. On the opening of the Imperial Institute in 1893, Abel was appointed its secretary and director, a post which he held, latterly in an honorary capacity, until his death. Although already far advanced in life, Abel threw himself with great courage and determination into the difficult task of organising the operations of the Institute, and continued to do so even in the face of steadily declining health. In relation to the history of the Imperial Institute, it need only be noticed here that in 1894 a laboratory was equipped on a small scale for the chemical examination of Indian and Colonial products. In 1896, a scientific and technical department, including extensive laboratories, was established with Prof. Dunstan as director, but the necessary funds were supplied by the Royal Commissioners of the 1851 exhibition, all the available funds of the Institute having been allocated to other purposes. Although it was Abel's intention to

retire from official connection with the Imperial Institute on its transfer to the Board of Trade at the end of the present year, he characteristically expressed his intention of continuing to take an active part in its proceedings as a member of the advisory committee.

Abel was an influential member of many scientific societies. He was elected a Fellow of the Royal Society in 1860, and was awarded a Royal medal in 1887 for his researches on explosives. He became at an early age a Fellow of the Chemical Society, and filled several offices in the Society, in which he was always deeply interested; at the time of his death he was one of the oldest of its past presidents. Abel took a leading part in the foundation of the Institute of Chemistry, of the Society of Chemical Industry and of the Institution of Electrical Engineers, of all of which he became president. He was also president of the British Association in 1890 and of the Iron and Steel Institute in 1891. He had filled the offices of vice-president and chairman of the council of the Society of Arts, which awarded him the Albert medal in 1884. Abel took an important part in the foundation of the City and Guilds of London Institute, and was at the time of his death chairman of its executive committee. He was an influential member of the court of the Goldsmiths' Company, of which he became prime warden in 1895. Abel's distinctions were numerous and varied. He was a D.C.L. of Oxford and a D.Sc. of Cambridge. He was made a C.B. in 1877 and was knighted six years later. The K.C.B. was conferred in 1891, and he was created a baronet on the occasion of the opening of the Imperial Institute in 1893. The last honour, that of the G.C.V.O., was conferred by the King soon after his accession, in recognition of Abel's personal services to the Royal Family.

Highly endowed with a practical mind, great common sense and a prodigious power of work, Abel was invaluable as a member of committees. His large experience in drafting official papers made him an excellent critic, and it may be safely asserted that few of the many documents submitted to him, by the institutions he was connected with, left his hands without substantial improvement. As time went on, routine work became a confirmed habit and the idea of a holiday positively repugnant to him, so much so that he found himself unable at the last to take rest and change, the necessity for which his friends and medical advisers so repeatedly urged on him.

W. R. D.

AN INSTRUMENT FOR AIMING GUNS UNDER COVER.

THE advantage of cover in military operations has been shown over and over again during the recent war in South Africa. But even when cover is available, the head of the soldier is exposed, while in the act of aiming, to the fire of an enemy. By means of the hyposcope the marksman is able to aim with considerable accuracy, while protected by a cover of earthwork or stones. Apparatus for sighting ordnance by means of mirrors has been employed by the war departments of several nations.¹ But the inventor of the hyposcope, Mr. W. Loulten, has dealt with the problem of furnishing any existing rifle with a system of mirrors, whereby the act of aiming may be performed from a point several inches below the trigger-guard. The hyposcope is shown in Fig. 1 attached to the service rifle, which is placed in position over the edge of a rough mass of stones used as cover. The marksman aims the rifle by looking into the mirror at the lower end of the vertical tube, his head being protected by cover. In this form of instrument, four mirrors are employed; on looking into the instrument, the sights of the rifle are

¹ "Treatise on Service Ordnance." (London, 1893).

seen nearly as clearly as under ordinary conditions, the system of mirrors merely translating the line of sight along the rifle, parallel to itself, to the distance of about eight or nine inches below the axis of the barrel of the rifle.

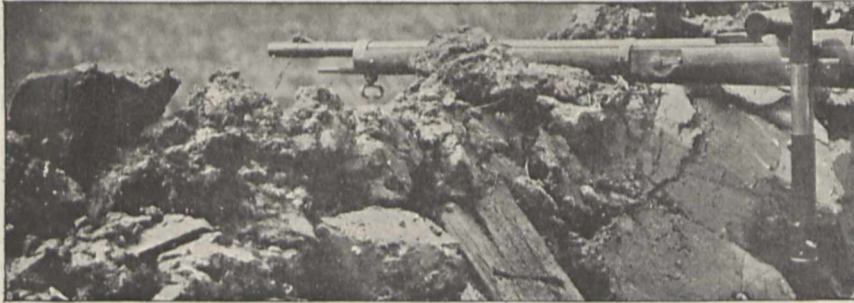


FIG. 1.

In another form of hyposcope, used to sight a Maxim gun, Fig. 2, two mirrors only are employed to translate the line of sight downwards, and but little light is lost. The tube which carries the mirrors is graduated, and the correct elevation is obtained by means of two easily made movements of the apparatus.

The National Rifle Association, recognising the importance of shooting while protected by cover, awarded prizes at the Bisley meeting this year for shooting with the hyposcope sighting. The range was 200 yards, the bullseye seven inches; each man of the thirteen who shot had seven shots. The highest possible score was 35 per man, and the average score per man was 32'15. The apparatus and the method of holding the rifle were new to nearly everyone who shot. In actual warfare, an enemy may approach a trench or cover from any direc-

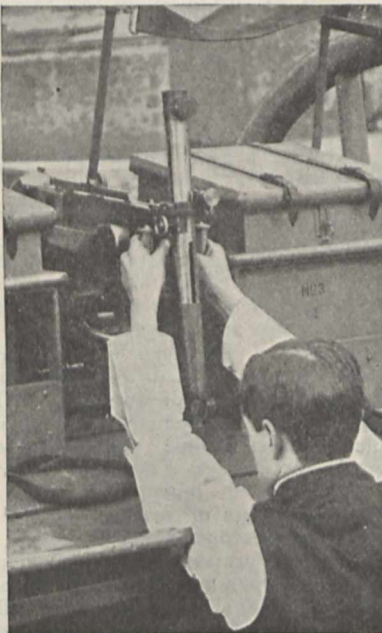


FIG. 2.

tion, and his approach must be seen, before the rifle is brought to bear on him. Probably the observation of the movements of the enemy might be found approximately by using a separate hyposcope, not attached to a

rifle in the usual way, so as to bring into view each portion of the foreground in succession. Such an instrument would only require two mirrors, and would enable an outlook to be kept with a minimum of danger to the observer. The instruments are strongly made, and with reasonable care they should efficiently answer their purpose.

THE BRITISH ASSOCIATION AT BELFAST.

IN point of numbers, the meeting of the British Association at Belfast has not been a very large one, but it has certainly been a decided success and has been full of interest. About sixteen hundred members and associates have attended, and in addition

many people have been present at the meetings who have not registered their names. The local committee has facilitated the work of the secretaries in every possible way, and the excursions have been a means of pleasure and profit to all who have been able to take advantage of them. No meetings were held on Saturday, so that members should be free to avail themselves of the opportunity of taking part in the interesting excursions arranged for that day.

At the first meeting of the General Committee, the report of the Council was read. Reference to the severe loss the Association has sustained by the death of Mr. Griffith, the late assistant general secretary, was made in the first paragraph of the report, and it was announced that Dr. J. G. Garson had been nominated to succeed him in this important office. Sir William Roberts-Austen, K.C.B., having informed the Council that he did not intend to offer himself for re-election as general secretary, Major P. A. MacMahon, F.R.S., was appointed as his successor, and Prof. D. J. Cunningham, F.R.S., was elected to fill the vacancy thus caused among the members of the Council. In addition to Prof. Cunningham, the following members have been elected on the Council, the new names in the list being in italics:—*Sir W. Abney, K.C.B., F.R.S.*; Prof. H. E. Armstrong, F.R.S.; Dr. J. Bonar; Prof. F. O. Bower, F.R.S.; Prof. H. L. Callendar, F.R.S.; Captain E. W. Creak, R.N., F.R.S.; Major L. Darwin; the Hon. Sir C. W. Fremantle, K.C.B.; Prof. F. Gotch, F.R.S.; *Prof. A. C. Haddon, F.R.S.*; Prof. W. D. Halliburton, F.R.S.; *Mr. C. Hawksley*; *Prof. G. B. Howes, F.R.S.*; Dr. J. Scott Keltie; Sir Oliver Lodge, F.R.S.; Prof. A. Macalister; Prof. W. H. Perkin, F.R.S.; Prof. John Perry, F.R.S.; Mr. L. L. Price; Mr. A. C. Seward, F.R.S.; Prof. W. J. Sollas, F.R.S.; Prof. W. A. Tilden, F.R.S.; *Prof. W. W. Watts*; Sir John Wolfe-Barry, K.C.B., F.R.S. Profs. H. Elster and J. Geitel have been elected corresponding members of the Association.

At the second meeting of the General Committee, Sir Norman Lockyer, K.C.B., F.R.S., was elected president of the Association next year. The meeting will be held at Southport, and will commence on September 9, 1903. It was resolved to hold the meeting of 1904 at Cambridge, and in all probability the meeting of the following year will be held at Cape Town. The invitation to visit South Africa has been backed up by the promise of substantial pecuniary support, so that a large and representative number of members of the Association may be enabled to accept it.

The following grants of money for scientific purposes were recommended by the General Committee at the meeting on Monday:—

Mathematics and Physics.

Rayleigh, Lord.—Electrical Standards	£35
Judd, Prof. J. W.—Seismological Observations	40
Shaw, Dr. W. N.—Investigation of the Upper Atmosphere	75
Preece, Sir W. H.—Magnetic Observations	40

Chemistry.

Divers, Prof. E.—Study of Hydroaromatic Substances.	20
Roscoe, Sir H. E.—Wave-length Tables of Spectra ...	5

Geology.

Herdman, Prof.—Fauna and Flora of British Trias ...	5
Marr, Mr. J. E.—Erratic Blocks	10
Scharff, Dr. R. E.—To Explore Irish Caves	40
Watts, Prof. W. W.—Underground Waters of North-West Yorkshire	40
Marr, Mr. J. E.—Life-zones in British Carboniferous Rocks	5
Geikie, Prof. J.—Geological Photographs	10

Zoology.

Herdman, Prof. W. A.—Table at the Zoological Station at Naples	100
Woodward, Dr. H.—Index Animalium	100

Geography.

Keltie, Dr. J. S.—Tidal Bore, Sea Waves and Beaches	15
Holdich, Sir T.—Scottish National Antarctic Expedition	50

Economic Science and Statistics.

Brabrook, Mr. E. W.—Economic Effect of Woman's Labour	25
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Mechanical Science.

Preece, Sir W. H.—Screw Gauges	5
Binnie, Sir A.—Resistance of Road Vehicles to Traction	90

Anthropology.

Evans, Sir J.—Researches in Crete	100
Read, Mr. C. H.—Exploration of Stone Circles	5
Cleland, Prof. J.—Anthropometric Investigation	5
Ridgeway, Prof.—Anthropology of the Todas and Tribes of Southern India	50
Read, Mr. C. H.—Anthropological Photographs (balance in hand)	—

Physiology.

Halliburton, Prof. W. D.—The State of Solution of Proteids	20
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Botany.

Miall, Prof. L. C.—Registration of Botanical Photographs	3
Farmer, Prof. J. B.—Investigation of the Cyanophyceae	25
Ward, Prof. Marshall.—Respiration of Plants	12

Educational Science.

Sherrington, Prof.—Conditions of Health essential for School Instruction	10
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Corresponding Societies.

Whitaker, Mr. W.—Preparing Report, &c.	20
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£960

SECTION B.

CHEMISTRY.

OPENING ADDRESS BY EDWARD DIVERS, M.D., D.Sc., F.R.S., V.P.C.S., EMERITUS PROFESSOR OF CHEMISTRY IN THE IMPERIAL UNIVERSITY OF TOKYO, JAPAN, PRESIDENT OF THE SECTION.

The Atomic Theory without Hypothesis.

IN opening the Chemical Section of the British Association in this city and in the halls of the Queen's College, my first words must be those of reverence for the memory of Thomas Andrews, for so many years the Professor of Chemistry in this College, whose investigations into the properties of gases—above all, those which resulted in the recognition and determination of the critical pressure and temperature of carbonic anhydride—have

become a part of the foundation of the Kinetic Theory of Gases. At the Meeting of the British Association here in 1852, Andrews was President of this Section, and again at the Meeting in Edinburgh in 1871.

Since the Meeting last year another distinguished chemist, formerly professor in one of the Queen's Colleges, Maxwell Simpson, has also passed away. He, too, acted as President of this Section, namely, at the Meeting in Dublin in 1878. The work by which Simpson's name will ever be recalled is more especially that upon the synthesis of polybasic organic acids.

One other name must not be left unmentioned in this Address: it is that of a long-time Fellow of the Chemical Society who has been intimately connected with the British Association—I mean that of George Griffith, the genial and most effective Assistant General Secretary of the Association for so many years, who died four months ago. He had visited Belfast in the spring and made the preliminary arrangements with the Local Committee for this Meeting. He joined the Chemical Society in 1859—just one year before I did—and remained a Fellow until his death.

It is now almost a century ago since John Dalton made known to the world his theory of the nature of chemical combination by the publication of a table of atomic weights. He had been occupying himself for some years with the study of the physical properties and atomic constitution of gases before he was led to extend the notion of the atom to chemical phenomena, and thus to form that conception which was to become celebrated as the atomic theory. In his laboratory note-books, preserved from 1802 onwards, the publication and analysis of which we owe to Sir Henry Roscoe and Dr. Harden, no reference is made to the theory till 1803, but we may well believe with Henry that it was already in Dalton's mind just a hundred years ago. But however that may have been, it seems fitting in a year so closely approaching the centennial of its publication as the present that the occupier of this Chair should address his audience on a subject of such general interest and importance as the atomic theory, if indeed there remains anything to be said on a subject which has so long and so fully engaged attention.

I dare not assert that I have found anything actually novel to bring before you with regard to the atomic theory, but I may say that there has certainly long seemed to me to exist the need to treat it as being a true theory instead of as an hypothesis, and to teach it and discuss it accordingly.

In thus setting forth what appears to me to be the proper form of the atomic theory, I shall have, at the risk of overtaxing your patience, to restate and examine most of the fundamental and familiar principles of our science in order to illustrate and justify the view I take. Not only this, but in order as directly and briefly as possible to meet the objection that whatever the atomic theory may be it cannot be introduced to the student of chemical philosophy in another form than that now in use, I shall sometimes have to adopt, in order to show what can be done, a didactic method which, in most other circumstances, would be quite inexcusable before so distinguished an assembly.

The atomic theory of chemistry stands unsurpassed for the way in which it has fulfilled the purpose of every great theory, that of giving intellectual mastery of the phenomena of which it treats. But in the form in which it was enunciated, and still is universally expressed and accepted, it has the defect of resting upon a metaphysical basis, namely, upon the ancient hypothesis that bodies are not continuous in texture, but consist of discrete, ultra-minute particles whose properties, if known, would account for those of the bodies themselves. Hence it has happened that, despite the light it throws upon the relations of chemical phenomena and the simple means it affords of expressing these relations, this theory has always been regarded with misgiving, and failed to achieve that explicit recognition which its abounding merit calls for. Indeed, the desire has been expressed to see the time when something on a more solid foundation shall have taken its place.

Now, it is not my intention to discuss the merits or demerits of the atomic hypothesis, which can indeed no longer be treated as a merely metaphysical speculation. What I would do to-day is to impress upon you that, in spite of all that has been said and written about the atomic hypothesis in connection with chemistry, the atomic theory propounded by Dalton and adopted, implicitly at least, by all chemists, is not founded upon the metaphysical conception of material discontinuity, and is not explained or illuminated by it. For if that should be the case there will no longer exist any grounds for hesitation in accepting

the theory quite explicitly, and then the anomalous condition of things will be removed of a theory being in universal use without its truth being freely and openly admitted. For the sake of clearness, it is convenient to restrict the term "atomic hypothesis" to the old metaphysical view of the discontinuity of matter whilst applying the term "atomic theory" to the current elaborated form of the Daltonian theory; this distinction is adhered to in the present Address.

In the peroration to his admirable discourse upon atomic weights or masses delivered before the Chemical Society in 1892 as the Stas Memorial Lecture, Prof. Mallet, F.R.S., said: "By the chemist at his balance the arm of reason is directed into those regions of almost inconceivable minuteness, which lie as far beyond the reach of the most powerful microscope as that carries us beyond the reach of the naked eye, quite as impressively as that same arm is stretched forth by the astronomer at his divided circle to reach and to weigh the mighty planets that shine in the remotest regions of our solar system." On two occasions I have heard the same comparison between the chemist and the astronomer made by Lord Kelvin when he was in the company of chemists; and undoubtedly both these high authorities have only then expressed the general view as to the nature of the domain of the chemist. Yet I venture to question whether there is anything in the ways and work of the chemist to support such a view and give point to Mallet and Kelvin's comparison. If, indeed, chemistry is a science which rests upon the atomic hypothesis and, therefore, would cease to exist in the form into which it has developed should matter prove to be continuous and not discrete, nothing can be said against the view that it is a science of the minute. But I am sure there can be no one ready to maintain that, if the hypothesis of the atomic constitution of substances were an unfounded one, the atomic theory would have been a discovery of no great importance; and Dalton himself, instead of being the founder of the chemistry of to-day, have been little more than the discoverer of the law of multiple proportions. If that cannot be maintained, what, then, becomes of this conception of chemistry as dealing with the minute? So far as comparison can be made between the operations of the astronomer and the chemist, it is the former and not the latter who, as a matter of fact, deals with the almost infinitely minute. For if, indeed, the chemist often works upon comparatively small amounts of substances, and, consequently, with very sensitive balances, that is, as we all know, only for reasons of economy of time, materials and apparatus; otherwise he works on the largest possible scale, with the object of attaining to the highest degree of accuracy and perfection. The astronomer, on the other hand, has, perforce, to deal with the smallest visible things in nature, the nearest approach there is to geometrical points, those fixed points of light in the heavens which are only known through scientific investigation to be other than what they seem to be. It is, therefore, only as interpreted by the atomic hypothesis that chemistry can be said to deal with the minute.

When the atomic theory is expounded in the usual way it is commonly and correctly stated that, on the assumption that substances consist of minute indivisible particles having weights or masses bearing the ratios of the combining numbers assigned to them, the laws of chemical combination by weight necessarily follow, and are thereby explained. But then the converse is not true—that because chemical combination obeys the well-known laws, substances consist of discrete particles. Nor does the assumption of the truth of the atomic hypothesis afford any real explanation of the facts expressed by the laws of chemical combination, or more comprehensively by the atomic theory, when that theory is given in non-hypothetical terms. It is just as difficult to see why the atoms should possess the weights on chemical grounds assigned to them as to see why substances interact in the proportions that they do; that they do so is, in either case, an ultimate fact, for which no explanation has presented itself. The atomic hypothesis masks this ignorance and deadens inquisitiveness. Notwithstanding all this, which is incontrovertible, it is certainly a common opinion that in chemistry we investigate the minute and intimate constitution of things.

But if, after all, chemistry does not deal with the minute, or, rather, if it has no concern with the magnitude of single bodies or their molecules; if the atomic hypothesis is not the foundation of, or necessary to, the atomic theory, then it is certainly most desirable and important that the theory of chemistry, which, with all its modern developments, I take to be indisputably the

atomic theory of Dalton, should be held and expounded without any reference to the physical constitution of matter, in so far as that remains unknown. The opinion that chemical theory should be developed without reference to the atomic hypothesis has indeed all along been held by many eminent chemists; but then the dilemma appears to have presented itself to them, that either the atomic hypothesis must be granted or the atomic theory must be dispensed with, since it falls with the hypothesis. That dilemma I do not recognise, and the practice of chemists shows beyond doubt that it is always ignored. Investigators use the theory whether they admit it or not; teachers of the science find it indispensable to their task, however much they may deprecate, and rightly so, unreserved acceptance of the atomic hypothesis as true.

