THURSDAY, SEPTEMBER 17, 1903.

THE WORTH OF EXPERIMENTAL PSYCHOLOGY.

Experimental Psychology and its Bearing on Culture. By George Malcolm Stratton, M.A., Ph.D. Pp. vi + 331. (New York: The Macmillan Company; London: Macmillan and Co., Ltd., 1903.) Price 8*s.* 6*d.* net.

THE aim of this well written and interesting book, we are informed, is "to present . . . the character and value of the laboratory psychology, especially as bearing on our moral and philosophical interests. . . . Considerable attention has thus been given to the interpretation of the experimental results—to their more immediate scientific meaning, as well as to what they suggest for life and for speculation." The work, however, contains little that is really relevant to "the bearing of psychology on culture." Such topics as the value and significance of memory, suggestion and illusions, and the relation of psychology to the body and to the soul, ably as they are treated, are hardly synonymous with culture; indeed, from start to finish the object of the book is by no means evident.

It is to be regretted that Prof. Stratton did not confine himself to "the immediate scientific meaning," the range and the worth of psychological laboratory work. Once or twice this task has been already attempted in our language, but it has not yet been satisfactorily performed. The need for such a work has never been greater than now, when the number of psychological laboratories and their workers is multiplying rapidly, while physicists and physiologists are for the most part ignorant of, and hence are prone to ignore and to condemn, the aims and methods of experimental psychology. To this class of readers the present work is not well suited, and will hardly carry conviction. It appeals more to an educated public, which prefers to nibble at the significance of experimental psychology, and to swallow certain inevitable crudities of statement, rather than to digest the subject with proper care. The ground covered by the book is too vast, and departures from purely experimental topics are too often and too far made to allow of a really accurate and critical exposition. For this reason, no doubt, the author has made little attempt to exhibit the various themes of experimental study in their proper perspective. He has been forced to neglect some of the most important advances in purely psychological method, *e.g.* the work of G. E. Müller and his Göttingen school, and the genetic and comparative sides of experimental psychology; while undue space is given to some trivial experiments in æsthetics that have scant meaning or interest, and a few others are made to bear interpretations which are far from being justified in fact.

"Some recent experiments by Dunlap," says the author (pp. 88, 89), "show that lines, so drawn as to produce an illusion of distance [*i.e.*, the angle-forming lines in the well-known illusion of Müller-Lyer], may influence our estimate of space even when these lines are quite imperceptible."

Reference, however, to the statistical results of the original paper and to its writer's own convictions shows that this conclusion is by no means so certain. The author uses these and other considerations in his chapters on the evidence for unconscious ideas. He ends with the statement (p. 92) that

"the results are not in favour of unconscious ideas, but rather of certain unconscious materials out of which conscious ideas arise."

One is tempted to ask how he can be sure, if the "materials" are unconscious, that they *are* "materials" and not "ideas." His psychological treatment of poetical rhythm is not convincing, the subject being too complex to tolerate an acrobatic arithmetic which connects all measures with "the pulse-time of attention." Probably the latter bears about the same relation to our appreciation of rhythm as our range of hearing to the enjoyment of a Beethoven symphony. Nor is it the whole truth, albeit the fashion to say (p. 269) that "what goes on in our minds never is really there until it is expressed," and that "in all manner of mental action there is some physical expression."

The chapters on the general character of psychological experiments, on imitation and suggestion, on illusions, and on the spatial perceptions of the blind, are quite ably and entertainingly written. The author's classification of illusions leads to curious results. He groups the illusion, in which a large box is judged lighter than a smaller box of equal weight, in the same class with the two fundamentally different illusions, in which truly isochronous intervals are subjectively resolved into rhythmic series, and in which a space of time filled with sounds is adjudged of different length from an equal but "empty" space of time. This class of illusions is said to arise "from stress of attention"! We are told also (p. 106) that within this class "the symbols themselves do not seem to be misinterpreted, they have been distorted . . . by our mental states." Elsewhere the author admits that *all* illusions "involve a misinterpretation."