Refusing to commit themselves to belief in the hypothesis, chemists have thought from the first to escape the adoption of the atomic theory by putting Dalton's discovery into something like these words: Numbers, called proportional or combining numbers, can be assigned to the chemical elements—one to each—which will express all the ratios of the weights or masses in which substances interact and combine together. Perhaps the atomic theory is here successfully set aside by expressing what is an actuality as an unaccounted-for possibility. But then those who use any such mode of expressing the facts, without reference to the theory, never fail also to adopt the doctrine of equivalents, and thus, by this double act, implicitly give in their adherence to the theory.

Divested of all reference to the physical constitution of matter, the atomic theory is that the quantities of substances which interact in single chemical changes are equal to one another—as truly equal in one way as equal masses are in another—and, therefore, that chemical interaction is a measure of quantity of unlike substances, distinct from and independent of dynamical or mass measurement.

Dalton, indeed, did not express himself in any such terms, his mind being fully possessed with the ancient and current belief upon which he framed his theory that substances are made up of minute, discrete particles. But it is clear enough that his theory was that of the existence of another order of equality between substances than that of weight. Up to his time, the weight or mass of every ultimate particle of any substance whatever appears to have been assumed to be the same, the atoms being alike in every way. That assumption is still made by many thinkers, chemists among them; we meet it, for example, in the different forms of the hypothesis that the elements are all, in some way, physically compounded of a universal and only true element, as in Prout's hypothesis. Dalton saw things differently, and recognised that, on the assumption of substances being constituted of particles which never subdivide, weight or mass cannot be the same for every such particle, except in the case of those of any one simple substance. Therefore, having given some numbers showing what he believed to be the respective weights of the atoms of several simple substances, taking that of hydrogen as of unit-weight, he proceeded at once to invent symbols for these atoms to indicate, not only their distinctness in kind, but above all things their indivisibility and their equality, properties which the use of their atomic numbers would have inadvertently concealed or even apparently denied, and could never have expressed or connoted.

It was only in this immediate invention and use of chemical symbols that Dalton's conception found clear expression; and again it is by the universal adoption of such symbols that chemists have shown their real acceptance of the atomic theory, even while displaying, not infrequently, their scepticism as to its truth. The replacement by Berzelius of Dalton's marked circles for atomic symbols by letters which should recall the names of the substances was in a way a great improvement, but it has had the serious consequence of causing chemical symbols to be usually first brought under notice merely as serviceable abbreviations for the names of the elements, and only then described as representing their atomic quantities. Now, evidently, what the character used as symbol shall be is, theoretically considered, but a petty detail; the vital point is what the character symbolises, and that is the atom. It does not symbolise the name; it only indicates that and recalls it. It may be said, indeed, to represent the atomic number, since it stands in place of it; but it is made to do so only in order that we may for the time forget this number and have in mind the integral character of the atom. It is not the 4006 parts of sodium hydroxide and 8097 parts of hydrobromic acid, or approximately twice as much of the latter

as of the former; it is not these gravimetrically expressed interacting quantities that we are to think of when the formulæ NaOH and HBr are before us, as we too often strive to do; it is not these, from a chemical point of view, meaningless numbers of parts, but quantities which are equal in the sense of chemistry, that are expressed as such by these symbolic formulæ. The real purpose of chemical formulation is not to abbreviate or replace language, but to facilitate, if not ensure, abstraction from and non-contemplation of gravimetric numbers.

I have just passed from atomic symbols to the formulæ of molecules; but this was not without warrant. In the form in which I have enunciated the atomic theory, it relates to the chemical interaction of substances, whether compound or simple, and the equality of the quantities concerned is the equality of molecules, since these are the quantities of substances entering into or coming out from single chemical interactions. Were it not, therefore, for fear of confounding it with the mechanical theory of that name, the atomic theory should be called the molecular theory of chemistry. It might, indeed, have happened to be so called by its author, for Dalton has told us that he had in mind both atom and molecule as names for his chemically ultimate particles, and chose the former because it carried with it the notion of indivisibility. He extended, also, as we do, the use of the term "atom" to chemically compound substances, since their combining quantities are chemically indivisible.

Next, I would point out that in the atomic theory the notions of indivisibility and equality are inseparably involved. The indivisibility of atom and molecule is not absolute or ultimate, and Dalton distinctly guarded himself against being understood to claim for the atom more than chemical indivisibility, and chemists of to-day assert no more than this. This indivisibility being conditioned by the equality of molecules, the importance of emphasising it rests only upon the danger, when it is overlooked, of losing sight also of the chemical equality through the gravimetric inequality receiving numerical expression, and thereby conveying the notion of divisibility, though only gravimetrically. The idea of indivisibility in connection with the atom or molecule is intrinsically quite subordinate to that of equality; for equality, being unity or oneness brought into relation with itself, the conception of it carries with it and includes that of indivisibility. Any rational hypothesis as to substances consisting of ultimate particles will include the notion of their being indivisible particles; and the import of the hypothesis in chemical theory must lie, therefore, not in this indivisibility, but in the nature of the equality of the particles. By his atomic theory Dalton asserted that where the substances are different this equality is chemical instead of gravimetric.

Molecules are equal in the sense that they are quantities of their substances which are interdependent and coordinate in any and every single chemical change in which they take part together. It is a form of equality for which no close parallel can be found; but as to that it should be remembered that this equality relates to the phenomena of the transformations of substances into each other, which, though they form so large a part of the phenomena of the universe, are fundamentally distinct in nature from the rest of the behaviour of bodies throughout which the substance remains what it was. In some agreement with it there is that of mechanical pressures when these balance or neutralise each other, and therefore are opposite and mutually destructive though equal. But such pressures when exerted in the same direction are also equal in their effect on any body in their path, whereas in chemical interactions the effects of molecules or equal quantities of two unlike substances are only equal in the sense that each is that quantity which interacts with the same quantity of some third substance, which itself proves to be also a chemically equal quantity to them. For the products of the interaction in the one case are in part at least not the same as those in the other, though all prove chemically equal in further interactions.

To give an example: the molecule of ammonia is equal to that of aldehyde in that it combines with it and with it disappears, or ceases to exist as such. For the same reason it is equal to the molecule of hydrocyanic acid, and molecules of aldehyde and hydrocyanic acid equal to each other, because they, too, combine and disappear as such in doing so. But the molecule of ammonia again equals that of aldehyde in effecting transformation of hydrocyanic acid and its own self into something else. And lastly, chemically equal or molecular are the products of these combinations; aldehyde ammonia, ammonium cyanide and

aldehyde-cyanhydrine, not only among themselves, but also with the quantities of ammonia, aldehyde and hydrocyanic acid from which they come and into which they return in other chemical changes. But with all this quantitative equality in transforming power, the substances produced are unlike and, each to each, peculiar to one of the three acts of chemical combination; and on this account exception may be taken to the treatment of molecules as equal chemical quantities. Yet the equality of molecules here asserted is but an extension of what is meant by the equivalence of certain atoms and radicals, since the atom and the radical are, nowadays, conceptions entirely dependent upon and derived from that of the molecule (apart, of course, from the atomic hypothesis); and this universally allowed equivalence admittedly does not extend to the identity of the products of the replacing activity of the atoms and radicals.

Quantitative equality and equivalency, it is true, have not the same meaning, equivalence being used to denote qualified equality, equality in certain specified ways, of quantities not equal in all other ways and possibly in no other. Quantities of different substances cannot, strictly speaking, ever be equal, and can only be styled so in the sense of being equivalent; for were they equal in every way the substances would obviously be the same. But this fact, if it ever strikes one, is ignored by universal custom, and quantities of substances, however unlike—feathers, air, water, salt, and what not—are taken to be all equal, even by chemists as by the world at large, if only they have the same weight, notwithstanding the incongruities of the substances. I proceed now to show the baselessness of this conviction, but only to bring out more strongly the claim of chemical activity to equal rights with weight or mass in determining what are equal quantities of substances, for I am aware that here I have nothing to tell you that you do not already know. Weight being only the gravitational measure of mass, which itself is independent of it, quantities of substances are held to be equal when their masses are equal. Now, mass is quantity of matter. But what then is meant by matter? The answer must be either that it is a general term for any and all substances, or else that it is the common basis of all substances, which presents itself in all the different forms which are known to us as such, by virtue of a corresponding variety in its intestinal motions. I gladly pass over the latter answer without discussing it, on the ground that it introduces the subject of the intimate constitution of substances, which it is my set purpose to keep independent of in this discourse. I will only say of it that it would probably be the answer of many physicists and chemists, and yet that it gives such a limitation to the nature of matter as makes the common expression "constitution of matter" devoid of all meaning. That expression means, and can only mean, the constitution of substances in common; and this brings me to the first answer, that matter is the term standing for all substances in common. Now, one thing which all substances possess in common is the property of resisting pressures; pressures not only of moving bodies, but of the motions of the ether and electrons. Measured or quantified, resistance becomes mass, all that can be signified by this term being the quantity of the resistance or inertia a substance exhibits when tested. It is the measure of a property of the substance, that is all; and there is no other way of quantifying a substance than through some one of its properties. No quantities of different substances can, as such, be commensurable throughout; and when compared and measured through some common property, such as the possession of mass, the equivalence or pseudo-equality found by this means is not the same as that found when some other common property is taken as the means of measurement. But experience has shown that though there are several rational and comprehensive ways of instituting, through some common property, comparisons between quantities of different substances, they all, with the exception of that of weighing, agree more or less exactly in pointing to the same order of equivalence, that of chemical activity; for with this are colligated those of gaseous volume and the other well-known physical activities, which give nearly the same quantities as it gives of different substances as being molecularly equivalent. There are, therefore, essentially only two measures of quantitative equivalency or pseudo-equality between substances, the dynamical and the chemical or molecular, the one wholly independent of and the other wholly dependent upon the particular nature of the substances compared. The former is the measure of dynamical phenomena, those of changes of bodies, due to their impacts and pressures, which may lead to their deformation and disruption, but do not involve transformations of the

substances of the bodies into others; the latter is the measure of chemical phenomena, those of changes of bodies induced by such of their interactions as do involve transformations of the substances of the interacting bodies into other substances. Since it is already settled for us by custom that quantities of different substances are to be called equal when or because they are equivalent gravimetrically, and as it is not to be supposed that we shall ever give up calling 16 kilos. of oxygen, of salt, of chalk, and of every other substance, however unlike, equal quantities of them from the gravimetric point of view, we have no choice but also to call molecular quantities of these substances equal from the chemical point of view, if the claim to coordination in equality of chemical with gravimetric equivalency is to be asserted and maintained.

The contention that chemical equality must be regarded as of as clearly defined a nature as gravimetric equality becomes the more weighty when it is reflected that our very definite views concerning gravimetric equality are due solely to the law of conservation of mass, the evidence for and against which, I may remind you, is just now to be discussed by Lord Rayleigh before the Physical Section. The mass of one pound of sodium remains unchanged when the metal is converted into salt, washing soda, or borax; if this were not the case, gravimetric equality would be just as definite as it is now, but physicists would have to argue for its general recognition in much the same way as I am doing now for the recognition of chemical equality.

In further justification of this claim of chemical equality to coordinate rank with dynamical equality in the quantification of substances, it may be well to take the fact into consideration that the determination of the former is independent of that of the latter. Overlooking the difficulties of the task, let there be at hand or always procurable unlimited numbers of parcels of the different substances to be experimented upon, each of which, by other means than weighing, such as spatial measurement, can be known to be equal to, or greater or less than, other parcels of the same substances. Suppose, now, that after many trials, one of a number of equal portions of sodium hydroxide has been found to be the quantity just necessary to interact with one of a number of portions of hydrochloric acid also equal among themselves. The products of the interaction will be some water and some salt. We can now have placed before us a parcel of sodium hydroxide equal to that previously used, another of hydrochloric acid also equal to that used, and the water and the salt obtained, and then have before us chemically equal quantities of four substances. Let now, by spatial measurement, a number of parcels of water be portioned out, all equal to that of the water obtained, and a number of parcels of salt equal to that of the salt obtained. By a series of trials we find a quantity of silver nitrate just sufficient to interact with the sodium chloride, and having, by supposition, taken this quantity of silver nitrate from a lot of other parcels equal to it, we find that one of these is just sufficient to interact with one of the portions of hydrochloric acid equal to that used in producing one of the portions of salt. Further, we find that the salt and the hydrochloric acid each produce a substance which is the same, namely, silver chloride, and in the same quantity as the other. Along with it in the case of the salt is sodium nitrate, and in the case of the hydrochloric acid, nitric acid. We can then find that this quantity of nitric acid is just enough to interact with one of those of sodium hydroxide; and thereby produce quantities of sodium nitrate and water, respectively equal to those obtained in the other interactions. If now we conjoin with these experiments others in which hydrogen, sodium and silver are each caused to combine with chlorine, and others in which hydrochloric acid, silver chloride and sodium chloride are electrolysed into these elementary substances, evidence is obtained of such facts of chemical composition and decomposition and of double decomposition (or what happens when compounds interact) as those upon which the science of chemistry is framed.

In teaching chemistry the point is kept too much in the background, if not altogether out of sight, that the chemical equality of quantities of different substances is independent of all other relations of equality between them, and that, therefore, its validity is not affected by the fact of its terms agreeing with some and not with other terms of equalities determined in other ways. Instead of bringing out this point the molecule of water is given out as being, primarily and prominently, that quantity which has eighteen units of mass and which measures two unit volumes. Both statements happen in the nature of things to be

true, but neither of them describes the molecule. Let it be clearly understood from illustrative examples what is meant by "chemically equal," and there is hardly more to be said as to what constitutes a molecule of water than that it is the quantity of it chemically equal to that of some other substance presenting itself for comparison. "Molecule" is a term of relation: it stands for an equal quantity, not for any particular quantity; but as such it is as easy to understand and as undefinable as an equal volume or an equal weight of a substance.

It is then only as colligated equalities, established by experiment, that gaseous volumes, osmotic pressures and other properties of substances come into consideration, first as enforcing the truth of the conception of the indicated quantities as equal, and then as the means of molecular measurement without resort to chemical change. But of the purposes served by the colligative properties, that of giving molecular measurements without recourse to the evidence afforded by chemical change is well known to be of the very widest application. To determine chemically the molecular equalities of substances, single chemical changes of suitable character, changes which are cases of double decomposition, have to be looked for; and to know these with the desirable degree of certainty calls for a much larger acquaintance with the chemical behaviour of the substances than can usually be gained at the early stage of work when the knowledge of the molecule is of the utmost assistance in the further investigation of the nature of the substances. Consequently, it is nearly always through recourse to physical methods that the molecule is first ascertained, and then through the molecule the certainty acquired that some particular interaction is a single one, thus reversing the normal order of things, which undoubtedly is that the molecule in chemistry, however it may have been first determined, is recognised as such by being what it is in chemical change.

I shall have been wholly misunderstood by you if you suppose that I would make light of the importance of the balance in chemical operations, or of the value of its indications in chemical investigations. Once the weights of molecular or atomic quantities have been ascertained the balance becomes the most accurate and generally the most easily applied instrument for apportioning substances in these quantities. Chemical interaction, to be employed in this way and without the aid of the balance, is practically useless, for the reason that it involves the destruction of the quantities it measures. Out of this dependence on the balance arises the exceeding importance of accurate tables of atomic weights, from which molecular weights are derived by addition; but the place for these tables is not on the walls of the lecture-theatre, but in the laboratory pocket-book, and, perhaps, in the balance-room. Besides the use of the balance and of atomic weight tables for getting and calculating out molecules of different substances at pleasure, there is the indispensable service they perform in enabling chemical analysis to be carried out and applied to the solution of the problems offered by chemical change. The primary problem of every science is to find some element of sameness in the diversity of its phenomena, in order that they may be compared, a problem which was solved for chemistry to a large extent by Dalton, and ceased to exist when the distinction had been made between molecule and atom. But this having been solved, there comes the other problem, namely, to find definite, that is, quantitative differences in the midst of the uniformities, and these for the chemist are differences of mass or weight. Through that redistribution of mass which attends chemical interactions, it has been possible to trace out to some extent the nature of the transformation of substances and develop the science on the lines of chemical composition and chemical constitution. Thus, then, the balance has become and will continue to be the necessary instrument of chemical research; but again I would remind you that it records its facts in units which are not ours, and of which we avail ourselves only as the means to an end. Sodium chloride is chemically composed, not of 3545 equal parts of chlorine with 2305 of the same equal parts of sodium, but of equal quantities of these simple substances.

The theory of chemical molecules or equalities and their relations to the equalities between the weights and gaseous volumes of different substances were brought to light, not by Richter's law of chemical combining proportions, and not by Avogadro's hypothesis as to there being equal numbers of particles in the same volume of different gases, but in the first place by Dalton's atomic theory and Gay-Lussac's law of simply related gaseous volumes in chemical change; and then, much

more fully in the middle of the last century, through the brilliant work of Gerhardt, Williamson, Laurent, Odling, Wurtz, and others, in the purely chemical field. Dalton gave us the conception of the molecule, though confused with that of the atom, as the unit of measure of chemical activity in place of the gravimetric unit; the work of the chemists of the last mid-century gave us a fuller conception of the molecule, along with the notion of chemical change as being substitution in the molecule effected by what became known as double decomposition. Up to that time chemistry had been treated only as the science of compounding and decomposing or reducing. Sodium added to oxygen gives soda, sulphur added to oxygen gives sulphuric anhydride, soda added to the anhydride gives sodium sulphate, ethylene added to chlorine gives dichloroethane, water subtracted from alcohol leaves ether, and so forth. All this is strictly true in a limited way, but then it is not chemistry; and the addition precedes and does not constitute the chemical union. In the sodium sulphate we perceive no soda, no anhydride, no sodium, sulphur or oxygen. That is to say, there is evidence of the addition and subtraction of mass and some other such evidence; but, for the rest, evidence of addition there is none. Were it otherwise there could be no chemistry. It is true that one of the great things accomplished by chemistry has been that of establishing the law of the conservation of mass, without which to rely upon the chemist would be unable to carry on his experimental investigations. But that is only because, like the steady point to the seismologist, it is there unchangeable when all else is changing. Since it is the law of no change, it cannot serve to explain what is change. Far from being the science of the composition of substances, chemistry might be defined as being the science of the non-composition of substances where that composition might have been looked for from the antecedents. If salt is verily a compound of sodium and chlorine, and can be broken up into these, why have the fragments not the marks on them of that whole of which they formed a part? It is true that 5850 parts of salt become 3545 parts of chlorine and 2305 parts of sodium, nothing being gained or lost in weight; but to account for that there is no need of chemistry, a science which takes cognisance of the phenomena of change, and not of those of unchanged properties. The use of the word "composition" in chemistry cannot be discarded now, and all that is necessary to make it unobjectionable is to see that the term is always qualified by the prefix "chemical" when there is a possibility of mistake about its significance, and that that significance is carefully explained, if not defined and fully illustrated, before it is given over to the beginner.

The facts of a chemical nature about common salt which cause the statement to be made that it is a chemical compound of chloride and sodium are such as these. Salt can be wholly changed into sodium and chlorine; these substances brought together change into salt and nothing else; salt and sodium, each under conditions appropriate to it, change into the same substance, called also a sodium compound, such as sodium hydroxide; salt and chlorine, each in its own way, change into the same chlorine compound, such as hydrochloric acid; neither sodium nor chlorine, one apart from the other or the other's chemical compounds, ever changes into salt; salt is, directly or indirectly, producible in the chemical interaction of a sodium compound with a chlorine compound; the properties of salt are much less like those of either sodium or chlorine than like those of some other substances; in sensible and other physical properties the chemically compound substance, salt, is as simple as or simpler than either of the chemically simple substances, sodium and chlorine; lastly, the laws of combining proportion by weight are obeyed in all the chemical changes in which salt takes part.

With exclusive reference to such facts as these, the chemical composition of a substance will, I think, be found to be satisfactorily defined, as its having the power, capacity or property, of being wholly producible from and wholly convertible into, directly or indirectly, those substances of which it is said to be composed. A simple substance differs from one that is compound only in not possessing the power of being by itself convertible into two others, or of being produced alone from any two others. Simple substances are not less varied or less complex in their physical properties than compound substances, while their chemical constitution is often more problematic than that of many which are compound. The term "simple," therefore, is as misleading in the language of chemistry as "compound," unless defined and qualified in use by the word "chemically."

The ground really occupied by chemical composition in theoretical chemistry is now greatly limited; for with the full acceptance of the idea of the molecule and of the atom as a derivative of it, its place has been taken by chemical constitution to an extent hardly realised. The useful and practically necessary expression of the results of the quantitative analysis of a new substance gravimetrically is all that can strictly receive the name of its chemical composition. When the term is applied more widely it is used for what are really the simpler forms of chemical constitution. It was otherwise before the conception of the molecule had become current and the atom had become a derived function of the molecule. Chemical composition as expressed by Dalton in atoms is indeed that and nothing else. Carbonic anhydride is composed, according to him, of two atoms of oxygen to one of carbon, as against carbonic oxide, which is composed of one; marsh gas of two atoms of hydrogen to one of carbon, as against olefiant gas composed of one. But then it was only numerical necessity which led him to adopt such a mode of expressing the facts. The same necessity, it is true, affects us also in the matter of carbon dioxide, of water and of ammonia, but how little it does so is shown by the many cases in which the empirical or simple composition is expressed in multiples. The atomic chemical composition of ethylene is two of hydrogen to one of carbon, and that of benzene one of hydrogen to one of carbon. When we say, as we always do, that the one substance is "composed" of four atoms of hydrogen to two of carbon, and the other of six of hydrogen to six of carbon, we give what is information concerning the constitution of these substances. Call it the composition of the molecule as we may, it is evident that by composition we can here mean only constitution. As with polymerism, so with isomerism, and in a more marked way. Mercurous sulphate and mercuric oxysulphite, quite distinct salts, have yet the same composition.

In the great reformation wrought by the chemists to whom I have referred, but by Gerhardt in particular, the new light set up in chemistry was the notion of what came to be called "double decomposition" in chemical change. The phrase is not, perhaps, happily constructed, but it has the merit of needing some explanation of its meaning before it can be understood, and troubles, therefore, through a too simple apprehension of the sense of the word "composition" are hardly to be feared. Its introduction into chemistry marked the ascendancy of the idea of the molecule as the factor in chemical change whose interactions with other molecules were to be considered, instead of those additions which, as chemical phenomena, never take place. It led also to new conceptions of the nature of the atom and the compound radical as being the quantitative and qualitative expressions of the powers possessed by substances to change into others, and to the conception of the valency of atoms and radicals as expressing the nature of the connection of successive chemical changes. The zeal with which it was attempted to force all chemical changes into the form of double decomposition interfered, perhaps, with the full recognition of its importance; but the fact remains that, with hardly an exception, all that is stated concerning the nature of those chemical changes in which two or three substances become one, or one becomes two or more, is based upon notions derived from the study of double decomposition.

The fundamental value of double decomposition consists in its displaying threads running through chemical transformations which can be followed up. When two substances change into two others, and only then, there can be found, in most cases, relations of resemblance, both physical and chemical, between the before and after of a chemical change. Instead of the striking unlikenesses shown by the substances formed by quasi-addition to those from which they are formed, there are here met with the similarities of the outcoming to the interacting substances, and the similarities between the products of different interactions in which the acting substances are similar. Chemists had been for very long familiar with acids, bases, salts, without becoming deeply impressed with the significance of the resemblances which these class-names imply, and also with the facts that acids beget acids, bases bases, and salts salts, or in more general terms, that substances in interaction produce others like them, and that differences between the products and the agents in one change are distinctly repeated in a similar change in which other substances are concerned, points now given expression to by such terms as "chemical constitution," "homologous" and "analogous series," "Kopp's law," &c.

What is so important to consider in the study of double decomposition is that the fact, that the sum of the masses of the two products of the change is the sum of the masses of the two interacting substances, presents itself no longer as being merely the evidence of the massing together of substances into a compound; for there is in double decomposition to be considered that redistribution of mass which, on the one hand, is found to correspond to and be part of a general though not sharply defined redistribution of physical and chemical properties; and, on the other hand, to be obviously irreducible to that interchange of those simpler substances which in many cases are produced in the simple decomposition of the acting substances.

The physical properties of substances, or rather their sensible qualities, are of too uncertain a character for their redistribution to be safely traced. But it generally does result, amongst inorganic substances, at least, that colour is transmitted, the saline, acid, bitter, or other taste of one of the active substances will appear, with more or less distinctness, in one of the products, a relatively volatile and a relatively fixed substance together will yield a similar pair of products, a dense and a light substance will yield a dense and a light substance, and so on. The chemical properties, however, are quite definitely redistributed to a large extent, a fact sufficiently illustrated by saying that an iron salt yields an iron salt, and a sulphate yields a sulphate.

But this is not a redistribution in which simpler substances, or indeed any other substances than those interacting, play a part; as soon becomes evident on attempting to establish the contrary by an appeal to the facts. While silver acetate and silver sulphate resemble each other and also silver nitrate as silver salts, they do not resemble silver itself; and though silver nitrate resembles sodium nitrate as nitrate, there is not even a substance known which is related to these salts as silver is related to silver salts. It might be objected to this that there may yet become known such a substance, which in its ultimate decomposition would give one molecule of nitrogen to three molecules of oxygen. If instead of nitrate were given acetate or cyanide, there would be found in the substances acetic peroxide and cyanogen, it might be said, the analogues of the as yet unknown substance of the nitrate. But the point I would make is that nitrate, sulphate, &c., are names with well-defined meanings independent of the fact that the corresponding substances are not known; for it follows without argument that also the terms silver, iron, chloride, &c., should be equally independent in meaning of the existence of the substances silver, sodium, chlorine, &c. It is a familiar historical fact that caesium, helium and fluorine were chemical names long before the substances caesium, helium and fluorine became known. We might well be convinced, therefore, without going further, that constitutional names, names which convey the facts of likenesses preserved in chemical change, cannot be indicators of the presence of the substances for which they may be also used. For, that being the case, we have no grounds for assuming that silver nitrate in interaction with sodium sulphate decomposes into the substance silver, which then combines to form silver sulphate. But fuller proof than any appearance of likeness or unlikeness can give is afforded by facts which became known and appreciated in connection with the chemical molecule. Typical of them all is the fact that in none of its interactions does chlormethane yield a hydrocarbon simpler than methane or than itself. Under those conditions in which it might have been expected to give a substance which would be methyl, it produces ethane, a substance which chlorine converts into another substance, having instead of one-third only one-sixth less hydrogen in its composition. Similar results have been obtained in all cases where the point can be determined—that is, where the simpler substance looked for would still be a compound substance, and such simpler derivatives are looked for no longer. The monohydride of oxygen or sulphur, the dihydride of nitrogen or phosphorus or arsenic, the mononitride of carbon, the organic compounds, methyl, phenyl, acetyl, are not only unknown, but are held to be non-existent substances, though their chemical compounds, the hydroxides, amides, cyanides and the rest are both numerous and well defined. Whatever other view we shall have to take of the constitution of Gomberg's remarkable "triphenylmethyl," it will certainly not be that it is identical with the radical of the triphenylchlormethane from which it is derived, unless we are prepared to allow that carbon is sometimes trivalent. Ethylene the substance differs from ethylene the radical in having its two

carbons differently related; but it is difficult to see how to make a similar distinction in the case of Gomberg's substance.

In those other cases in which the point is not strictly determinable, only because the resulting substances are the simple substances themselves, it required but the recognition of molecular quantities to make it evident that these cases run parallel with the others. For, in all changes which can be satisfactorily followed out, the resulting or entering quantity of the simple substance is twice as great as that which can have come from, or gone to form the molecule of either of the compound substances. But if, so far as can be traced, a simple substance comes only half from one molecule of any of its compounds, none of these compounds can contain or be composed of simple substances. All simple substances, therefore, as well as all compound substances, enter into and come out from chemical changes as dual in all of them in origin and disappearance. Their colligative properties have been appealed to in order to confirm this observation, but with conflicting results, sometimes confirmatory of the chemical evidence, sometimes contradictory of it, and sometimes too complex for confident chemical interpretation.

I refer here more especially to Avogadro's proposition, which is in effect that equal volumes of gases are chemically equal or molecular. As in the case of Dalton's atomic theory, there is to be distinguished in this proposition what Avogadro really put forward as new from what he took for granted. Admitting, as was to him a matter of course, that gases have in equal volumes equal numbers of particles, he asserted that in the case of elementary substances these particles are not the atomic particles, but, as in the case of compound substances, particles compounded of these, which interact with the particles of other gases as chemically equal each to each. If now this proposition is divested of all hypothesis, all reference to the mechanical structure of gases, it becomes the law that equal volumes of gases at the same temperature and pressure, whether simple or compound, are almost exactly chemically equal quantities, and once in possession of this law we find nothing becomes clearer by assuming that equal volumes of different gases contain the same number of chemically equal particles. This law is, obviously, an advance upon Gay-Lussac's law similar to that of the chemical molecular theory upon the atomic theory of Dalton. Unfortunately, however, it does not hold good in the case of not a few simple substances, and it seems impossible from the chemical point of view, and consistently with the molecular theory, to admit that, because the gas-volume has only half the expected mass, the chemical molecule of sodium or mercury is not bipartite like that of hydrogen or oxygen, and chemically equal to either.

The dual constitution or chemically compound nature of the simple substances as thus established by the part they take in chemical interactions furnishes further evidence of the untenability of the belief that the molecule is chemically composed of two substances, or their substitutes, simpler than itself, when we consider that, were this true, there would be chemical union between two things perfectly alike, two portions of the same thing. This difficulty was, I believe, first raised by Berzelius, and has never been met. Physically, the matter is simple enough, if motion in the opposite direction is not counted as a difference between two masses. But this would be a non-elective union, whilst chemical union is elective.

The difficulty, insurmountable when made, does not arise when the fact is recognised that every chemically single substance, whether simple or compound, is, as a substance, one and without parts, and can never, therefore, be built up of or broken down into parts different from itself. One substance (as two molecules) or two substances change into two others or into two molecules of one, in an interaction which is instant, uninterrupted, and irresolvable into stages, where the interaction is single in character. But just as a body can be mentally analysed (as in the investigations of dynamics) into mass and motion, which apart are unknown, and as these again can each be conceived of as further divided, resolved, condensed, and otherwise qualified as centres of mass, compounded motions, and so forth, so the chemist is enabled mentally to find quantitatively defined this, that, and the other mark of the many chemical interactions which have or may have gone to bring it into existence, and will or may again have place in the possible forms of its dissolution into others. The two methyls in the constitution of ethane, about which we are quite certain, are not two things held together till some interaction sunders them in

the chemical dissolution of ethane, but the double mark of similarity between it and other methyl compounds in their chemical interactions. We cannot say that only one part of the ethane is methyl, or hydrogen, or carbon, but that part of its nature, of its constitution, is its behaviour as a methyl compound, or, again, as an ethyl compound; or, more comprehensively but less specifically, part of its constitution is its behaviour as a hydrocarbon, as a hydrogen and as a carbon compound. But these are different aspects of it, different relations of it, not differing parts of the one homogeneous substance.

With the laudable object of combating the prevalent notion that matter is something which is the basis or essence of a body, something acting as the medium of the manifestation of its forms of energy, a distinguished and most lucid writer on chemistry has, adequately perhaps for that object, represented a body as a compound of the various forms of energy subsisting together and cohering in certain proportions within the volume of the body. But this presentation of a subject as a cohesion or association of forms of energy is on the same footing as the presentation of ethane as consisting of two methyls bonded together, or two portions of carbon with six of hydrogen. It is compounding what cannot be had apart, what cannot be even conceived of as separate, so far as bodies are concerned. The analysis of bodies into manifestations of different properties are only mental operations. A moving body, a hot body, a green body, an explosive body, becomes by legitimate abstraction a phenomenon of motion, of heat, of colour or of light, or a chemical phenomenon as our needs require; but the body is there all the while, and its undivided and continuous existence is indispensable to the phenomenon. The body can be hotter or colder, but not that only—not that without other differences; red-hot iron is throughout a very different thing from cold iron, and ice differs widely from steam in most of its properties. A substance is no more composed of its properties or energies than it is composed of its so-called elements. It manifests its presence in a thousand and one ways more or less distinguishable; its properties are so to manifest itself. But no divisibility of itself while it remains itself can be thought of, no differentiation can be suggested, no nucleus with its superinduced properties can be traced.

It ought, therefore, to be possible to express all the particulars of chemical constitution without making any assumption as to substances having parts or structure. Of chemical constitution itself, I doubt whether there is to be found a definition which is not couched in language having reference to the minute mechanical structure of substances, notwithstanding the fact that all knowledge of their chemical constitution has come to us through observation of the properties of the substances themselves, and more particularly their relations in cases of double decomposition. Bearing in mind that all terms are relative, I think the chemical constitution of a substance may be defined as the resemblances shown by it in its chemical changes to other substances, often better known than it and taken as types, these resemblances being indicated and described usually by means of special nomenclature and notation. As this nomenclature and notation have been developed out of those designed to express chemical composition, it is well to point out that the notion of chemical constitution is independent of that of the latter, though clothed to some extent in its language and symbols.

The notions of radical and atom are so intimately related as to be often used indifferently, the one for the other. The radical ethylene is always an atom of ethylene, the radical nitrogen always an atom of nitrogen. Radical and atom are, in fact, the qualitative and quantitative aspects of the same thing. They are thus exactly parallel with substance and molecule. We can think of unquantified substance, and perhaps of unquantified radical, but in chemistry we never really want such conceptions; one of the many definitions of science is the quantification of phenomena, and in every chemical phenomenon the substances concerned are quantified as molecules. The quantification of radicals expressed by the atom is fundamentally the same in principle as that of substances, namely, that of chemical equality in interaction; but it may be better to say that it is dependent upon the quantification of substances as molecules.

In the interaction of double decomposition each substance by contact and union with the other develops and manifests a dual character by becoming distributed as the two new substances, with the consequence that each of these has certain properties the same as those of the one, and certain others the same as those of the second interacting substance. What is common in

this way to one of the interacting and one of the resulting substances is a radical of these substances, of which there are evidently four in every double decomposition. These radicals of a single interaction are defined as whatever two parts of the powers of a substance to yield the simple substances of its chemical composition are, in certain interactions, continued separately from each other in the two new substances. But the pair of radicals developed in the various double decompositions of a substance being by no means always the same, one of the radicals of one pair must include in its composition part or all of one of those of another pair. Acetic acid has for one pair of radicals methyl and carboxyl, and for another pair acetyl and hydroxyl. Of these, carboxyl includes hydroxyl and acetyl includes methyl. Again, acetic acid yields the hydrogen and acetate radicals in one interaction, and hydroxyl and acetyl in another, so that in these cases the acetate radical includes acetyl and the hydroxyl includes the radical hydrogen. Now, what is common to carboxyl and acetyl and what is common to the acetate radical and hydroxyl are also treated as radicals, the one being known as carbonyl and the other as the radical oxygen. These are examples of what may be distinguished from the others as the polyvalent radicals. They are radicals of radicals, and therefore also radicals of substances. They may be defined as the common part of two or more other radicals. A single definition of all radicals can be given, but it is not instructive. A radical is any single power or any interdependent association of the powers of a substance to produce simple substances which continue in any product or series of successive products of its chemical change.

Before I leave the subject of the radical I wish to repeat that it is only when it is interacting that a substance shows a dual character or division, as it were, into parts or radicals, and that the duality it then shows is determined as much by the nature of the other substance as by his own. A substance is neither actually nor conceptually the sum of its radicals. The very fact of the difference of these in different interactions should be proof of this; though it only leads to its being taken to be at least the sum of its ultimate or simple radicals. If, however, it is not the sum of its proximate radicals, it is hard to see how it can be imagined to be that of the ultimate ones. In relation to its radicals, a substance must be held to present itself as any one of these for the purpose of investigation, and at the standpoint from which it is considered. It is then to the mind that particular radical, though also something else; just as snow is white and cold, yet also something else, for the moment unconsidered. Nor can the two products of an interaction be looked upon as themselves the sum in properties of the interacting substances. To a limited extent, and imperfectly, we can attach to a given radical certain of the properties common to its compounds; but it needs no greater insight than we have already to recognise that a substance cannot be what it is in one way, without being in that way greatly affected by what it is in another. This is now a recognised but not sufficiently considered point, and I therefore welcome those publications of Prof. Vorlaender, of Halle (who now honours this Section with his presence), in which he has been vigorously calling attention to the extent to which the properties of a substance, acid, basic, stable, and what not, depend as much as, if not more, upon the interrelations of the radicals than upon the radicals themselves.

One other thing I have to say about the radical, which is as to the spelling of the word. I plead for a return to the ending of the word radical with "al," now interdicted in the *Journal* of the Chemical Society. It seems appropriate to call the powers of a substance to behave chemically as it does, the roots or radical parts of its chemical nature, but it does not seem appropriate to call them radicles or rootlets. Americans and all other nationalities but our own use the original spelling.

I have put off too long, perhaps, all reference to the properties of very dilute aqueous solutions of salts, but I wished first to discuss the nature of the radical. The osmotic pressure and other dependent points which are particular in the behaviour of such solutions are in full accordance with the assumption that an electrolyte by dissolution in much water becomes a pair or a binary system of two interdiffused quasi-substances called "ions." These ions must differ from isolated substances in bearing equal and opposite quantities of electricity; in being each unknown apart from its fellow; and in having a composition not to be found in actual substances, though identical possibly with that which a radical would have were it a

substance. The ions can be indeed separated from each other, but not to continue as themselves, since in the act of separating they form ordinary substances, either by uniting with other ions, or by two molecules of ion becoming one molecule of substance. In the former way of separation the ions of two salts interact on mixing their solutions; in the other way, the ions become substances when their solution is placed in a galvanic circuit. In this mode of separation—by electrolysis, that is—the substances corresponding with the two ions, or else secondary products of their change, are produced, the one substance at the cathode and the other at the anode, while the solution away from the electrodes, but between them, remains for the time unaltered in composition. Along with this there occurs in many cases a phenomenon first recorded by Daniell, and afterwards investigated by Hittorf with such beautiful results. This consists in a greater fall taking place in the concentration of the salt solution close to one electrode than in the concentration of that close to the other, as though the ions were hydrate compounds, and that the one ion was a higher hydrate than the other. Until we know more of the nature of the ions themselves this phenomenon is most conveniently quantified on the hypothesis that the ions travel as molecular particles, but the discussion of this hypothesis is beside my present purpose.