But sufficient has been said to give a general notion of the faults and virtues of this book. In broad principles there is little to which the psychologist can take exception. Its style and language appear to be excellently suited to its readers, and the author has an adequately wide grasp of his subject. If he has failed in his task, the reason is because he has attempted too much. For to treat of the problem, which he has set himself, in three hundred or more pages is as impossible as it is to do justice to his bold endeavour within the compass of this review. C. S. MYERS.

HYDRAULICS.

Treatise on Hydraulics. By Mansfield Merriman, Professor of Civil Engineering in Lehigh University. Eighth Edition, Rewritten and Enlarged. Pp. viii + 585. (New York: John Wiley and Sons; London: Chapman and Hall, Ltd., 1903.) Price 21*s.* net.

THIS book bears the same title, has practically the same number of pages, and is published by the same firms, as a book by Prof. Bovey, of McGill University, Montreal, which appeared in 1901, and was reviewed in these columns in February last year.

Though, however, the present book, like its predecessor, is intended primarily for students in colleges and technical schools, and secondly for engineers, and one or more problems, intended to be solved by the reader, are appended at the end of each article, relating to the special subject treated of in the article, it deals with the various hydraulic principles and problems successively investigated in a more simple manner than the former book, which is calculated to commend it to the favourable notice of practical engineers, too engrossed in their work to be able to spare the time for fully grasping abstruse mathematical considerations.

The book is divided into sixteen chapters, and is further subdivided into one hundred and ninety-two articles, each numbered, and dealing with a subject under a special heading connected with the general purpose of the chapter which contains it; whilst an appendix at the end, occupying forty-three pages, after pointing out certain analogies between the flow of water in pipes and the passage of the electric current along wires, and adding some miscellaneous problems for solution, furnishes fifty-five useful hydraulic and mathematical tables, the former being given both in English and in metric measures.

The first four chapters treat successively of "Fundamental Data," "Hydrostatics," "Theoretical Hydraulics," and "Instruments and Observations"; whilst the following six chapters are devoted to the consideration of the various kinds of flow, namely, through orifices, over weirs, through tubes, through pipes, in conduits, and the flow of rivers. The remaining six chapters deal with the important practical subjects of "Water-Supply and Water-Power," "Dynamic Pressure of Water," "Water-Wheels," "Turbines," "Naval Hydromechanics," and "Pumps and Pumping." Nearly two hundred figures in the text, mostly in the form of small, simple diagrams, serve still further to elucidate the hydraulic principles so clearly and concisely enunciated; and these diagrams, instead of being numbered consecutively in the usual manner, are given the same number as the articles which they illustrate, adding *a*, *b*, *c*, &c., where more than one occur in a single article; whilst the same system of numbering is adopted for distinguishing the formulas given in the several articles, and the problems appended at the end of them. The advantage of this peculiar method of numbering is not very clear, though possibly it furnishes an excuse for omitting headings from the diagrams, and for dispensing with a list of them. By the above arrangement, however, each article, with its special number and descriptive heading, constitutes a distinct unit, in which the diagrams and formulas are merged; and whereas the chapters in the text are only headed by their special subject, the headings in the table of contents under the main headings consist merely of an enumeration of the headings of the articles in each chapter, preceded by their distinguishing numbers.

The way in which several independent articles are grouped together in the chapters to which their subjects appertain, is well illustrated by the list of articles contained in the chapter on naval hydromechanics, comprising "General Principles," "Frictional Resistance," "Work for Propulsion," "The Jet Propeller," "Paddle-Wheels," "The Screw Propeller," "Stability of a Ship," "Action of the Rudder," and "Tides and Waves." The concise and somewhat cursory manner in which the practical subjects considered in the last six chapters are touched upon, is sufficiently indicated by their taking up less than one-third of the whole contents of the book, and by such important and complex questions as water-supply and water-power being together dealt with in a single chapter of twenty-eight pages. This circumstance, however, must not be regarded as at all detracting from the merits of the book; for evidently the author is mainly concerned in laying down the principles of hydraulics, indicating the means and methods of taking observations, and establishing the laws of the flow of water under various conditions, to which subjects considerably the larger portion of the book is devoted. Then, after the principles and laws of hydraulics have been thoroughly elucidated, the methods of their application to various practical purposes, such, for instance, as water-power, water motors, propulsion, and pumping, are successively indicated, without the slightest intention on the part of the author that the brief treatment of these subjects should furnish substitutes for the standard treatises on them.