The phenomena of ionisation or, in other words, the particular properties of dilute solutions of salts, belong evidently to a change unlike all other chemical changes. It is a polarised chemical change, in which the equivalent and complementary products of the interaction appear apart and at remote surfaces of the mass of decomposing salt solution. Two points which call for notice in connection with my present subject are that an ion is one of a pair of quantities commensurate with the quantity of the salt itself that is or would be in interaction; and that it is molecular in character and therefore to be regarded as a relative and wholly variable quantity.

Dalton's atoms were both the atoms and the molecules of present-day chemistry, but much more the latter than the former. Although the chemical atom can now be no more than a dependency of the molecule, it is commonly set up as the starting-point in chemical theory, and as having an independent existence as a quantity of the substance, while the molecule is represented as being a conjugation of atoms. But there cannot be two standards in reference to the same thing, and in molecular chemistry the atom must give way. As I have already had occasion to point out, the atom is of the radical, the molecule is of the substance.

The four radicals of a double decomposition are equal and chemically complementary. These chemically equal quantities of such radicals are atoms. The quantities of all other radicals are also atoms, but only those of proximate radicals, those of a single interaction, are equal. Similarly, the quantities of the four substances of a single interaction are all equal and are molecules, but the quantities of substances are not equal in other interactions. These others are treated as the simultaneous occurrence of two or more single interactions, which they can always be represented and sometimes demonstrated to be. Calcium hydroxide and hydrogen sulphide give calcium hydrosulphide and water by two single interactions together, which in this case can be easily distinguished, since the calcium hydroxide will also interact with only half as much hydrogen sulphide to form the insoluble crystalline calcium hydroxyhydrosulphide and half as much water as before; this calcium salt will then interact with as much more hydrogen sulphide as went to form it, and produce the very soluble crystalline calcium hydrosulphide. Or the calcium hydrosulphide and as much calcium hydroxide as yielded it will readily interact to form twice as much as the first-obtained quantity of calcium hydroxyhydrosulphide. Thirdly, the calcium hydrosulphide and half as much water as was formed with it from calcium hydroxide readily interact to produce calcium hydroxyhydrosulphide, and half as much hydrogen sulphide as was needed to form the hydrosulphide. Therefore, and on other grounds, we say and know that one molecule of calcium hydroxide and two molecules of hydrogen sulphide give one molecule of calcium hydrosulphide and two molecules of water. This is, of course, only the law of multiple proportions introduced into chemical interactions. The expression "two or more molecules of a substance" has a meaning only as indicating the number of simultaneous or successive single interactions which have led to the conversion of certain substances into others.

Now a similar but complementary state of things meets us in

the case of radicals. Instead of the coefficients of molecules, necessitated by having to consider many chemical changes as being cases of two or more single interactions occurring together, there are the valency coefficients of the polyvalent radicals, called out also by such a compound interaction. Thus, in the above case, whilst the single interaction between hydrogen sulphide and calcium hydroxide shows calciumhydroxyl as one of the radicals, the succeeding interaction between the calcium hydroxyhydrosulphide and more hydrogen sulphide shows the radical calciumhydrosulphuryl, and the common part of these two radicals is the bivalent radical, calcium. It will be evident that to give the atom of the calcium radical as bivalent is a statement reciprocal or complementary to that of giving two molecules of hydrogen sulphide as interacting with one of calcium hydroxide. Chemical equality remains still the measure of the atom, but that, in complex changes, whereas the number of molecules of one substance marks the number of single interactions, the valency number of the atom marks the same thing for the radical. It is a matter of valency, and not otherwise a matter of the atom. The radical calcium is never actively bivalent in a single interaction; in other words, it is never equal to two atoms of hydrogen. As a simple radical it does not take part in such an interaction; but it does do so as a radical of radicals, such as calciumhydroxyl and calciumhydrosulphuryl, and then has the same measure as—is equal in exchange to—the atom of hydrogen, though carrying with it of necessity other radicals, a thing the hydrogen radical never does or can do. To take another example; when acetamide is formed from acetic acid, the nitrogen of the amidogen and the oxygen of the hydroxyl are equal in exchange, but because of their valencies the one carries with it two atoms and the other one atom of hydrogen. This is no matter of merely academic contention, for upon its recognition rests the doctrine of valency itself.

The quantity of the radical is the only proper and sufficient definition of the atom, whether the radical be that of a single interaction, or a radical of radicals, that is, a polyvalent radical. The atom is, therefore, the quantified power of a substance, as the compound of the radical, to produce other compounds of the radical, including its compound with itself, where that is possible. As with the molecule of a substance, so with the atom of the radical, it is of no fixed magnitude, and may weigh a kilogram just as well as only a milligram or something much less. Being a relative quantity and nothing by itself, of its indivisibility there is nothing to be said outside its definition; whilst, as to its being the smallest relative quantity interchanging in an interaction, it had only thus to be defined when there was uncertainty as to the molecule and the single interaction.

It has been impossible for me to discuss the nature of the radical and the atom without referring to valency, but it is itself a subject of such importance as to need special consideration. It does not seem right to me to say even the little I can say about valency without naming with the respect they deserve from us the distinguished chemists who laid the foundations of the doctrine and developed it: Williamson, Odling, Wurtz, Edward Frankland and Kekulé. I had the good fortune to be in the same laboratory as, and then intimate with, Kekulé when, in 1854, he was working out the bivalency of sulphur and oxygen by his investigation of thioacetic acid, some time, that is, before he had thought out the benzene ring and the valency of carbon.

Only when, as is usual, propositions are made in which a separate and independent existence, with valency as a property, is imputed to a radical does the question, as to what valency is, present any difficulty. Approaching it from the side of the molecule and of double decomposition, and therefore from the experimental side instead of from that of the radical itself, as is customary, valency presents itself as being the number of single interactions necessary in order to have a certain radical occur, first as that of one substance, and then as that of another which has no other radical in common with the first substance. That ammonia possesses one atom of the radical nitrogen and three atoms of the radical hydrogen, and that the nitrogen radical is trivalent and the hydrogen radical univalent, are statements mutually based upon facts such as the following. Potassium nitrosulphate, which contains nitrogen but no hydrogen, is converted by water in a sharply defined single interaction, into potassium hydrogen sulphate, and into potassium imidosulphate, a substance which contains all the nitrogen along now with hydrogen. This salt passes, also sharply and by a single inter-

action with water, into as much more sulphate along now with potassium amidosulphate, which latter substance contains all the nitrogen and twice as much hydrogen as belonged to the imidosulphate. Lastly, the amidosulphate interacting with water gives a third quantity of potassium sulphate, equal to the last, and also ammonia, having all the nitrogen of the nitrilosulphate started with, three times as much hydrogen as the imidosulphate, and nothing else. That is to say, the nitrilosulphate and the ammonia have no other radical than the nitrogen the same, while three single interactions have been necessary to separate in this way the nitrogen radical from the three atoms of the potassiumsulphonyl radical. Therefore the nitrogen radical is trivalent and its quantity is the atom. Again, there are three atoms of the univalent hydrogen radical in the ammonia molecule, because in each of the three interactions an equal quantity of this radical is brought in from water. Ammonia shows only one pair of radicals, behaving, so far as its own interactions go, exclusively as a compound of amidogen and hydrogen, and these radicals are referred to as united or bound together in being ammonia. It is only the interactions of its derivatives, primary, secondary and tertiary, that are indicated by treating the amidogen as ultimately nitrogen and two hydrogen radicals. But this involves the consideration of all three hydrogens as bound to the nitrogen; and it becomes, therefore, of vital importance to bear in mind that the hydrogen radical, proper to the ammonia itself, is bound to a nitrogen radical which carries also bound to it two other hydrogen radicals.

Chemical formulæ still remain to be considered. They are symbolisations of deductions from experimentally ascertained facts, and are independent of the interpretation commonly given to them as referring to the minute differentiated structure of substances. A chemical equation expresses a chemical change quantitatively by means of chemical formulæ which are molecular. In a case of double decomposition, therefore, there are four formulæ; but when two or more such interactions are expressed in one equation, because they occur together, the formulæ of transition-substances do not appear, and then numerals before formulæ tell the number of interactions in which separate molecules of the substance have taken part. A formula represents the relative interacting quantity or molecule of a substance, while the single symbols composing it stand each for an atom of the radical of a certain simple substance as possessed by the substance formulated. The connecting lines and dots, and certain collocations of the symbols, indicate the association of the simple radicals as compound radicals in different interactions.

What is symbolised by position formulæ, and indeed by the formula altogether, are the chemical activities and abilities of the substance and its derivatives, and their analogies with those of other substances. When not in interaction, a substance has no constitution and no formula. In is certainly not on any experimental grounds that it can be regarded as some spatial arrangement of unlike parts. To take the simplest case; if we start with sodium hydroxide and symbolise its molecule by some mark, such as X to begin with, the interaction of the substance with an acid leads us to replace the X by two symbols and a connecting mark. One of these will be Na for the sodium radical; let the second be Z for the other radical, and let a dot or stroke be placed between the symbols to mark them as those of a pair of radicals in interaction. In other interactions, such as that with melted potassium acetate, we find need for a new pair of symbols, one being H for the hydrogen radical, while the other may be Q. But it is easy to decompose two molecules of sodium hydroxide in one operation into molecules of sodium, hydrogen and oxygen, from which fact we learn that Z is replaceable by the double symbol O-H, and Q by O-Na. Thus, Na-Z and H-Q became equally Na-O-H, which records the ultimate radicals of sodium hydroxide, together with all its interactions, immediate and remote. But it does this with no more implication of spatially placed and tied parts than is made by expressing the measured flow of time by a straight line, or than is to be found in t^2 seconds of time, or in c^3 as the third power of a number, unless we specifically condition this symbol as stereometric. A formula is not to be read—on experimental grounds, I mean—as a symbol of parts juxtaposed and joined on, and should be regarded as an intricate but legible monogram telling the chemical nature of the substance. Every symbol in it is to call to mind a phase of the chemical activity of the substance or of its derivatives, a phase that may be for the time as the

substance itself to the investigator, just as a pigment substance becomes only a red or a white to the painter. For example, salt is often nothing more than its chlorine phase to the chemist when he wants only a soluble chloride; whether it is of potassium, sodium or ammonium, then, matters not to him.

The double linking of the carbons in ethylene is a symbolised expression of facts without reference to hypothesis. The two carbon radicals of ethane or of alcohol behave together just as does the single carbon of methane or the nitrogen of ammonia in being, but with a valency of six, continued to other compounds devoid of all the other radicals of the ethane or alcohol—that is, of the hydroxyl and the hydrogens. The quadrivalency of each carbon is made up by the interaction necessary to dissociate or to bring together the two methyls, which counts as a unit of valency to each carbon. Ethyl hydrogen sulphate decomposes into sulphuric acid and ethylene, the hydrogen-sulphate radical with a hydrogen radical becomes the acid as the one product, while the methylene radicals again pair off as the two methyls had done when ethane was formed, thus producing the non-saturated substance, ethylene. Since there is a perchlorethylene, the second linking mark falls between the two carbons; and when ethylene passes back to an ethane compound two units of valency are displayed by it without the carbons becoming dissociated.

Position formulæ of isomerides, such as those of propyl alcohol and acetone, present no difficulty, because they are interpreted as the expressions of unlike double decompositions. It is not unfrequently the case that no constitutional or structural formula can be given to a substance which shall express all the pairs of radicals possible in its interactions, of which the best-studied example is that of ethyl acetoacetate. This state of things, known as tautomerism, admits of no other interpretation than that there are really two substances existent, of which one only is known, the other or so-called "pseudomorph" requiring the assumption of its existence as a transition-substance only. The notion of the shifting hydrogen radical is but the hypothetical way of viewing the intervention of the intramolecular change by which the substance becomes its "pseudomorph."

The cyclic formula of benzene expresses the fact that, unlike a fatty hydrocarbon, benzene shows but one pair of interaction radicals, hydrogen and phenyl. The "ortho-," "meta-" and "para-" positions in benzene derivatives are only expressions of facts of "position" isomerism, such as those pertaining to other non-saturated compounds, but more complex to unravel and more varied and interesting. It is doubtful whether the Kekulé ring does not remain as efficient a symbol as any stereographic substitute yet proposed for it; but it itself is purely a symbol of chemical interactions, and has no spatial significance other than what may be put into it by convention. "Adjacent," "opposite" and the like have only application literally to the arrangement of the symbols; but if the symbolisation is perfect the "opposite" carbons will, as a matter of course, always indicate the same point concerning the chemical interactions.

Whether the chemical formulæ for the lactic acids are better arranged in a plane or as a tetrahedron is to be decided by the facts concerning these and other asymmetric carbon compounds, the object being to symbolise or formulate as distinct and complementary in certain physical properties, but alike in their chemical interactions, two isometric substances, simultaneously formed in molecular quantities. Enantiomorphous arrangements of the respective formulæ of dextro- and lævo-lactic acids fully meet the case, but the facts are in no way explained by these formulæ. In the enantiomorphously related hemihedral crystals of the corresponding salts of the dextro- and lævo-acids, and in their opposite rotatory effect in solution upon the plane of polarised light, we recognise something like a torsioned state of the whole homogeneous substance, something to be accounted for by peculiarity of chemical origin, but not something made more intelligible by any imagined arrangement of unlike parts. It is possible to give an account of the chemical facts without making reference to mechanical structure, and then to reason about them somewhat in the following way: Given the case of a substance doubly equipped with the power to take part in a certain interaction, and considering that the exercise of the power can only be single, and that it cannot be made without affecting and transforming, or perhaps nullifying, the second equipment with power, predict what will happen. That is the prediction called for concerning any interaction which generates an asymmetric carbon compound. The result could never have been predicted; yet how natural and beautiful it is when it comes to us through

experiment enlightened by the genius of Pasteur, Le Bel and Van 't Hoff! That answer is that a twinned substance results, one indeed in most respects and chemically, but two in certain physical properties, characterised by presenting phenomena as of equal and opposite strains, a polarised pair of substances, in fact. What I mean by the double equipment with power is, of course, the pair of identically related and self-identical radicals, or the bivalency of one radical wholly and directly associated with the carbon radical. The case of the oxygen radical of aldehyde is that of the bivalent radical; the other case is that of the two carboxyl radicals of hydroxytartronic acid, or that of the two methylene hydrogen radicals of alcohol which these carboxyls have replaced. The tetrahedral formula with its reflected form admirably symbolises the case of enantiomorphously related pairs of substances. But no light whatever is thrown upon the nature of this pairing by the tetrahedron model; its value depends upon the fact that as a symbol it so fully matches the constitution of the substances.

Here I bring my summary of chemical theory and its formulation without hypothesis to a conclusion, hoping that, to some extent, I may have impressed you with the fact that the exposition of even advanced chemistry, in its symbolic, equally as in its ordinary language and nomenclature, is independent of any hypothesis as to the mechanically and chemically differentiated structure of substances, and that chemistry can be studied and still further developed without reference to such a structure. I have asked for few or no reforms in the use of either terms or symbols, my point having been only to press for a consideration and discussion of the doctrines of chemistry and the great atomic theory itself as something concerned exclusively with experimental chemical facts.

SECTION C.

GEOLOGY.

OPENING ADDRESS BY LIEUT.-GENERAL CHARLES ALEXANDER McMAHON, F.R.S., F.G.S., PRESIDENT OF THE SECTION.

Rock Metamorphism.

I WISH to offer some observations to-day on some aspects of rock metamorphism; and as this is a complex subject, and the time at my disposal is brief, I purpose to deal with it in simple language, and to avoid as far as possible all petrological technicalities.

A short description of a granite in the Satlej Valley of the Himalayas will, I think, introduce us by a short cut to the consideration of "contact metamorphism," an important branch of the subject under consideration.

The granite I allude to is an intruder in the normal gneissose-granite of the Himalayas, and cuts through it at right angles to its foliation.

The intruder, which is some yards wide, did not rise through a simple crack or fissure, for its passage upwards was interrupted by a sheet of dark intrusive diorite, older than itself, which ran, roughly speaking, parallel to the foliation of the gneissose-granite.

This sheet of diorite offered considerable resistance to the rising granite.

The granite zigzagged backwards and forwards across the diorite and ran along its edges for fifty yards or more, converting it into a mica trap.

It then tore itself away and continued its upward course. The granite I am describing was in a molten or fluid condition at the time of its eruption, as I hope to show in my subsequent remarks.

I may pause here, however, to consider in passing what was the probable temperature reached by a granite such as that above described.

The question is one of very great difficulty, as we know so little about the plutonic conditions of igneous rocks, and can only arrive at an answer to our question by indirect evidence.

The melting point of quartz ranges from 1425° to 1450° C., but the fusion point of granite need not necessarily be as high as this, inasmuch as the presence of water at high temperature materially lowers the melting or solution point.

The fusion point of the other constituents of granite may here be mentioned: that of orthoclase ranges from 1164° to 1168°; microcline, 1169°; albite, 1172°; augite and hornblende, 1188° to 1200°; apatite, 1221°. Zircon, which is commonly found in

granites, and is one of the first minerals to separate out of the magma, is shown by Ralph Cusack to have probably a melting point of 1760°; whilst topaz, a not uncommon mineral in granite, is infusible up to the melting point of platinum, namely, 1770° C.

If we consider, therefore, the melting points of the mineral constituents of granite, we can hardly avoid the conclusion that for the magma to have attained perfect fluidity it must have reached a temperature of at least 1200° C.

Vernadsky has shown that kyanite is transformed into sillimanite, a well-known product of contact-metamorphism at a temperature of 1320° to 1380°.

If rocks in contact with granitic masses have been raised to this temperature, it follows that the granite itself must have been still more heated. Vernadsky's observations have been relied on by Mr. George Barrow in his well-known paper "On an Intrusion of Muscovite-biotite Gneiss" in the S.E. Highlands of Scotland to account for the presence of sillimanite in the inner zone of metamorphism between the kyanite schists and the granite, and he considered that the temperature attained by the "central masses of the Highland rocks" was probably higher than the figures indicated by Vernadsky.

Bearing all considerations in mind, including the influence of water and alkali in reducing, and of pressure in raising, the melting point, I think we may safely infer that granites, such as the Himalayan granite alluded to above, must have been raised at plutonic depth to a temperature midway between red and white heat, that is to say, to at least 1200° C.

To return to the granite of the Satlej Valley under consideration, I wish to draw attention to its condition just before crystallisation commenced.

A study of the mineral beryl will, it seems to me, throw light on this point.

Beryl is an important accessory mineral of the granite under description. It is clearly an original mineral, and it is material to note that it was the first mineral to crystallise out of the magma of the Satlej granite. This is shown by several circumstances.

In the first place the beryl preserved its perfect crystallographic shape, showing that its molecules during the entire period of crystallisation possessed comparative freedom of motion, and were not interfered with or molested by other solid minerals. In the second place all the essential minerals of the granite when they subsequently crystallised out of the magma were deposited on the crystals of beryl. I have specimens of the granite showing crystals of beryl enclosed in feldspar, in muscovite and in quartz.

The beryl, therefore, having been the first mineral to crystallise, the examination of thin slices of it under the microscope ought to give us a clue to the condition of the magma at the time the beryl was formed.

I have made such an examination, and I find that the beryl is crowded with liquid and gas cavities, the former containing movable bubbles and deposited crystals as well as water.

The bubbles are of substantial size relative to the area of the cavities, showing that the water suffered considerable contraction after it was sealed up in the beryl.

Scrope long ago suggested that the fluidity of lavas below the melting point was due chiefly to the water they contained, and attributed the liquidity of granite to the same cause.

Scrope, however, in ascribing the mobility of an igneous rock to the presence of water, seems to have had regard principally or wholly to its mechanical action in furnishing an elastic medium in the interstices between the crystals or grains of the rock. He observes that a lava consists "of more or less granular or crystalline matter, containing minute quantities of either red-hot water, or steam in a state of extreme condensation, and consequent tension, disseminated interstitially among the crystals or granules, so as to communicate a certain mobility to them, and an imperfect liquidity to the compound itself," and he quotes Scheerer and Delesse, both of whom assert that water exists in mechanical combination with all crystalline rocks, "its minute molecules being intercalated between the crystals."

Nowadays one would attribute the liquidity of an igneous rock not so much to the mechanical action of the water present in it as to the combination of the water with the mineral contents of the lava, producing a state of solution.

Sorby's investigations supported Scrope's observations, for he proved that the liquid contained in the inclusions in granite is

water, and showed that it was caught up during the formation of the crystals, "and was not introduced subsequent to the consolidation of the rock."

The water now contained in cavities in the beryl was probably held in solution by the constituents of that mineral at the time of its formation, and as it cooled down the water separated from the substance of the beryl and formed the cavities in which we now find it imprisoned.

If this be so, it follows that when the beryl crystallised out of the magma, the latter was in a fluid condition, and held a considerable amount of heated water in solution. The temperature of the magma must have been above that of red heat, and the potential energy of the water held in a fluid state by pressure must have been great. When therefore in the course of the earth movements which accompany or in some cases are caused by the intrusion of eruptive igneous masses, pressure was temporarily relieved by the rupture and faulting of rocks, the superheated water contained in the magma would be ready to flash into steam with almost explosive violence.

It must also be borne in mind that water under great pressure, at or above a red heat, has a powerfully solvent action on most minerals, even on so refractory a mineral as quartz. When therefore granite in the molten and fluid condition of the Satlej granite was erupted along a line of faulting, fissure, or weakness, the superheated water or steam, bearing with it much mineral matter in solution, must have acted with great chemical energy on the rocks into which it was intruded.

I have spoken of water carrying mineral matter in solution, and of a magma carrying water in solution. These two conditions may rapidly succeed each other under varying conditions of temperature and pressure. To use the words of Van Hise, "under sufficient pressure and at a high temperature there are all gradations between heated waters containing mineral material in solution and a magma containing water in solution."

The condition of the beryl crystals, crowded as they are with liquid cavities, shows how high a proportion of superheated water was contained in the fluid granite magma at the time of their formation.

Sorby estimated that the fluid cavities in the quartz of granites sometimes amount to more than ten thousand millions to the cubic inch. As quartz, however, is usually the last mineral of a granite to consolidate, it may be thought that the water contained in it is a residuum left by the felspar and muscovite on their separation from the magma; but the case of the beryl above quoted shows clearly that the amount of water diffused through the magma before the mica, felspar and quartz began to consolidate must have been very considerable. The amount of water held in solution by a granite, during the time of its aqueo-igneous fusion, cannot be estimated by the amount of water given in the analysis of consolidated and dried hand-specimens of that rock. A considerable proportion of this liquid must necessarily have been lost during the gradual cooling of the rock, and in the course of its intrusion into neighbouring sedimentary strata as sheets, dykes and veins. Sorby, as the result of other lines of investigation, came to the conclusion that the amount of water present in granite, though limited, is considerable.

We must now turn for a few minutes to consider the important question of the porosity of minerals, and their permeability by heated water and gas at high pressure.

The fact that solid substances are built up of molecules having interstitial spaces between them hardly needs demonstration nowadays.

But have we all quite realised that the molecules of rock-forming minerals and crystals are not inert particles of matter, but that they vibrate or revolve or are endowed with other orderly movement that may be likened to the motion of the planets round the sun?

Far, far away in space the solar system would, to an eye formed like our own, in all probability present a nebulous appearance, because the eye would not be able to see the individual members of our system.

So, too, the molecules of which crystals are built up may have their appropriate motions, but we cannot see them with the eyes of sense because the molecules are beyond the highest powers of the microscope.

We can, however, I think, perceive them with the eye of the scientific imagination; and the hypothesis that the molecules of minerals are separated from each other by intermolecular spaces,

and have their modes of motion, seems essential to the comprehension of rock metamorphism.

The important experiments of Sir W. Roberts-Austen on the diffusion of gold in pure lead throw considerable light on this subject.

Disks of solid gold were held against the bases of cylinders of lead by clamps, and were kept in an upright position at the ordinary temperature for four years. At the end of this time it was found that the gold had diffused upwards in the solid lead, for a distance of 7.65 mm., in sufficient quantity to be detected by the ordinary methods adopted by assayers. Traces of gold were found still higher.

When a column of molten lead, 16 cm. high, was placed above solid gold and kept at a mean temperature of 492° C., that is to say, at 166° above the melting point of lead, but 569.7° below that of gold, the gold diffused in considerable amount, to the top of the lead column, in a single day.

Sir W. Roberts-Austen's experiments, above alluded to, demonstrate that even such metals as gold, whose melting point is as high as 1061.7° C., exhibit a measurable amount of kinetic energy at the ordinary temperature and pressure. Great results may no doubt be brought about at ordinary temperatures and pressures, when time, as in the laboratory of nature, is practically unlimited; nevertheless the importance of high temperature and high pressure, in operations connected with metamorphism, can hardly be overrated.

Not only does a rise in temperature increase the energy of the chemical actions and reactions which produce the mineralogical changes embraced by the term metamorphism, but it increases the porosity of minerals and facilitates the passage of liquids and gases through their pores.

The cohesion of molecules is lessened, the amplitudes of their vibrations, rotatory or other movements, are increased, and a passage is opened for the advance of chemical materials into the heart of the crystal.

Increase of temperature thus not only throws open the doors of the mineral fortress attacked, but gives enhanced energy to the invaders. The fact that the mineral components of a rock are, under conditions of heat and pressure practically porous to heated water, laden with chemical reagents in solution, is frequently brought home to the mind of the petrologist in a very tangible way. We sometimes observe, for instance, that metamorphic changes begin at the heart of a crystal, and leave the peripheral portions of it fresh and unaltered.

In such cases the chemical agents of change have evidently passed freely through the outer parts of the crystal, and have by preference selected its internal parts for attack.

In order to explain clearly how this remarkable result takes place, in the cases referred to, it will be necessary to diverge for a few minutes to consider another branch of our subject. It is difficult, if not impossible, to lay down any hard-and-fast rule of universal application, because the conditions under which igneous rocks crystallise vary with temperature, pressure, the relative proportion of constituents and other local causes, and these variations in the conditions may materially affect the results; but I think the rule that minerals crystallise out of a molten magma in the order of their basicity is of very frequent if not of absolutely general application. This rule also governs the growth of individual crystals, especially those that exhibit what is known as zonal structure. Take, for instance, the felspars of an igneous rock. A gradual passage may frequently be traced by the petrologist from one species of felspar at the heart of a crystal to another distinct species at its periphery. Sometimes a crystal is made up of more than two species, which shade more or less gradually into each other. In accordance with the rule laid down above, the more basic species formed first; then, as the percentage of the bases left in the magma gradually decreased, owing to the first formed crystals having taken a lion's share of the available bases, the felspars that formed later became gradually more and more acid in composition. Thus a large felspar of slow and gradual growth may be composed of several zones, each zone being successively less basic and more acid than that upon which it crystallised, each successive zone thus possessing slightly different physical properties from the one that formed before it. These statements are capable of proof. When sections of felspar, such as occur in thin slices of igneous rock, are examined under the microscope in polarised light, petrologists can distinguish one species from the other—when the direction in which the sections were cut is approximately known

—by measuring the angles at which they extinguish from the twinning or the pinacoidal plane.

This is not mere theory. Each species of feldspar has its own angle of extinction and its own index of refraction. The determination of these two factors enables a petrologist to prove optically the change in composition; or, in other words, the change in species which has taken place in the successive zones, during the gradual growth of a large zonal feldspar.

Another general rule must now be mentioned. I think it may safely be asserted as a broad rule that the different species of feldspars are attackable by the chemical reagents which make themselves felt in metamorphic action, in the order of their basicity; that is to say, the more basic feldspars are more easily attacked than the acid ones. When we bear in mind the facts stated above, we shall, I think, be able to see clearly how it is that the peripheral portions of large feldspars in igneous rocks sometimes escape alteration, whilst the cores of these crystals are converted into secondary minerals, such as chlorite, silvery mica, zoisite, epidote, kaolin, steatite, saussurite, calcite and scapolite.

The chemical reagents flowing in solution through the pores of the feldspars, pass by the more acid and refractory species and devote their energies to the more susceptible basic species embedded at the heart of the zonal crystals.

The point I wish to enforce most strongly is that the phenomenon above described, namely, the formation of secondary metamorphic minerals in the interior of a crystal, combined with the comparative immunity to change of the external portions, shows that the agents which brought about chemical changes at the core of the crystal flowed freely through its unaltered peripheral portions.

But some may ask whether the chemical agents referred to may not have gained access to the heart of a crystal by a crack. I answer that a crack is a coarse and tangible object that looms large under the microscope. A crack in a mineral liable to metamorphic action, through which chemical reagents have flowed, could not escape detection. The finest crack through a homogeneous mineral, such as, for instance, an olivine, can be readily seen, not only by the small canal worn by the corrosive action of the chemical agents that flowed through it, but by the alteration set up in the mineral along the whole course of the canal.

I have a thin slice from a beautifully fresh olivine contained in one of the lavas of Vesuvius collected by myself. A volcanic explosion or other cause, operating after the crystallisation of the olivine, produced a very fine crack in the mineral through which water, charged with chemical reagents, subsequently flowed. The crack, though of microscopic width, is filled with serpentine, and on both margins fibrous serpentine has been formed at the expense of the parent olivine, and constitutes a fibrous band on both sides of the crack throughout its entire length, the direction of the fibres being at right angles to the crack.

The rest of the olivine is of virgin purity and polarises in the most brilliant colours, contrasting strongly with the serpentine.

In this case it is clear that the chemical reagents, through free to flow along the crack, had commenced to extend beyond its walls, encouraged thereto by the porosity of the olivine itself. But how different is this case from those in which the entrance of the chemical agents had not been facilitated by a crack. In the case above described, the chemical changes set up were limited to the borders of the crack, and even had they gradually extended in the course of time to the whole of the olivine, the original canal by which the chemical reagents had gained access to the crystal would have remained to tell its tale, and exhibit along its course the banks of iron oxide thrown down by the chemical navvies that had excavated it.

Cracks save time as roads and canals do, but they leave behind them evidence of their former existence. In order to understand fully how rocks and minerals are so completely open to the attacks of chemical reagents, which penetrate and produce chemical and mineralogical changes at the very hearts of minerals, we must fully realise how completely porous rocks and minerals are, to the heated liquids which carry these reagents with them in solution. Heat, as before stated, not only increases chemical energy, but destroys more or less completely the cohesion between molecules, and increases the amplitude of the vibrations, or other motions of the molecules, and consequently facilitates the entrance of liquids and gases into the pores of minerals, and their complete permeation by these powerful agents of change. Thus far we have been

chiefly concerned with some of the principles underlying the branch of our subject embraced by the term contact metamorphism, which implies operations conducted at considerable depths below the surface of the ground, under conditions of heat and pressure.

We must now consider very briefly changes produced at or near the surface by the agency of water, or, as Bischof in his well-known work termed it, metamorphism in the "wet way."

No hard-and-fast line, however, can be drawn between the two classes of operations, as the one gradually shades by fine gradations into the other. At one end of the scale we have high pressure and high temperature, and a fluid igneous magma holding water in solution, above a red heat, and giving up heated water or vapour charged with salts to the rocks in contact with it.

Passing to the other end of the scale through diminishing temperatures and pressures, we reach a condition in which the water circulating through the rocks at ordinary pressure and temperature is more abundant in amount, and holds acids and salts in solution, capable of setting up important chemical reactions in the rocks and minerals to which it gains access.

In the case of surface operations, moreover, the metamorphic agents—water, acids, salts—are being constantly renewed. Conditions differing as widely as the conditions at the extreme ends of our scale do not yield, however, precisely the same results. In both metamorphic change goes on with more or less briskness, but the products are different. Some minerals require great heat and great pressure for their production, and such minerals are never formed by any surface process of weathering. For instance, the temperature reached determines whether titanium dioxide crystallises as rutile, or in one of its other two forms, rutile requiring a temperature of more than 1000° C., and being the only form of titanium dioxide "stable at a high temperature."

Temperature also seems to determine whether the silicate of alumina crystallises as andalusite, kyanite or sillimanite, the two former being transformed into the latter, at a temperature of 1320° C. to 1380° C.

On the other hand, some minerals require little heat for their formation, and are readily produced by metamorphic changes in the "wet way."

There seems to be some correspondence between the melting point of minerals and their density; thus in the case of eleven minerals produced by contact metamorphism, whose average specific gravity ranges from 3.06 to 4.03, I find that their melting point ranges from 954° to above 1770° C., high temperature and high pressure (a concomitant of plutonic conditions) appearing to be factors in the production of high specific gravity in minerals.

The genesis of individual species of minerals is a fascinating study, but the subject is too large to enter upon here.

Water gains access to rocks in several ways. It falls as rain; it rises from hidden depths; it leaks from the sea into horizontal beds or into strata dipping away from it; and it penetrates through faults and fissures. Rain in its descent takes up from the air oxygen, nitrogen, carbonic acid, and in some cases small amounts of nitric acid.

It is thus in itself a powerful solvent and potent agent in producing chemical change.

In its passage through the surface soil it dissolves humic and other organic acids, the products of vegetable decay, which add greatly to its solvent power and enable it to break up many silicates and to dissolve even silica.

By the time the rain-water reaches the solid rocks below the surface soil, it has become a very active agent in producing chemical change in them. It is by such agents, persistently applied during long periods of time, that large areas of ultra-basic igneous rocks have been altered into serpentine.

Hot springs are a well-known instance of water rising in considerable quantity from plutonic depths. They are known to occur in the plains of India, and are especially abundant in the Himalayas. I visited two very interesting ones at Suni, in the bed of the Satlej River, west of Simla. These springs rise apparently under the very bed of the river, and come to the surface on both banks within a yard or two of the rushing water of the Satlej. When I visited the springs they had a temperature of 130° F., and contrasted strongly with the cold water of the river flowing past them, which had descended from high Himalayan glaciers and had a temperature of 49° F.

The native inhabitants of neighbouring villages told me that

the hot springs always appear at the very edge of the river, whatever may be the height of its waters during drought or flood. The statement is probably true, for I think the springs well up from below through the walls of a fault that traverses the bed of the Satlej at a high angle to its course, and the springs thus come to the surface on both its banks.

The metamorphic influence of these springs on the rocks in this locality has been very powerful. The ancient volcanic rocks there exposed have, for some distance up the river, been altered by aqueous agents almost out of recognition. The original structural characters of these lavas have been almost completely broken down and an amorphous substance substituted for the crystals and minerals of which they were originally composed.

This result shows that the crystals and minerals of these old lavas must, for all practical purposes, have been completely porous to the aqueous agents brought to bear on them.

The general transmutation of one mineral into another by the action of heated water holding mineral agents in solution, aided by heat and pressure, may take place in a variety of ways. Some of these processes are simple, but others are highly complex. Many are the results of a single operation, others of a series of changes, some of which prepare the way for those that follow.

In some cases the change may be brought about by the removal, in whole or in part, of one or more of the essential constituents of a mineral, whereby the relative proportions and mutual relations of those that remain are altered, as the following examples will show.

By loss of water limonite passes into hæmatite, and opal into crystalline quartz. Dyscrasite, by loss of antimony, passes into native silver, and pyroxene, by the removal of its lime and iron, is changed into talc. Simple oxidation or the absorption of oxygen by a mineral is responsible for another class of changes, as in the conversion of zinc blende into goslarite, and antimony into valentinite.

The loss of one or more of the ingredients, concurrently with the introduction of one or more new ones, causes many metamorphic changes, as in the conversion of marcasite into magnetite, of witherite into barite, and of azurite into malachite.

The well-known conversion of a peridotite into serpentine is a case in point. Here, part of the iron and magnesia is removed from the olivine, and water is introduced. A simple process like this, brought about by the percolation of surface waters through an igneous rock, is sufficient to transform considerable areas of rock masses into serpentine, as has been the case in parts of Cornwall.

Some metamorphic processes are more complex than those alluded to above, but Nature has unlimited time at her disposal, and is able to manufacture potent chemical reagents as her processes proceed. For instance, the sulphides of various metals of common occurrence in rocks, most of which, with the exception of those of the alkaline metals, are insoluble in water, by taking up oxygen pass into sulphates, most of which are soluble in that liquid at the ordinary temperature.

These sulphates are readily carried away in solution, and become potent factors of change in rocks through which water charged with these salts flows. Again, carbon dioxide, so abundant in percolating water, decomposes minerals containing lime or alkali, and removes them as soluble carbonates to effect powerful chemical reactions elsewhere.

I must pass over the subjects of paramorphism and pseudomorphism, as the limited time at my disposal does not permit me to enter upon these subjects.

In the above sketch I have contented myself with a brief discussion of some of the leading principles that seem to me to underlie contact action and metamorphism in the wet way, because I venture to think that, if we really understand these two divisions of our inquiry, it will be unnecessary on the present occasion to enlarge on other branches of our subject.

Take, for instance, what is commonly called dynamic metamorphism. The main factors in this kind of metamorphism are the folding, crumpling, crushing and shearing of rocks by earth movements, especially during the upheaval of mountains.

But these dynamic forces are potent factors in the development of heat.

In the case, therefore, of dynamic metamorphism, as in contact metamorphism, pressure and heat are the main factors acting in conjunction with the water shut up in or circulating

through a rock. If we understand how these factors operate and produce the results we see in cases of contact metamorphism, we shall not fail to understand their action in a case of dynamic metamorphism.

These observations also apply to regional metamorphism; that is to say, to metamorphism produced in rocks at great depth, by being brought within the influence of the interior heat of the earth. The action of heat in increasing molecular motion and kinetic energy is well understood nowadays, and so long as we get heat it seems to me immaterial how heat is generated in rocks subject to metamorphic action.

In the above sketch I have intentionally omitted to enter into the details of chemical and mineralogical action that have brought about individual cases of metamorphic change.

Volumes would be required to do justice to so complex a subject, and the details would, in an opening Address, be out of place.

In conclusion I have, I trust, shown how important a part water plays as an agent of metamorphism, not only at and near the surface of the earth, but at plutonic depths. We have seen that the molten granite of the Satlej Valley, which was given as an illustration of a fluid igneous magma, contained a considerable proportion of water held in solution at considerably above red heat, and that the fluidity of the magma was due to its presence. We also saw that the great heat to which the magma was raised increased the potential energy of the contained water when a relief of pressure opened the way for the intrusion of the molten magma into neighbouring rocks. We also saw that this water was rendered by heat a powerful solvent, and that it carried with it into the adjoining rocks the mineral matter of the granite in solution. We also saw that heat increased the porosity of minerals, facilitated the passage of liquids laden with mineral matter through their pores, and increased the potency of chemical action.

SECTION F.

ECONOMIC SCIENCE AND STATISTICS.

OPENING ADDRESS BY EDWIN CANNAN, M.A., LL.D.,
PRESIDENT OF THE SECTION.

If it happened every year that the President of this Section undertook to justify his own existence, I am afraid the Section would become weary. But my four distinguished predecessors have all been drawn from the Civil Service, and though each of us may have doubts about particular branches of the Civil Service, we are mostly willing to allow that as a whole it is at least a necessary evil, so that we do not get apologies from the Presidents who, so to speak, represent the practice of political economy. I hope, therefore, that you will bear with me if I offer some reasons for thinking that the teaching and study of the theory of economics is not, as many people seem to suppose, a wholly unnecessary evil, but, on the contrary, a thing of very great practical utility.