In the latter part of the book, indeed, the general features of the subjects introduced, and the action of the hydraulic machines are concisely sketched in suggestive descriptions, leaving a full investigation of the various matters touched upon to be sought elsewhere, according to the special branch on which more detailed information is required. Nevertheless, in spite of the brevity of the treatment, interesting particulars are here and there referred to, as, for example, the present utilisation of the Falls of Niagara in the development of 105,000 electrical horse-power, by means of turbines which are described, and the prospect in the near future of a largely increased use of this natural source of power; whilst it is suggested that the tides and waves afford a source of power which at present is wasted, but which, on the exhaustion of the supplies of coal, wood, and oil, may be utilised for generating power, heat, and light in unlimited quantities.

OUR BOOK SHELF.

Synthesen in der Purin- und Zuckergruppe. By Emil Fischer. Pp. 29. (Braunschweig: Friedrich Vieweg und Sohn, 1903.)

THIS lecture, delivered before the Swedish Academy at Stockholm on December 12 of last year, contains an account of Prof. Emil Fischer's work in organic synthesis, and of the motives that have guided him in attacking successively the problems of the uric acid, sugar, and more recently the albuminoid, groups of organic compounds. The synthetical methods by which the constitution of so many naturally occurring substances have been determined are described in outline only, and in a way that will appeal especially to the non-chemical reader. To the chemist the chief charm of the lecture lies in the frankness with which the lecturer describes the purpose and the ultimate goal of the work to which he has devoted himself.

Incidentally the commercial aspects of the purin syntheses are referred to. The sale of caffein and theobromine for medicinal purposes amounts to a million marks annually; at present this is all extracted from tea and cacao, but theophyllin prepared from uric acid is already on the market, and before long it may be possible to manufacture theobromine and caffein at a price that will render it possible to compete with the natural products. T. M. L.

Report on Field Experiments in Victoria, 1887–1900. By A. N. Pearson. Pp. 124; with illustrations and tables. (Melbourne, 1901.)

A RECORD of experiments on the manuring of the staple farm crops (chiefly wheat) and of fruit conducted with the cooperation of farmers at many different localities in Victoria during the ten years previous to publication. The discussion is popular in nature, and intended for the farmers of the colony. One point is very noticeable, the comparative inutility of nitrogenous manures on the soils tested and the great returns given by phosphatic dressings. A large number of results are reported, and care has been taken to analyse them and reject those vitiated by some of the many irregular factors to which field experiments are liable. The report sadly needs a digest and an index to make it useful to students of agricultural science.

THE BRITISH ASSOCIATION.

THE attendance at the Southport meeting of the British Association, while passing the numbers at Belfast last year, has fallen short of the Southport meeting of 1883 by about 1000. The weather, no doubt, is accountable for a certain diminution of numbers, for given fine weather in the middle part of last week, it is certain the figures would have reached 2000. As it is, they number 1751. Comparing this figure with those of recent meetings, however, it will be seen that a good average has been maintained, the numbers at Southport this year exceeding those at the meetings at Belfast, Dover, Toronto, Ipswich, Nottingham, and Cardiff, and falling only a little way behind the Leeds meeting of 1890. It is only when the meeting is compared with the former one at Southport that the falling off of numbers is noticeable.

On all hands the local arrangements have met with praise, the suite of rooms in the municipal buildings having proved admirably fitting for the purposes for which they were allotted.

Unfortunately, the climatic conditions during the earlier part of the meeting prevented the local arrangements being carried out to their full extent, the Mayor's reception on Thursday night taking place under most depressing conditions of rain and storm, rendering the outdoor portion of the programme an impossibility. The weather, fortunately, cleared for the excursions on Saturday, but the downpour of the previous days prevented many people from taking tickets, and many of the parties had not their full number.

The experiments in kite-flying had to be abandoned owing to various causes, and Mr. Dines has had to be content to exhibit his apparatus without taking it out to sea.

Prof. Pernter's experiments in the firing of vortex rings took place on Monday afternoon before a large number of spectators, the firing taking place from the roof of the boathouse over the North Marine Park.

The International Meteorological Committee has been sitting in the Town Hall during the meeting of the British Association, and the members were formally received by the Mayor of Southport in the Mayor's Parlour prior to the beginning of their deliberations. Opportunities have been afforded the many distinguished foreign men of science present in Southport for visiting some of the laboratories, schools, factories, and dockyards of Manchester and Liverpool.

The lecture to working men on Saturday proved very popular, the Cambridge Hall being crowded. A dinner was given by the Mayor at his residence at Greaves Hall to meet Sir Norman Lockyer and Prof. Mascart (President of the International Meteorological Committee). The guests numbered nearly 100, and included Prof. J. Dewar, A. Hopkinson (Vice-Chancellor of Victoria University), Sir George Pilkington, E. Marshall Hall, K.C., M.P., Charles Scarisbrick (Vice-Presidents), Prof. Carey Foster, Major MacMahon, Dr. Adam Paulsen, M. Teisserenc de Bort, Dr. H. Hildebrandsson, Prof. Pernter, General Rykatcheff, Dr. Hellemann, Dr. Hergesell, Dr. H. Mohn, Prof. Willis Moore, A. L. Rotch, Dr. W. N. Shaw, Dr. Ludwig Boltzmann, Dr. T. P. Lotzy, Prof. O. Lignier, Dr. M. Snellen, Dr. G. G. MacCurdy, Dr. H. C. White, T. H. Yoxall, M.P., Hon. T. E. Fuller, Monsignor Molloy, Monsignor Nugent, Canon Denton Thompson, Dr. J. G. Garson, most of the presidents, vice-presidents, and recorders of Sections, and the local secretaries and treasurer.

At the meeting of the general committee held on Friday last, the names of Profs. Mascart, Simon Newcomb, and Boltzmann were added to the list of vice-presidents of Section A.

The Hon. T. E. Fuller, Agent-General for the Cape Colony, Sir Walter Peace, Agent-General for Natal, and Mr. Fiddes, of the Colonial Office (representing the Transvaal), attended on behalf of their respective Governments for the purpose of formally inviting the Association to South Africa in 1905.

On the proposition of Prof. Dewar, seconded by Prof. H. Marshall Ward, it was decided to hold the 1905 meeting in South Africa.

On the motion of Sir Henry Roscoe, seconded by Prof. Forsyth, the Right Hon. A. J. Balfour was elected President of the meeting to be held next year in Cambridge, the meeting to begin on August 17.

The Lord Lieutenant of Cambridgeshire, the Vice-Chancellor of the University, and the Mayor of Cambridge were elected vice-presidents of the Association.

The following elections for the Cambridge meeting were made:—Local secretaries, Messrs. Ginn, A. C. Seward, G. Skinner, and Mr. A. E. L. Whitehead; local treasurers, Mr. A. E. Shipley and Mr. Parker.

Prof. Carey Foster was re-elected treasurer; Major MacMahon and Prof. Herdman general secretaries; and Dr. Garson assistant general secretary.

At the meeting of the committee of recommendations on Tuesday, the following resolutions were adopted:—

(1) That as urged by the President in his address it is desirable that scientific workers and persons interested in science be so organised that they may exert a permanent influence on public opinion in order more effectively to carry out the third object of this Association originally laid down by the founders, viz.:—"to obtain a more general attention to the objects of science and a removal of any disadvantages of a public kind which impede its progress," and that the council be recommended to take steps to promote such organisation.

(2) That the council be requested to consider the desirability of urging upon the Government by a deputation to the First Lord of the Treasury or other-

wise the importance of increased national provision being made for University education.