I do not mean to argue that a knowledge of economic theory will enable a man to conduct his private business with success. Doubtless many of the particular subjects of study which come under the head of economics are useful in the conduct of business, but I doubt if economic theory itself is. It does not indeed in any way disable a man from successful conduct of business; I have never met a decent economist who was in a position of pecuniary embarrassment, and many good economists have died wealthy. But economic theory does not tell a man the exact moment to leave off the production of one thing and begin that of another; it does not tell him the precise moment when prices have reached the bottom or the top. It is, perhaps, rather likely to make him expect the inevitable to arrive far sooner than it actually does, and to make him underrate, not the foresight, but the want of foresight of the rest of the world.

The practical usefulness of economic theory is not in private business, but in politics, and I for one regret the disappearance of the old-name "political economy," in which that truth was recognised.

One of the commonest complaints of the time is that there is no text-book of economics which commands any really wide approval, and you may therefore, I think, fairly ask me to explain what I mean by the teaching and study of economic theory before I undertake to prove its practical usefulness in the discussion of legislative and administrative measures. I will

therefore endeavour to sketch as shortly as possible the course of instruction which the modern teacher of economic theory, if unhampered by too close adherence to traditional standards, puts before those who come to him for instruction.

The first, or almost the first, thing he will do is to try to open the eyes of his pupils to the wonderful way in which the people of the whole civilised world now cooperate in the production of wealth. He may perhaps read them Adam Smith's famous description of the making of the labourer's coat, a description which required three generations and three great writers to elaborate in the form in which we know it. Or he will ask them to consider the daily feeding of London. There are, he will point out, six millions of people in and about London, so closely packed together that they cannot grow anything for their own consumption, and yet every morning their food arrives with unflinching regularity, so that all but an infinitesimal fraction of them would be extremely surprised if they did not find their breakfast ready to hand. To prepare it they use coal which has been dug from great depths hundreds of miles away in the Midlands or Durham; in consuming it they eat and drink products which have come from Wiltshire, Jamaica, Dakota, India, or China, with no more thought than an infant consuming its mother's milk. It is clear that there is in existence some machinery, some organisation for production which, in spite of occasional failures here and there, does its work on the whole with extraordinary success. It is easy to be pessimistic, especially when the weather is damp, and we are apt to concentrate our attention, and to endeavour to make others concentrate their attention, on this or that defect, and to forget that the system is not made up of defects, but on the whole works very well. Imagine the report of a really outside observer. In all civilised planets, I have no doubt, there must be an institution more or less resembling the British Association. An economist in Mars, let us say, has been favoured with a glimpse of this island through a new mammoth telescope of sufficient power to let him see us walking about, and he is reporting to Section F what he saw. Will he say that he saw a confused scramble for the scanty natural products of the earth? That most people were obviously in a state of starvation? That few had clothes? And that scarcely any were housed? No, truly; he will be much more likely to report that he saw a wonderfully orderly population, going to and from its work with amazing regularity, without a sign of compulsion or unwillingness; that it appeared to be fed and clothed and housed in a way extraordinarily creditable on the whole to some mysterious organisation, the nature of which he could only guess at.

Having endeavoured to make his pupils recognise that we are organised, and that the organisation works, the teacher will go on to show how it works; why things that are wanted are produced in the places where they can be easiest produced and taken to the places where it is most convenient to consume them; why people go to live in large numbers in spots where it is desirable they should work, and leave great areas sparsely inhabited; why more people are brought up to follow an occupation when the desire for its products increases, and fewer when it decreases; why if the harvest is short the consumption is economised so as to spread it over the year; and so on. The answer to all these questions is of course "self-interest" or "the hope of gain." Durham coal, Wiltshire milk, Danish butter, Jamaica sugar, Dakota wheat and China tea go to London because it pays to send them there. People congregate in London or Belfast because it pays them to work there. More do not come because it would not pay them. Young people leave agriculture and go to towns to make agricultural implements or bicycles because it pays. The consumption of grain is economised and spread over the year because it pays to hold the stock. If people with one accord left off doing what paid we should all be dead in two months.

The reasons why it pays to do the right thing—to do nearly what an omniscient and omnipotent benevolent Inca would order to be done—are to be looked for in the laws of value. This used to be regarded as a somewhat arid subject, but the discussions of recent years, especially the contribution made by Jevons and the Austrian school, have fertilised it. Long ago economists pointed out how the much-abused corn-dealer who held out for a higher price saved the people from starvation; and we now, thanks to the theory of final utility, not only know that it is a fact, but also why it is a fact, that value rises with the extent and urgency of demand, so that when a thing is much wanted, much is offered to those who produce it, or are ready

to part with it, and consequently its production is stimulated or its consumption economised, as need be.

This will naturally lead to the question of distribution—the question, that is, why much of the produce falls to the share of one individual and little to that of another; why, in a word, some are rich and others poor. The teacher will here explain that the share of each person depends on the amount and value of his contribution to production, whether that contribution be labour or the use of property. He will show how this system of distribution is essential to the existing system of production, where no man is compelled to work or to allow his property to be used by others, and where every man has legal freedom to choose his own occupation and the uses to which he will put his property. He will beware of claiming for it that it is just in the sense in which justice is understood in the nurseries where jam is given when the children are good. There is, he will explain, no claim on behalf of the system that it rewards moral excellence, but only that it rewards economic service. There is no claim that economic service is meritorious. Whether a man can and does perform valuable economic service does not by any means depend entirely on his own volition. His valuable property may have come to him by bequest or inheritance; his incapacity to do any but the least valuable work may be the result of conditions over which he has had no control. The system exists, not because it is just, or to reward merit, but because it is inextricably mixed up with the system of production. It has one great evil—its inequality. Moralists and statesmen have long seen the evils of great inequality of wealth, and now, thanks to modern discoveries in economic theory, the economist is able to explain that it is wasteful, that it makes a given amount of produce less useful, because each successive increment of expenditure yields, as a rule, less enjoyment to the spender. The teacher will go on to show how this organisation of production and distribution is made possible by the order enforced by Government, and how, in various ways, Government supplements or modifies it; but I shall not enlarge upon this part of the teaching of economics, as its practical usefulness is obvious. My theme is the usefulness of the other part, the explanation of the organisation of production and distribution in so far as it depends on separate property, free labour, and the consequent action of self-interest.

In the first place, I maintain that the widespread dissemination of such teaching would help to do away with a vast amount of most disastrous obstruction of necessary and desirable changes. Take, for example, the obstruction offered to changes in international trade. Of course every conceivable argument has been used by different writers in wholly different circumstances for obstructing the cooperation of mankind in production, as soon as it oversteps a national boundary. But what is the real support of this kind of obstruction? Obviously the fact that certain producers, or owners of certain means of production, are damaged by an increase in the importation of a particular article. Their loss, their suffering, if their loss is severe enough to deserve that name, appeals to popular compassion, and their request for "protection" is easily granted, the new trade is nipped in the bud, and things are forced to remain in their accustomed channels. The same principle is not applied as between county and county or between province and province, simply because there is then visible to everyone an opposing interest, the interest of the new producers, within the hallowed pale of the national boundary. Adam Smith tells us that when the great roads into London were improved, some of the landlords in the home counties protested on the ground that the competition of the more distant counties would reduce their rent. The home counties did not get the protection they wanted, because it was obviously to the interest of the more distant counties that they should not have it. These two interests being balanced, the interest of the consumer, London, turned the scale. So it usually happens that beneficial changes in internal trade are allowed to take their course without obstruction because the votes of two sets of producers counteract each other, and the consumer's interest settles the question. But in international trade one of the two sets of producers is outside the country; it consists of hated foreigners, the fact that it will benefit is an argument against rather than for the threatened change in trade, and the consumers therefore feel it patriotic to sacrifice their own interest and vote for protection. But if they were properly instructed in economic theory they would see at once that such magnanimity is entirely misplaced. They would see that it would cut away all international trade, since, if

there were no fallacy involved in it, the stoppage of each import taken separately would benefit home producers and damage foreign producers. Even if some of the imported commodities could not be produced at all at home, substitutes, more or less efficient, could be produced and give all the more employment. Having acquired some notion of the advantages of cooperation and the territorial division of labour, the consumers would regard this as a *reductio ad absurdum*, and after thinking a little further they would soon see that, after all, there is another set of producers, actual or potential, within the country who will gain—namely, the producers, present or future, who will supply the articles which are to go abroad in exchange for the new import. They will see that what they are asked to do is not to maintain the amount of national production, but merely to prevent a change in its character which will be accompanied by an increase in its amount.

Take another example of Chinese obstructiveness to desirable change. As great cities grow, it becomes convenient that their centres should be devoted to offices, warehouses and shops, and that people who work in these places, and still more their families, should live in the outskirts. I do not know that anyone has denied this. Certainly the great majority are willing to admit it. At one time it is believed that a quarter of a million people lived in the square mile comprised within the City of London; no one supposes that would be convenient now. There is no reason to suppose that further change in the same direction will not be desirable in the future. Yet, incredible as it will appear to future generations, public opinion, the House of Commons, the London County Council and some town councils think, or at any rate act as if they thought, that the process has now gone far enough and ought to be stopped; as if the state of things reached about the year 1891 was to be permanent, to last for ever and ever. Private owners are indeed still allowed to pull down dwelling-houses and erect shops and offices, but they are abused for doing so, and their liberty is at least threatened. But if a new railway or a new street is made—in all probability with the intention of increasing the accessibility of the centre from the suburbs—if even a new London Board School is built, and houses inhabited by persons who have less than a certain income are pulled down in any of these processes, it is required by law or parliamentary resolution that other houses for these people must be built in the neighbourhood. So it comes about that there are in quarters of London most unsuitable for the purpose enormous and repulsive barrack dwellings, the sites of which are devoted *in secula seculorum* to the housing of the working classes; while the immense cost of devoting them to this instead of to their proper purpose is debited to the cost of improving the facilities for locomotion or to education, and is defrayed principally by the rates on London property, which chiefly consists of houses, and to some extent by the higher charges on the railways consequent on the restriction of facilities for extension. Fifty pounds a head is the average loss involved to the rates of London on every man, woman and child for whom these dwellings are provided. Such is the wisdom of practical men uninformed by instruction in economic theory.

This palpable absurdity could never have been perpetrated if the general working of the economic organisation had been understood. In that case it would have been seen at once that the extrusion of over 200,000 inhabitants from the City of London in the past, which is admitted to have been desirable, was effected by the quiet operation of the laws of value. It would have been seen that as it became desirable to turn the City to other purposes, the ground in the City became too valuable to use as bedrooms and as living-rooms for mothers and children, and this increase of value drove out the 200,000 inhabitants. It would have been seen that the change had not come to an end, and no responsible body would have dreamt of putting themselves in opposition to it by buying sites and writing them down to 2 per cent. of their actual value in order that they might be tied up for ever and ever to be the homes of a certain number of persons with less than a certain income. If some unusually dense individual who had failed after many attempts to pass his examination in economic theory had proposed the policy which has been adopted, he would have been asked two questions: first, "What peculiar sanctity is there about the position occupied in the closing years of the nineteenth century? Why should this be stereotyped for all time? Why should not the position at the end of the seventeenth century have been maintained? Why should we not endeavour to

restore the working classes to their old home in the City, and remove the Bank of England to Tooting?" Secondly, "Whom do you imagine you will benefit by the policy you propose?"

It is difficult to conceive of any answer to the first question. To the second the reply of the dunce would of course be that he thought the policy proposed would benefit the people housed on these expensive sites. This answer would at once be condemned as unsatisfactory. To build houses on land worth 100,000 $\frac{1}{2}$, and let them to the first-comers of respectable antecedents at rents which would pay if the land were worth 2000 $\frac{1}{2}$, would be a very stupid sort of almsgiving if these respectable first-comers actually got the difference between the interest on the 100,000 $\frac{1}{2}$ and the 2000 $\frac{1}{2}$. But no one supposes that they do get this difference or any considerable part of it. The difference is almost entirely pure loss to the community. The chief immediate effects of the policy are, first, to retain in the centre the men, women and children who inhabit the dwellings; secondly, to retain other workers who perform various offices for these inhabitants; and thirdly, to ensure a supply of labour for factories which would otherwise (to the advantage of everyone concerned) be driven into the country by the pressure of the high wages necessary to bring workmen to the centre or to pay their house rent if they lived there.

So much for the utility of economic theory in preventing obstruction of desirable changes. My second claim on its behalf is that it serves to hinder the adoption of specious but illusory projects. This, I think, may be illustrated by examples closely connected with those which we have already considered under the head of obstruction.

The people who are most anxious to obstruct changes in the channels of trade which are coming about of themselves because they are profitable, are often extremely anxious to promote changes which will not come about of themselves because they are not profitable. For this end one of their most favourite devices at present is a State or municipal subsidy to locomotion or transport between particular points. So we have shipping subsidies, free grants to light railways, the construction of unprofitable telegraph lines by the Post Office, and the advocacy, at any rate, of the construction of unprofitable tramways by municipalities. The practical man, uninstructed in economic theory, feels uneasy about such projects because he does not see where he is to stop, and he feels obscurely that a universal subsidisation would mean ruin. But he does not see why he should not go a little way, and he goes sufficiently far to involve a loss quite worth considering. A knowledge of economic theory would come to his assistance by showing him that, as a rule, the most profitable enterprises are those which it is most desirable to undertake first, and that the subsidisation of the less profitable does not create new enterprises, but merely changes the order from the more desirable to the less desirable. I suppose that if in 1830 Parliament had offered a sufficient subsidy a railway might have been at once made and worked from Fort William to Fort Augustus, to the great satisfaction of the inhabitants of Fort Augustus and the intermediate places. But it is obvious that it was more desirable, in the interests of the whole community, that the railway from Fort William to Fort Augustus should wait for seventy years, and that the railway from Manchester to Liverpool, and many others, should be made first.

Then, too, we find people who are not quite so stupid as to think the working classes should always remain in the places where they were at the end of the nineteenth century, alleging that the way to cure overcrowding is for local authorities to enter the building trade in a general way, and build houses inside or outside their districts, wherever it seems most convenient. To the mind uninstructed in economic theory it seems obvious that the larger amount of housing there is the less overcrowding there will be, and that the more housing local authorities provide the more housing there will be. Economic theory, with its explanation of the general working of the organisation of production, suggests two objections. First, an addition to the housing in any locality will not be effectual in diminishing overcrowding, in so far as it attracts new inhabitants to the spot; a policy which assumes that the comparative plentifulness of houses is not a factor in the determination of the enormous and perpetual migration of people from place to place which is indicated in the tables of birthplaces and births and deaths in the census, is doomed to failure. Secondly, economic theory suggests the reflection that the mere fact of a local authority building some houses will not cause the whole number to be greater, if for

every house built by the local authority one less is built by private enterprise, and that this is very likely to happen. Houses have been built by private enterprise in the past, and in these houses nearly the whole population is at present housed. I have seen an enthusiast for municipal housing stand in the empty streets of a town late at night, when every soul in the town was evidently housed, and say, in a tone of conviction, "Private enterprise has failed." In that town four small houses had been built by municipal enterprise and more than ten thousand by private enterprise, and private enterprise was adding hundreds every year, while the housing committee of the corporation was meeting once a year to re-elect its chairman. Is it likely that private enterprise will build as much when it is competed with or supplemented by—the term does not matter—municipal enterprise? Why should it? If the municipality turned baker, would the private bakers continue to bake as much bread? Is not the attempt to stop overcrowding by inducing local authorities to build houses exactly the same thing and just as absurd as it would be to attempt to cure under-feeding by opening municipal butchers' and bakers' shops?

In the long run, I admit, experience teaches. Protection has fallen once in this country, and I have little doubt that it will fall again if it becomes considerable. The policy of obstructing the removal of dwellings from the centre of a great city already excites opposition in the London County Council, though unanimity still reigns in those last homes of extinct superstitions, the Houses of Parliament. Chancellors of the Exchequer and finance committees may be trusted to offer a stout resistance, on what they call financial grounds, to any really great development of the system of subsidies. There is hope even that the municipal building policy may be checked by the laborious inquiries which show by statistics what everyone knows, that the poor are ill-fed and ill-clothed as well as ill-housed, and therefore lead people to consider how the poor may be made more able to pay for houses, among other things, instead of simply how houses may be built in the absence of an effective demand for them. But I claim that, in matters such as these, a more widespread appreciation of economic theory, and the quickened intelligence which that would produce, would save us much painful experience, many expensive experiments, and an enormous mass of tedious investigation.

Thirdly and, at any rate on the present occasion, lastly, I claim that the teaching and study of economic theory has great practical utility in promoting peace and good will between classes and nations.

Between classes within the same nation the peacemaking influence of economic theory lies chiefly in the fact that it tends to get rid of that stupid cry for "rights" and "justice" which causes and exacerbates industrial and commercial quarrels. When demand for some commodity falls, or supply from some new quarter arises, and profits and wages fall, the workers cry out that they are being unjustly treated, because they have the unfounded belief that reward is or ought to be proportional to moral merit, and they are not conscious of any diminution of their moral merit. They demand a living wage or a minimum wage and employment for all who happen to have been hitherto employed in the trade, rend the air with complaints, and get subscriptions from a compassionate but ill-informed public. We cannot, of course, expect people who suffer by them to regard even the most beneficial operations of the economic organisation with enthusiasm or even satisfaction. It would be absurd to do so. But all the same, it is true that a wider apprehension of the fact that it is only by raising and lowering the advantages offered by different employments that production is at present regulated so as to meet demand would not only diminish the dissatisfaction, but also, which is more important, diminish the actual suffering by causing transitions to be less obstinately resisted. The present fashion of deploring rapid changes of trade and dwelling-place is a most unfortunate one; the ordinary forms of labour do not, as a matter of fact, require such specialised ability that there should be much difficulty in changing from one to another; and surely it is much better for a man to work at several different things at different places in the course of his life than to stick for ever in the same place, surrounded by the same objects, going through the same monotonous round of duties. Anything which will weaken the present obstructive sentiment and lead people to regard the necessity of a change of employment or residence as a temporary inconvenience rather than a cruel injustice is to be warmly welcomed.

It is not, however, only the poor and the industrious who would be taught by a greater knowledge of economic theory not to kick against very necessary pricks. The rich, both industrious and idle, would be taught to be far more tolerant than they are of attempts to diminish inequality of wealth by reducing the wealth of the rich as well as increasing that of the poor. The economist may be a little annoyed with the workman who insists that he ought to have thirty shillings a week for producing something worth fifteen shillings, or five shillings, or nothing at all, but he can only have hearty contempt for the millionaire who holds up his hands in holy horror and murmurs "confiscation," "robbery," "eighth commandment," when it is proposed to relieve him of a fraction of a farthing in the pound in order to bring up destitute orphans to an occupation in which they may earn twenty-five shillings a week. The sanguine teacher of economic theory has hopes of making even such a man see that he has his wealth, not because Moses brought it down from Sinai, or because of his own super-eminent virtue, but simply because it happens to be convenient, at any rate for the present, for society to allow him to hold it, whether he obtained it by inheritance or otherwise. In other words, that private property exists for the sake of production, not for the sake of the particular kind of distribution which it causes. Some, I know, say that the rich are so few that it does not much matter whether they acquiesce in the measure meted to them or not; but that is not the teaching of history, and I think you will agree with me that for the progress of the whole community it is, in practice, quite as important to secure the acquiescence of the rich as of the poor.