A recommendation was received from Section A referring to a suggestion from the International Meteorological Committee. At a meeting of that committee on September 11 it was decided to direct the attention of Section A to the inconveniences which arise from lack of uniformity in the units adopted in meteorological observations, and to ask it to consider if the time has not come for bringing about this uniformity. Acting upon this suggestion, the committee of Section A expressed the opinion "that the introduction of international uniformity in the units adopted for the records of meteorological observations would be of great practical advantage to science." The committee of recommendations was asked to take such steps as it may think fit toward giving effect to the above resolutions. It was decided that the matter should be sent to the council through the general committee.

It was resolved to ask the council to consider whether the form of the daily journal of the Association should not be changed so that a provisional list of arrangements for the reading of papers could be published in the journal at as early a date as possible.

The committee also decided to forward the following recommendation to the council:—

"It is desirable that further steps should be taken to make the reports (as distinguished from papers) communicated to the Association more accessible to the general public by the provision of indices to the published volumes and otherwise."

The following is a synopsis of the grants made at the meeting just concluded:—

Mathematics and Physics.	
Rayleigh, Lord—Electrical Standards	Unexpended balance
Judd, Prof. J. W.—Seismological Observations	£40
Shaw, Dr. W. N.—Upper Atmosphere Investigations	50 and unexpended balance
Preece, Sir W. H.—Magnetic Observations	60
Chemistry.	
Roscoe, Sir H.—Wave-length Tables of Spectra	10
Divers, Prof. E.—Study of Hydroaromatics	25
Geology.	
Marr, Mr. J. E.—Erratic Blocks	10 and balance in hand
Scharff, Dr. R. F.—To Explore Irish Caves	Balance in hand
Watts, Prof. W.—Movements of Underground Waters	Balance in hand
Marr, Mr. J. E.—Life Zones in Carboniferous Rocks	35
Herdman, Prof.—Fauna and Flora of the Trias	10
Lamplugh, Mr. G. W.—To Investigate Fossiliferous Drifts	50
Zoology.	
Hickson, Prof. S. J.—Zoological Table at Naples	100
Woodward, Dr. H.—Index Animalium	60
Weldon, Prof.—Investigations in Development in the Frog	15
Hickson, Prof. S. J.—Researches on the Higher Crustacea	15
Economic Science and Statistics.	
Cannan, Dr. E.—British and Foreign Statistics of International Trade	25
Mechanical Science.	
Thornycroft, Sir J. J.—Resistance of Road Vehicles to Traction	90
Anthropology.	
Evans, Sir John—Archæological and Ethnological Researches in Crete	100
Munro, Dr. R.—Researches in Glastonbury Lake Village	25
Macalister, Prof. A.—Anthropometric Investigation on Egyptian Troops	10
Evans, Dr. A. J.—Excavations on Roman Sites in Britain	25
Physiology.	
Halliburton, Prof.—The State of Solution of Proteids	20
Gotch, Prof.—Metabolism of Individual Tissues	40
Botany.	
Vines, Prof. S. H.—Completion of Monograph on Potamogeton	10
Miall, Prof. L. C.—Botanical Photographs	5
Ward, Prof. M.—Respiration of Plants	15
Ward, Prof. M.—Experimental Studies in Heredity	35
Corresponding Societies.	
Whitaker, Mr. W.	20
	£900

SECTION A.

SUB-SECTION OF ASTRONOMY AND METEOROLOGY.

OPENING ADDRESS BY W. N. SHAW, SC.D., F.R.S., CHAIRMAN OF THE SUB-SECTION.

Methods of Meteorological Investigation.

IN opening the proceedings of the Sub-section devoted to Cosmical Physics, which we may take to be the application of the methods and results of Mathematics and Physics to problems suggested by observations of the earth, the air, or the sky, I desire permission to call your attention to some points of general interest in connection with that department which deals with the air. My justification for doing so is that this is the first occasion upon which a position in any way similar to that which I am now called upon to fill has been occupied by one whose primary obligations are meteorological. That honour I may with confidence attribute to the desire of the Council of the Association to recognise the subject so admirably represented by the distinguished men of science who have come across the seas to deliberate upon those meteorological questions which are the common concern of all nations, and whom we are specially glad to welcome as members of this Sub-section. Their presence and their scientific work are proof, if proof is required, that meteorologists cannot regard meteorological problems as dissociable from Section A; that the prosecution of meteorological research is by the study of the kinematics, the mechanics, the physics, or the mathematics of the data compiled by laborious observation of the earth's atmosphere.

But this is not the first occasion upon which the Address from the Chair of the Sub-section has been devoted to Meteorology. Many of you will recollect the trenchant manner in which a university professor, himself a meteorologist, an astronomer, a physicist, and a mathematician, dealt candidly with the present position of Meteorology. After that Address I am conscious that I have no claim to be called a meteorologist according to the scientific standard of Section A. Prof. Schuster has explained—and I cannot deny it—that the responsible duty of an office from which I cannot dissociate myself is signing weather reports; and I could wish that the duty of making the next Address had been intrusted to one of my colleagues from across the sea. But as Prof. Schuster has set forth the aspect of official meteorology as seen from the academic standpoint with a frankness and candour which I think worthy of imitation, I shall endeavour to put before you the aspect which the relation between Meteorology and academic science wears from the point of view of an official meteorologist whose experience is not long enough to have hardened into that most comfortable of all states of mind, a pessimistic contentment.

Meteorology occupies a peculiar position in this country. From the point of view of Mathematics and Physics, the problems which the subject presents are not devoid of interest, nor are they free from that difficulty which should stimulate scientific effort in academic minds. They afford a most ample field for the display of trained intellect, and even of genius, in devising and applying theoretical and experimental methods. And can we say that the work is unimportant? Look where you will over the countries which the British Association may be supposed to represent, either directly or indirectly, and say where a more satisfactory knowledge of the laws governing the weather would be unimportant from any point of view. Will you take the British Isles on the eastern shores of the Atlantic, the great meteorological laboratory of the world, with the far-reaching interests of their carrying trade; or India, where the phenomena of the monsoon show most conspicuously the effects of the irregular distribution of land, the second great meteorological cause, and where recurring famines still overstrain the resources of administration. Take the Australasian colonies and the Cape, which, with the Argentine Republic, where Mr. Davis is developing so admirably the methods of the Weather Bureau, constitute the only land projections into the great southern ocean, the region of "planetary meteorology"· Australia, with its periods of paralysing drought; the Cape, where the adjustment of crops to climate is a question of the hour; or take Canada, which owns at the same time a granary of enormous dimensions and a large portion of the Arctic Circle; or take the scattered islets of the Atlantic and Pacific or the shipping that goes wherever ships can go. The merest glance will show that we stand to gain more by scientific knowledge, and lose more by unscientific ignorance of the weather, than any other country. The annual loss on account of the weather would work out at no inconsiderable sum per head of the population, and the merest fraction of success in the prevention of what science must regard as preventable loss would compensate for half a century of expenditure on meteorological offices. Or take a less selfish view and consider for a moment our responsibilities to the general community of nations, the advantages we possess as occupying the most important posts of observation. If the meteorology of the world were placed, as perhaps it ought to be, in the hands of an International Commission, it can be no exaggeration to say that a considerable majority of the selected sites for stations of observation would be on British soil or British ships. We cannot help being the most important agency for promoting or for obstructing the extension of meteorological science. I say this bluntly and perhaps crudely because I feel sure that ideas not dissimilar from these must occasionally suggest themselves to every meteorologist, British or foreign; and if they are to be expressed—and I think you will agree with me that they ought to be—a British meteorologist ought to take the responsibility of expressing them.