In regard to international relations, the first business of the teacher of economic theory is to tear to pieces and trample upon the misleading military metaphors which have been applied by sciolists to the peaceful exchange of commodities. We hear much, for example, in these days of "England's commercial supremacy," and of other nations "challenging" it, and how it is our duty to "repel the attack," and so on. The economist asks what is "commercial supremacy"? and there is no answer. No one knows what it means, least of all those who talk most about it. Is it selling goods dear? Is it selling them cheap? Is it selling a large quantity of goods in proportion to the area or of the country? or in proportion to its population? or absolutely, without any reference to its area or population? It seems to be a wonderful muddle of all these various and often contradictory ideas rolled into one. Yet what a pile of international jealousy and ill-feeling rests on that and equally meaningless phrases! The teacher of economic theory analyses or attempts to analyse these phrases, and they disappear, and with them go the jealousies suggested by them.

When misleading metaphors and fallacies are dismissed, we are left with the facts that foreign trade—the trade of an area under one Government with areas under other Governments—is merely an incident of the division of labour, and that its magnitude and increase are no measures of the wealth and prosperity of the country, but merely of the extent to which the country finds it convenient to exchange commodities of its own growth or manufacture for commodities produced elsewhere. If the city of York were made independent, and registered its imports and exports, they would come out far larger per head of population than those of the United Kingdom or any other great country. Should we be justified in concluding York to be far richer than any great country? If means were discovered of doubling the present produce of arable land with no increase of labour, much less corn would be imported into Great Britain and less of other goods would be exported to pay for it; the foreign trade of the country would consequently be diminished, but would the people be any less prosperous? What jealousies, heart-burnings, and unfounded terrors leading to hatred would be extinguished if only these elementary facts were generally understood!

To anyone who has once grasped the main drift of economic theory, it will be plain that the economic ideal is not for the nation any more than for the family that it should buy and sell the largest possible quantity of goods. The true statesman desires for his countrymen, just as the sensible parent desires for his children, that they should do the best paid work of the world. This ideal is not to be obtained by wars of tariffs, still less by that much greater abomination, real war, with all its degrading accompaniments, but by health, strength and skill, honesty, energy and intelligence.

NOTES.

A NOTE in the *Times* states that the continuance of the meteorological work at Ben Nevis Observatory is practically assured. The staff had received notice that their services would not be required longer than October, but so satisfactory have been the offers of support that this order has been cancelled and winter stores have already been conveyed to the summit. The composition of the departmental committee of inquiry promised by Mr. Balfour will be announced shortly. So great has been the clamour against the threatened stoppage of the valuable work at the Observatory that it is confidently believed that the Treasury, guided by the advice of the committee, will enable the governing body to place the institution on a satisfactory financial footing of a permanent kind.

THE thirteenth annual general meeting of the Mining Institute of Great Britain was opened on Tuesday last at Newcastle-upon-Tyne, and at the same time the jubilee meeting of the North of England Institution of Mining and Mechanical Engineers, upon the foundation of which the Mining Institute was laid, was held.

THE *Pioneer Mail*, Allahabad, states that a donation of 50,000 rupees has been made by the Government of India to the Pasteur Institute of India at Kasauli, and the Punjab Government has handed over to the central committee of the Institute as a free gift Drumbar House at Kasauli for the accommodation of the poorer class of European and Eurasian patients, while Sir Charles Rivas has given 10,000 rupees to the Institute for the years 1902-3; grants have also been made by the Governments of Burma and the United Provinces of Agra and Oudh, and the chief commissioners of the Central Provinces and Assam. It is pointed out by our contemporary that no grants have been made by the Governments of Bombay and Madras.

THE next international conference on tuberculosis will be held in Berlin from October 22 to 26, and a provisional programme of the proceedings has just been issued. The subjects suggested for debate are the position of Governments with regard to the prevention of consumption; obligation to give information to the police; organisation of dispensaries; the task of schools with regard to the prevention of consumption; precautions against the dangers of milk; tuberculosis during infancy; protection of labour and prevention of consumption; classification and different modes of accommodating consumptives. In addition to the consideration of the foregoing questions, the members of the congress will inspect various establishments for the treatment of tuberculosis, and preparations are being made for a number of social functions.

THE sixth International Congress of Hydrology, Climatology and Geology will be opened at Grenoble on Monday, September 29, and continue in session until the following Saturday.

THE ninth expedition of the Liverpool School of Tropical Medicine has just proceeded to the Suez Canal to institute preventive measures against malaria. Major Ronald Ross, F.R.S., the leader of the expedition, will be joined at Brindisi by Sir William MacGregor, the Governor of Lagos, who has expressed a desire to witness the operations at Ismailia. The work will be begun immediately on the arrival of the expedition, and extensive operations commenced against mosquitoes.

AN archaeological expedition, composed of seven Japanese, has just started for Central Asia, under the leadership of Count Otani Kozui and M. Watanabe Tetsushin. The object of the expedition is to search for the Buddhist remains in Central Asia, India and China, and to trace so far as is possible the course of Buddhism from its source northwards and eastwards to Japan.

WE have to report the death of Dr. H. von Wild at Zürich on September 5, in his sixty-ninth year. He was director of the Central Meteorological Station at Berne from 1863-5, director of the Russian Meteorological Service from 1868-1895, and president of the International Meteorological Committee from 1882-1892. He was the author of numerous works on meteorology and terrestrial magnetism, and the inventor of a wind-vane with a simple swinging wind-force plate which was much used in Switzerland. Prof. von Wild was probably best known to our readers as the editor of the Russian *Repertorium der Meteorologie*, which contained valuable elaborate discussions of scientific subjects. His greatest work was "Temperatur-Verhältnisse des russischen Reiches," which embraced 349 pages of text and 271 plates.

THE death is announced of Prof. J. J. Hummel, principal of the dyeing department of the Yorkshire College, Leeds; also of Mr. Alexander Sutherland, registrar of the University of Melbourne, and author of, among other works, "The Origin and Growth of the Moral Instinct."

LETTERS received from Uganda give a good account of the progress of Mr. Budgett, Balfour travelling student of Cambridge, on his zoological mission to the Semliki. On July 13, he writes that he was proposing to start next day from Kampala for Lake Albert, where he would probably stay at Batyaba, near the Nile end, the Polypterus which he was in quest of being stated to be abundant at this spot. Afterwards his plans were to proceed southward to Fort Portal and thence to the Semliki valley, where he would make a general collection and look after the okapi in the neighbouring forest. Mr. Jackson has most kindly allowed Mr. Budgett to have the assistance of one of his trained taxidermists.

A COMMISSION will shortly leave England to settle the boundary line between the western portion of northern Rhodesia and the Portuguese territory. The commissioners selected for the purpose are Lieut.-Colonel Jackson and Lieut.-Colonel J. M. Woodward, of the Intelligence Department of the War Office, and Colonel Harding, the resident of the British South Africa Company in Barotse-land, will probably accompany the party. As the country to be traversed is very little known, it is much to be desired that a naturalist should be attached to this expedition, and we are informed that the authorities of the Natural History Museum have been consulted on the subject. The commissioners, it is said, are quite favourable to this being done, if the necessary arrangements can be made.

A DESPATCH has been received at New York from Lieutenant Peary, dated from Chateau Bay, Labrador, stating that he is homeward bound on board the *Windward* and that all is well.

AN international marine laboratory is, it is stated, to be established at Christiania under the direction of Dr. Fridtjof Nansen.

Science announces that Mr. William H. Wright, of the Lick Observatory, has been selected to take charge of the D. O. Mills expedition, which is at present being got ready for a two years' stay in Chile to make a special study of the stars of the southern hemisphere. The superintendence of the erection of the observing station and the inauguration of the work of the expedition will be undertaken by Director W. W. Campbell.

A FUNGUS foray in connection with the Yorkshire Naturalists' Union will take place in Arnecliffe Woods and other portions of Eskdale from Saturday, September 27, to Thursday, October 2.

DURING the past week, Vesuvius has been showing a certain amount of activity and Stromboli has also been active, frequent explosions and detonations having taken place and much

black smoke having been emitted. Travellers from Alaska report that great volumes of steam are rising from the volcanoes Redoubt and Iliamna in the Augustine Mountains, while the Redoubt is also throwing up immense clouds of smoke. According to advices from Honolulu dated September 3, Mount Kaluaha is active and is ejecting streams of fire. M. Lacroix, of the French Natural History Museum, left on Tuesday last to begin his work at Martinique.

ACCORDING to a Reuter telegram from Rome, the Italian postal authorities have examined a scheme submitted by an engineer, named Piscicelli, for the establishment of an electric postal service. It is proposed, by means of this system, to transmit letters in aluminium boxes, travelling along overhead wires at the rate of 400 kilometres an hour. A letter could thus be sent from Rome to Naples in twenty-five minutes and from Rome to Paris in five hours. A technical commission has been appointed to report on the system before instituting a series of experiments between Rome and Naples.

It is stated in the *British Medical Journal* that a somewhat new departure is about to be made by the North-Western Railway (U.S.), the headquarters of which are in Chicago. The plan is to equip every freight and passenger train with emergency chests containing splints, cotton bandages, antiseptics, restoratives, &c., and to open a school of instruction in first aid to the injured. The employés on all trains are to be required to attend the same and demonstrate that they comprehend the purpose of the teaching. The great purpose of the plan is to save lives, in the case of injuries, by the prompt and intelligent use of modern principles of treatment such as could be reasonably applied by an ordinary train crew, the contention being that an injured person in such circumstances will be able to reach the nearest hospital in a far better condition, and that his chances in all respects will be correspondingly heightened.

The *Electrician* states that a patent has just been issued in America for a coin-controlled X-ray machine for public use. The external appearance of the apparatus is similar to that of the automatic cinematograph machines so commonly seen on railway platforms and other places. The observer places a coin in the slot, moves a lever, puts his hand, or whatever he wishes to examine, into a box without any sides, and looks down at it through a fluorescent screen which forms the top of the box. The coin, on being inserted, closes the primary circuit of an induction coil worked by a few dry cells, and the vacuum tube is in a position immediately below the object to be observed.

SOME four years ago, the Belgian Government offered a prize of 50,000 francs for a paste for matches which should not contain white sulphur. The commission appointed to judge the results of the competition has now reported that after careful experiment and analysis it finds that none of the products so far submitted fulfil the required conditions, being defective in inflammability, ignite on any surface, or in igniting eject inflammable matter containing some poisonous substance.

THE sum of 5000 dollars has, according to *Science*, been bequeathed to the Astronomical Society of the Pacific by Mr. John Dolbeer, of San Francisco. The money will be invested, and the interest devoted to the diffusion of astronomical knowledge.

A GOTHENBURG physician has, it is stated in the *Journal* of the Society of Arts, invented an apparatus by which milk can be brought into the form of powder similar in appearance to flour, and possessing all the qualities of milk in concentrated form, moisture excepted. It is maintained that the flour is perfectly soluble in water, and can be used for all purposes for which ordinary milk is employed. It is also claimed for it that

it does not get sour, or ferment, and in its dry state is not sensitive to changes in the weather. The cost of its production is estimated at 1s. 1d. per 106 quarts.

THE zoological station of Arcachon, under the direction of M. le Dr. F. Jolyet, professor of medicine in the University of Bordeaux, is now in full work, but we are sorry to learn that the laboratories are not fully occupied. Arcachon, with its grand "basin" always accessible, and large fishing fleet, is such a favourable spot for the marine zoologist that we are surprised that such should be the case. The report of the station for 1900-1 contains the results of several pieces of scientific work of much interest. Arcachon is a good place for the student of animal electricity, Torpedo being of common occurrence there. A new subsidiary station has recently been opened at Guethary, a small bathing-place near St. Jean de Luz, which is stated to have an excellent beach for dredging operations.

THERE are now three examples of the Grevy's zebra (*Equus grevyi*) in the Regent's Park Gardens, placed under the Zoological Society's care by the order of the King. Two of these were presented to His Majesty by the Emperor Menelik, and the third is the survivor of a pair presented by the same Emperor to Queen Victoria. Unfortunately, they are all three of the female sex. But Colonel Harrington, the British representative in Abyssinia, has most kindly presented to the Zoological Society a pair of this zebra now living in his compound at Abis Abeba, and it has been arranged to send out one of the keepers to bring them home next month, so that there is a good chance of this magnificent animal, by far the largest and finest of all the wild Equidæ now in existence on the earth's surface, being permanently established in England.

THE weekly weather reports issued by the Meteorological Council up to August 30 show that in the principal wheat-producing districts, which include the eastern portions of Great Britain and the south of England, the only part where the rainfall had reached the average amount was the east of England; in the east of Scotland the deficit was 3 inches. In the principal grazing districts, which include the western portions of Great Britain, the south-west of England and the whole of Ireland, the only part where the rainfall had reached the normal amount was the north of Ireland; in the south-west of England the deficit was 5 inches. These figures will be somewhat modified by the heavy fall that accompanied the severe storm which passed along St. George's Channel and the Irish Sea on the night of September 2-3, when the amount exceeded an inch both in the north and south of Ireland; and in the counties of Wicklow and Dublin, which lay in the direct path of the centre of the storm, the fall in twenty-four hours amounted to nearly 3 inches. Nearly 2 inches fell on parts of the south coast of England during the same night.

METEOROLOGISTS are much indebted to Mr. R. C. Mossman for the publication of part iii. of his valuable papers on the meteorology of Edinburgh, which appears in a recent number of the *Transactions* of the Royal Society of Edinburgh. The present paper deals more particularly with new monthly and annual averages for the ten years 1891-1900 and the fifty years 1851-1900, and includes, *inter alia*, means of temperature and pressure, and rainfall values for periods varying from 124 to 137 years. An appendix continues the very interesting account, commenced in part ii., of remarkable atmospheric and celestial phenomena that have occurred in past years, and contains references to two events as far back as the twelfth century. The complete work undoubtedly forms the most useful and comprehensive discussion of the climatology of Edinburgh that exists.

A PAPER by Mr. Walter Wesché in the *Journal* of the Royal Microscopical Society for August bids fair to throw light on the

relations between the mouth-organs of diptera and those of other insects. Even in such dipterous genera as *Tabanus* and *Culex*, the full number of mouth parts of a typical insect is not present, the absent parts being one pair of palpi, which are commonly regarded as the labial palpi. In other families, such as the *Muscidæ* and *Syrphidæ*, where mandibles and even maxillæ are absent, chitinous structures are visible on the dorsal side of the labium representing the aborted parts. Mr. Wesché now finds that certain members of the *Muscidæ* are provided with a second pair of palpi in addition to those always present and which are generally regarded as maxillary. "In several species of the *Anthomyia* family, in the genera *Hyetodesia*, *Spilogaster* and *Hydrotea*, are to be found at the base of the labium and hypopharynx, and connected with the apodemes or levers that work those parts, two hairy processes, one on each apodeme. These are jointless, chitinous in structure, and have much the appearance of ordinary palpi." In *Hyetodesia basalis*, the organs measure about 0.003 inch (0.085 mm.) in length, while in *Spilogaster duplicata* they are the same length and about half the breadth. In other species of the same family, the rudiments are reduced to a few hairs and a minute tubercle; in the *Sarcophagidæ*, rudiments are found in *Myiocera carinifrons*; in the *Muscidæ* proper in *Musca corvina* and *M. domestica*, and the palpi have also been found in the families *Sepsidæ*, *Opomyzidæ* and *Borboridæ*. The discovery of these rudimentary palpi, which are undoubtedly maxillary, leads to the conclusion that the palpi so conspicuous on the proboscis of many flies are not the maxillary but the labial palpi.

EIGHT years ago Prof. Omori studied the distribution in time of the after-shocks of several great Japanese earthquakes, and concluded that a strong earthquake is almost invariably followed by weaker ones, and a destructive one by hundreds or even thousands of minor shocks, which gradually diminish in frequency and strength, but may continue to be felt for several years. In a recent valuable memoir (*Boll. Soc. Sism. Ital.*, vol. viii. pp. 17-48), Dr. Cancani has investigated the distribution in intensity of the after-shocks of three hundred Italian earthquakes, all strong enough to produce at least slight damage in buildings. Such earthquakes, he finds, are never isolated, but are always preceded or followed by others generally weaker. The total duration of an earthquake-period (perhaps earthquake-series or group would be a better term) is a function of several variables, but depends especially on the depth of the seismic focus. When the depth is small, the earthquake-period is of brief duration, generally about ten days; when moderate, the after-shocks may continue for about three months, and when the depth is great they may last for several years. In 70 per cent. of the earthquake-periods, the strongest shock occurred during the initial phase or first tenth part of its total duration.

THE Report of the Botanical Exchange Club of the British Isles for 1901 has been delayed, as the distributor, the Rev. E. S. Marshall, explains, in order to obtain critical opinions on some of the specimens. The number of specimens sent in by twenty-five contributors amounts to more than 2700. Many of these are varieties or hybrids, others represent new localities. Several new species are recorded for Lancashire, notably *Helleborus viridis* and *Helleborus foetidus*, *Scirpus caricis* and *Carex teretriscula*. A discovery of *Euphorbia exigua* in limestone crevices on the north coast of Wales lends support to the view that it is a native of Britain. *Statice Limonium* × *raviflora* and *Salicornia lignosa*, both growing near Bosham in west Sussex, have elicited interesting criticisms, but the most important collection, *Diotis candidissima*, was made by Mr. C. P. Hurst in Wexford. There it grows in quantity on a sandy bar, as may be seen from the two illustrations given, which are reproduced from photographs taken by the finder.

A NUMBER of papers dealing with electric traction, which were read before the Association Française pour l'Avancement des Sciences last month, are summarised in *L'Éclairage électrique* for August 23. These will be found especially useful by those who are interested in accumulator traction, whether for tramways or automobiles, as the suitability of the accumulator is considered from several points of view. The general conclusions are not very favourable to the accumulator in its present commercial form, although accumulator traction was voted a perfectly practical solution of the problem of running a tramway electrically in a position in which trolley wires were inadmissible. Accumulators were not, however, regarded as so suitable for automobiles, as their weight involved difficulties in the construction of the cars and tyres which were not so important in a tramcar heavy in itself and running on a prepared track. For a public service of electric automobiles, the only system considered practical was one in which power was obtained from a trolley wire, with omnibuses or carriages running on the ordinary roadway, a system which obviously possesses some advantages over even the electric tramway.

A BRIEF account of the latest apparatus for rendering air respirable in a closed space is described by M. Desgrez in the *Bulletin of the French Physical Society*, No. 185, the apparatus having been devised by M. Desgrez in collaboration with M. Balthazard. The underlying principle is the decomposition by water of sodium peroxide, with liberation of oxygen, absorption of carbon dioxide and destruction of the toxic products of respiration. The apparatus consists of (1) a distributor which, by the action of clockwork, drops the peroxide into water at regular intervals; (2) a cubical steel box containing the water; and (3) a ventilating fan. A refrigerator is also supplied, as a general rule, to counteract the heating effects of the chemical reactions. A complete apparatus has been constructed, capable of enabling a man to work for at least three-quarters of an hour in a closed space, and weighing in all about 12 kilograms.

THE current number of the *Proceedings* of the Edinburgh Mathematical Society contains a note on decimal coinage and approximations by Mr. J. W. Butters. Apart from the advantages of a decimal system of coinage, the author calls attention to several points which cannot be too strongly emphasised. One is the common complaint as to the time wasted by learners in using long and cumbersome methods (often calculating sums of money to a fraction of a penny with a long numerator and denominator), from ignorance of the use of decimals. This evil, the author thinks, could be remedied by teaching decimals before vulgar fractions, as is often done in Germany. Another point is the use of the unit's figure instead of the decimal point as a landmark in counting places in multiplication and division. Everyone knows, or should know, that the characteristic of a logarithm is given by the number of places that its first significant figure is to the left of the unit's figure, whereas if the decimal point is taken as the landmark, we are told that the characteristic is one more or one less than something or other and confusion may arise. Mr. Butters suggests that the decimal point be called the unit's point and regarded as used for fixing the unit's place, and he shows how multiplication and division of decimals are simplified by adopting this view. The necessity for such a change is emphasised by the fact that the ordinary method of dividing decimals fails to give the correct remainder. Finally, the author points out the saving in labour in using decimals of a pound and contracted methods for ordinary calculations.

THE current number of the *Journal* of the Anthropological Institute fully maintains the great reputation which that publication has earned. There are three papers on customs and beliefs of various African tribes, one on a remarkable musical

instrument of the Bushmen and two papers on Kabyle pottery. Indian ethnography is represented by one paper and Malay ethnography by three; other papers deal with the Nicobars, Sarawak, Tasmania, Tonga and New Zealand. The range is wide alike in geography and matter, so that practically all departments of anthropology are represented, and the twenty plates are of exceptional interest and excellence.

ANTHROPOLOGY is to be congratulated in having found so able and enthusiastic a student as the Rev. J. Roscoe, of Uganda, whose paper on the manners and customs of the Baganda is of extreme interest. Amongst other important novelties, it contains an account of a typical form of totemism which was previously unrecorded among the Baganda, and even the magical aspect appears to be present. Very suggestive are the customs relating to twins and the sympathy between human beings and plantains. The people appear to have but recently emerged from matriarchy into patriarchy.

ANOTHER important paper in the same *Journal* of the Anthropological Institute is that on some animistic beliefs among the Yaos of British Central Africa, by the Rev. A. Hetherwick. The Yao present us with three stages of animistic belief, (1) the *lisoka* or human shade, the agent in dreams, delirium, &c.; (2) this *lisoka* regarded as *mulungu* and an object of worship, the controller of the affairs of this life; and (3) *mulungu* as expressing the great spirit agency, the creator of the world and of all life. Between these three conceptions of the spirit nature no definite line can be drawn.

In the concluding portion of his article on "Regeneration in Plants" in the *Biologisches Centralblatt*, Prof. Goebel has an instructive chapter on the disposition of adventitious developments which follow upon injury or wounding. That it may be referred to a polarity depending upon internal, not external, factors follows from Vochting's researches. Tracing the argument back further—*e.g.*, what does polarity mean?—Beijerinck's hypothesis of an upward current shoot forming and a downward current root forming is accepted in part, and experiments which can be explained upon this hypothesis are mentioned. Sometimes, however, this is not satisfactory, and Prof. Goebel finds that a more general and correct explanation of certain anomalous cases is obtained by a consideration of the direction of flow of the food current. Finally, Prof. Goebel regards with favour the idea of a controlling enzyme as postulated by Beijerinck.

The Geological Survey of Western Australia, in *Bulletin* No. 6 (1902), gives the results of the chemical and mineralogical research work carried out by Mr. E. S. Simpson since the laboratory was established in 1897. There are notes on native gold and its compounds with tellurium and other elements, as well as notes on various ores, on coal, peat, clays, water, and on sundry intrusive rocks.

WE have received three important papers devoted to embryology and development. Two of these, dealing respectively with amphibians and the brachiopod *Lingula*, appear in a recent issue of the *Journal* of the Tokio College of Science. The third, by Dr. J. A. Masterman, which is published in the *Transactions* of the Royal Society of Edinburgh, treats of echinoderm development.

THE August issue of the *Journal* of the Department of Agriculture of Victoria is composed of the annual reports of the officers in charge of the various branches of the Department, prefaced by a brief summary of the whole by Mr. S. Williamson Wallace, the Director of Agriculture for the colony. The reports are interesting reading, and tell of much good work done on scientific lines at a comparatively small cost.

THE *Scientific American*, New York, for August 30, contains an illustrated article, by Mr. F. Moore, upon the United States Naval Observatory.

PART 4 of the new and cheaper edition of Kerner and Oliver's "The Natural History of Plants" has reached us from Messrs. Blackie and Son, Ltd.

MR. BERNARD QUARITCH has just issued a new part, devoted to India and the Far East, of his "Catalogue of Works on Oriental History, Languages and Literature," containing particulars of many rare and valuable books.

THE additions to the Zoological Society's Gardens during the past week include two Bonnet Monkeys (*Macacus sinicus*) from India, presented by Mr. J. H. Osborne; two Diana Monkeys (*Cercopithecus diana*) from West Africa, presented by Mr. E. Skinner; a Levaillant's Cynictis (*Cynictis penicillata*) from South Africa, presented by Mr. E. C. S. Jervis; two Cape Eared Owls (*Asio capensis*) from Africa, presented by Captain Fraser; a Diana Monkey (*Cercopithecus diana*), a White-thighed Colobus (*Colobus vellerosus*), two Grey-headed Sparrows (*Passer simplex*) from West Africa, a Simpae Monkey (*Semnopithecus melalophus*) from Sumatra, a Salle's Amazon (*Chrysotis ventralis*) from St. Domingo, two Striated Tanagers (*Tanagra striata*) from Buenos Ayres, a Blue Sugar-bird (*Dacnis cayana*), an All-green Tanager (*Chlorophonia viridis*) from Brazil, deposited; two Swinhoe's Pheasants (*Euplocamus swinhoii*), an Argus Pheasant (*Argus giganteus*) bred in the Gardens.

OUR ASTRONOMICAL COLUMN.

ANOTHER NEW COMET.—From information received, through Mr. E. W. Maunder, from Mr. John Grigg (a member of the Cometary Section of the British Astronomical Association), of Thames, New Zealand, it appears that the comet discovered by Perrine, which, if this news is confirmed, has been erroneously named 1902 *b*, is not the second, but the third comet discovered this year.

Mr. Grigg says that whilst using his 3½-inch Wray equatorial, with a power of 25 on July 22d. 18h. 30m. G.M.T., he saw a nebulous object which was roughly noted as R.A. = 11h. 35m., Dec. = +7° 0', and reference to various charts and tables elicited the fact that this was not a previously recorded nebula or comet. On the following evening, the same object was doubtfully recorded as 24' further south and 7' eastward of its previous position. Feeling satisfied that this was really a new comet, Mr. Grigg acquainted Mr. Baracchi (Melbourne Observatory) and the Press Association of his supposed discovery.

Three days later, and also on August 1 and 2, the same observer again saw the suspected comet and recorded the following positions:—

d.	h. m.	Dec. =
July 23·8	G.M.T. R.A. = 11 40	+ 6 35
26·8	" " = 12 0	" + 5 30
29·8	" " = 12 20	" + 4 20

and from these he calculated the following elements:—

$$\begin{aligned}
 T &= \text{June } 20, 1902. \\
 \omega &= 292 \text{ } 43 \\
 \Omega &= 217 \text{ } 48 \\
 i &= 18 \text{ } 24 \\
 \log q &= 9 \cdot 7241.
 \end{aligned}$$

The observations are all of them a little doubtful owing to persistent haze and moonlight, but Mr. Grigg gives the particulars for "what they are worth," and has sent them in this uncertain state in order to catch the outgoing mail.

The position of his observatory is:

Longitude	...	175 32 38" 54 E.
Latitude	...	37 8 23" 21 S.

COMET 1902 *b*.—Circular No. 51 from Kiel gives the sub-joined elements and ephemeris, as calculated by Herr Elis Strömgen from the observations made at Lick on September 1, at Urania on September 2, and at Copenhagen on September 4, for the comet discovered by Perrine at Lick on September 1.

Elements.

T = 1902 Nov. 23^h 31^m 5^s Berlin.

$$\left. \begin{aligned} \omega &= 153 \ 53 \cdot 2 \\ \Omega &= 50 \ 10 \cdot 6 \\ i &= 157 \ 8 \cdot 2 \end{aligned} \right\} 1902 \cdot 0$$

log $q = 9 \cdot 60094$.

Ephemeris.

1902.	a app.		δ app.	
	h.	m. s.		
Sept. 6 ...	3	11 48 ...	+37	0'3
10 ...	3	4 26 ...	+39	10'4
14 ...	2	52 59 ...	+41	51'4
18 ...	2	34 47 ...	+45	13'2
22 ...	2	4 19 ...	+49	23'3
26 ...	1	10 1 ...	+54	3'8

Perrine describes the comet as "slightly elongated, mean diameter 4', magnitude = 9, tolerably well-defined nucleus, possesses a tail." Struve, observing at Königsberg on September 2, 10h. 41m. 2 (Königsberg), saw a sharply defined nucleus of the 11th magnitude.

NEW ALGOL VARIABLE.—Mr. A. Stanley Williams announces in the *Astronomische Nachrichten*, No. 3811, the discovery of a new Algal variable (13, 1902 Lyræ), the position of which he gives as

$$\alpha = 19h. 10m. 48s. 7. \quad \delta = +32^{\circ} 10' 1'' (1855).$$

This object is the most following, and normally the brightest, of the three stars forming a small triangle south of the 9'1 mag. star B.D. + 32° 3377. On the scale used, its normal magnitude is 10'98, whilst at minimum it is only just visible with the 6.5-inch reflector, *i.e.* its magnitude is about 12'8.

The star remains at its normal brightness for about 3d. 6h. 22m., and the increase and decrease each occupy about 4 hours; there is no apparent interval at minimum, and the observations, so far, have not indicated the presence of any secondary minimum.

Subjoined is an extract from an ephemeris, calculated for every fifth minimum by Mr. Williams.

1902.	G.M.T.	
	h.	m.
Sept. 21	11 28
Oct. 9	11 20
Oct. 27	11 12
Nov. 14	11 4
Dec. 2	10 56
Dec. 20	10 48

Prof. E. Hartwig observed this variable from 9h. 22m. to 11h. 19m. (Bamberg M.T.) on August 16, and found that, during that period, its light decreased by 1'3 magnitudes; cloud and strong moonshine prevented the observations from being carried on throughout the minimum.

SIR DAVID GILL'S NEW THEORY OF STELLAR MOVEMENT.—Mr. Carpenter has recently been examining the measures of the stellar photographs obtained at Oxford during the last seven or eight years, in order to see if they indicate any such movement of the brighter stars as a whole, with respect to the fainter stars as a whole, as was recently suggested by Sir David Gill. Although this was too great a task for Mr. Carpenter to finish during his holiday, he got far enough to find indications which supported Gill's hypothesis.

This result was considered so important that the whole of the Oxford staff was deputed to examine the photographic measures for a belt of stars about Dec. + 26°, and the result indicates that there is an apparent movement as suggested amounting to about 0s. 002 per magnitude per year. This corresponds in magnitude to the quantity found by Gill, "but its sign is opposite to that found by him." If this sign is found on further revision to be correct, then it is difficult to imagine that the movement is simply one of rotation, and further investigation must be made before any definite theory may be accepted (*The Observatory*, September, 1902).

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

DR. W. H. MILLS, Fellow of Jesus College, Cambridge, has been appointed head of the chemical department of the Northern Polytechnic Institute in succession to Mr. H. C. L. Bloxam.

MR. H. W. MALCOLM, B.Sc., has been appointed lecturer and demonstrator in physics at University College, Bristol, in the place of Mr. L. N. Tyack.

MR. W. R. KELSEY, late of the Bradford Technical College and of the South-West London Polytechnic, has been appointed principal of the Taunton Municipal Technical Institute.

THE University of Nebraska has this year added a course of study in forestry to its curriculum. The course will extend over a period of four years.

THE sum of 1000*l.* has been placed by Sir Conan Doyle at the disposal of the senatus of Edinburgh University for the purpose of instituting a bursary in the faculty of medicine, available only for students from South Africa. The bursary is to be administered in detail as the University may direct.

Science for September 5 publishes for the fifth year in succession statistics of the conferment of the degree of Doctor of Philosophy by American universities. In the present year, some 214 doctorates have been conferred by twenty-seven institutions, as against 253 in 1901, 233 in 1900, 224 in 1899 and 234 in 1898. The largest numbers of degrees conferred were in the subjects of chemistry, zoology, physics and botany, the numbers being respectively 24, 16, 12 and 11.

SIR HENRY CRAIK'S report for the year 1902 on secondary education in Scotland shows that there has been a large increase in the number of schools presenting candidates in science subjects at the leaving certificate examination, and also in the total number of candidates presented. In many cases there has been a distinct advance in the quality of the work done as compared with former years. It is satisfactory to know that in the examinations of Scottish secondary schools great prominence is given to oral and practical methods of testing the work, and the examinations in the case of each school are shaped by the curriculum of that school.

THE educational announcements for the session 1902-3 of the Northampton Institute, Clerkenwell, make an imposing volume of some 200 pages. Classes will be provided in a large number of technological and trade subjects, but students who require instruction in literary or commercial subjects must go to one of the other City polytechnics, for the Northampton Institute is primarily intended to teach technology. Very properly, great attention is given to subjects which directly assist the industries of the immediate neighbourhood. The courses of instruction fall into two distinct sections, the engineering day classes for students willing to give the whole of their time for one or more years to a systematic training in some branch of engineering, and the evening classes in a variety of subjects for working men engaged during the day.

THE new regulations of the University of Oxford School of Geography show that admission is not confined to members of the University, but all applicants must give satisfactory evidence of sufficient general education to profit by the teaching. A course of instruction in the subjects required for the University diploma in geography begins in October and extends over one academic year. Weekly lectures are delivered by all the members of the staff, six in number, and practical instruction is given on at least four days in each week, and includes position-finding, topographical surveying and map-projection. A scholarship of the value of 60*l.* is offered annually for competition among members of the University who have taken honours in one of the final schools of the University. During 1901-2 the lectures were attended by 208 students, of whom 163 were men from twenty-one colleges, and forty-five women from five colleges or halls.

IN urging the necessity for a more extensive and highly developed system of technical education in this country, English men of science often refer to the provisions made in the United States of America to equip American workers with a practical education of a technical kind so as to fit them to take a useful place in the industries of their country. A recent address, by Prof. V. C. Alderson, Dean of the Armour Institute of Technology at Chicago, on "Technical Education an Economic Necessity," shows some imperfections in the American system. Prof. Alderson is of opinion that up to the present the existing admirable technical institutions in the United States have concerned

themselves only with the needs of the highest grades of workers, "the commissioned officers of our industrial army," as he calls them. "The great mass of non-commissioned officers and privates are left uncared for." The region of what may with approximate correctness be called "secondary technical education" is represented in the United States, Prof. Alderson says, "by more or less feeble efforts in a few trade schools, in a limited number of private institutions aimed to help the working men and in night schools." American educational authorities are urged, later in the address, to follow the example of Switzerland, and, "recognising the dependence of national prosperity upon technical education, to set about the task of providing an education for all classes of workers suited to their callings. The technical high school, if properly equipped and put in close relationship with the trades and industries, will satisfy this national need; it will not be a copy of the European trade school, but rather an adaptation of the trade school which will be in harmony with American thought and American educational ideals."

SOCIETIES AND ACADEMIES.

PARIS.

Academy of Sciences, September 8—M. Bouquet de la Grye in the chair.—The president announced to the Academy the death of M. R. Virchow, Foreign Associate of the Academy.—Address by M. Bouchard on the occasion of the death of R. Virchow.—On the irreducibility of uniform transcendentals defined by differential equations of the second order, by M. Paul Painlevé.—The experimental study of the resistance to compression of armed mortar, by M. Considère. A study of the mechanical properties of prisms of cement having embedded in its mass metallic wires of various shapes. The results are summarised in a graphical form.—On the eruption of Martinique, by MM. A. Lacroix, Rollet de l'Isle and Giraud. In discussing the calorific and physiological effects of the eruption in the town of St. Pierre, all the observations indicate the rapid and persistent action of a source of heat at a high temperature, producing asphyxia. In a central zone the temperature was sufficiently high to determine combustion, to superficially carbonise the bodies after burning their clothes, but it was insufficient to melt thin copper wires, or below 1054° C. On the edges of this zone the phenomena of asphyxia continue, but the temperature was hardly high enough even to char the clothes. The presence of steam and ashes in the destructive cloud which overwhelmed the city is certain; the presence of combustible gases such as hydrogen sulphide, hydrocarbons or hydrogen cannot be proved with certainty, but such a supposition would explain many of the effects produced. The commission consider the complete evacuation of the entire neighbourhood of Mont Pelée is imperative, and must be maintained until the complete cessation of the volcanic disturbances.—On the secular acceleration of the mean longitude of the moon, by M. H. Andoyer.—The comet 1902 *b*, discovered on September 1 by M. Perrine and independently by M. Borrelly, September 2, at the Observatory of Marseilles. Observations made by MM. Borrelly and L. Fabry.—Observations of the comet 1902 *b*, made at the Observatory of Besançon, by M. P. Chofardet.—On certain differential equations, by M. Edmond Mailet.—On the properties of closed chambers relating to electric waves, by M. A. Turpain.—On a new acidimetric indicator, by M. L. J. Simon. By the dry distillation of tartaric acid with potassium bisulphate, a new acid isomeric with pyrotartaric acid has been obtained the ferric salt of which may be used as an indicator. It possesses the curious property of giving similar indications to a mixture of methyl-orange and phenolphthalein, and in some cases conveniently replaces such a mixture.—On the interrenal bodies of Plagiostomes, by M. Ed. Grynfelt.—On some india-rubber plants on the west coast of Africa, by M. Aug. Chevalier.—On the duration of the germinating period in seeds exposed to sunlight, by M. Victor Jodin.

NEW SOUTH WALES.

Linnean Society, July 30.—Mr. J. H. Maiden, president, in the chair.—Descriptions of some new species of plants from Western Australia, by Mr. W. V. Fitzgerald. Five additions to the flora of Western Australia referable to the genera *Mitrasacme*, *Cremnophila*, *Grevillea* and *Schœnus* (two species) are described.—Descriptions of new species of Queensland Lepidoptera, by

Dr. Thomas P. Lucas. Two genera and five species, distributed among three families (Cossidae, Pyralididae and Xyloricidae), are described as new.—A revision of the genus *Notonotus* (fam. Carabidae; subfam. Feronini), by Mr. Thomas G. Sloane. Seventy-two species are attributed to the genus, twenty-seven being described as new.—Contributions to a knowledge of Australian Entozoa. No. ii. On a new species of *Distomum* from the sawfish-shark (*Pristiophorus cirratus*, Lath.), by Mr. S. J. Johnston. The worm has an extremely mobile neck in the living state. Its most characteristic features are its size, the character and position of the suckers, the folded but unbranched limbs of the intestine, the grape-like vitelline glands and the very marked development of the excretory system. It falls into Dujardin's subgenus *Brachylaimus*.—Notes on Australian Lycenidae, by Mr. G. A. Waterhouse. *Lycæna nigra*, Misk., is referred to the genus *Megisba*, Moore. *Holochila purpurea*, Grose-Smith and Kirby, is given as a synonym of *H. cyprotus*, Olliff. *Holochila androodus*, Miskin, and *H. subargentea*, Grose-Smith and Kirby, are given as synonyms of *H. helenita*, Semper. The sexes of *Ogyris oroteles*, Hew., and *O. amaryllis*, Hew., are described; likewise two new species. The paper concludes with a note on *O. ianthis*, Waterh.

GÖTTINGEN.

Royal Society of Sciences.—The *Nachrichten* (physico-mathematical section), part 4 for 1902, contains the following memoirs communicated to the Society:—

November 8, 1901.—David Hilbert: On the bases of geometry.

May 3, 1902.—Ernst Richard Neumann: New integral properties of successive potentials. W. Voigt: On the absolute retardation of light-waves on reflection.

The accompanying *Proceedings* include reports on the progress of the "Mathematical Encyclopædia" and the publication of Gauss's works; obituary notices of Friedrich Leo, Adolf Erik von Nordenskiöld, Karl Hegel; and congratulatory addresses to Eduard Süss, of Vienna, and Dedekind, of Brunswick.

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