And how does our academic organisation help us in this matter of more than parochial or even national importance? There was a time when Meteorology was a recognised member of the large physical family and shared the paternal affection of all professors of Physics; but when the poor nestling began to grow up and develop some individuality electricity developed simultaneously with the speed of a young cuckoo. The professors of Physics soon recognised that the nest was not large enough for both, and with a unanimity which is the more remarkable because in some of these academic circles utilitarianism is not a condition of existence, and pure science, not market value, might be the dominant consideration—with singular unanimity the science which bears in its left hand, if not in its right, sources of wealth beyond the dreams of avarice was recognised as a veritable Isaac, and the science wherein the fruits of discovery must be free for all the world, and in which there is not even the most distant prospect of making a fortune—that science was ejected as an Ishmael. Electrical engineering has an abundance of academic representatives; brewing has its professorship and its corps of students, but the specialised physics of the atmosphere has ceased to share the academic hospitality. So far as I know the British universities are unanimous in dissembling their love for Meteorology as a science, and if they do not actually kick it downstairs they are at least content that it has no encouragement to go up. In none is there a professorship, a lectureship, or even a scholarship, to help to form the nucleus of that corps of students which may be regarded as the primary condition of scientific development.

Having cut the knot of their difficulties in this very human but not very humane method, the universities are, I think, disposed to adopt a method of justification which is not unusual in such cases; indications are not wanting which disclose an opinion that Meteorology is, after all, not a science. There are, I am aware, some notable exceptions; but do I exaggerate if I say that when university professors are kind enough to take an interest in the labours of meteorologists, who are doing their best amid many discouragements, it is generally to point out that their work is on the wrong lines; that they had better give it up and do something else? And the interest which the universities display in a general way is a good-humoured jest about the futility of weather prophecy, and the kindly suggestion that the improvement in the prediction of the next twenty-four hours' weather is a natural limit to the orbit of an Ishmaelite's ambition.

In these circumstances such an Address as Prof. Schuster's is very welcome: it recognises at least a scientific brotherhood and points to the responsibility for a scientific standard; it even displays some of the characteristics of the Good Samaritan, for it offers his own beast on which to ride, though it recommends the unfortunate traveller to dispose of what little clothing the stripping has left to provide the two pence for the host.

It is quite possible that the unformulated opinion of the vast majority of people in this country who are only too familiar with the meteorological vagaries of the British Isles is that the weather does just as it pleases; that any day of the year may give you an August storm or a January summer's day; that there are no laws to be discovered, and that the further prosecution of so unsatisfactory a study is not worth the time and money already spent upon it. They forget that there are countries where, to judge by their languages, the weather has so nearly the regularity of "old time" that one word is sufficient to do duty for both ideas. They forget that our interests extend to many climates, and that the characteristics of the eastern shores of the North Atlantic are not appropriate to, say, western Tropical Africa. That may be a sufficient explanation of the attitude of the man in the street, but as regards the British universities dare I offer the difficulty of the subject as a reason for any want of encouragement? Or shall I say that the general ignorance on the part of the public of the scientific aspirations and aims of meteorologists and of the results already obtained is a reason for the universities to keep silence on the subject? With all respect I may say that the aspect which the matter presents to official meteorologists is that the universities are somewhat oblivious of their responsibilities and their opportunities.

I have no doubt that it will at once be said that Meteorology is supported by Government funds, and that alma mater must keep her maternal affection and her exiguous income for subjects that do not enjoy State support. I do not wish just now to discuss the complexities of alma mater's housekeeping. I know she does not adopt the same attitude with regard to astronomy, physics, geology, mineralogy, zoology, or botany, but let that pass. From the point of view of the advancement of science I should like to protest against the idea that the care of certain branches of science by the State and by the universities can be regarded as alternative. The advancement of science demands the co-operation of both in their appropriate ways. As regards Meteorology, in my experience, which I acknowledge is limited, the general attitude towards the department seems to be dictated by the consideration that it must be left severely alone in order to avoid the vicious precedent of doing what is, or perhaps what is thought to be, Government work without getting Government pay, and the result is an almost monastic isolation.

There is too much isolation of scientific agencies in this country. You have recently established a National Physical Laboratory the breath of whose life is its association with the working world of physics and engineering, and you have put it—where? At Cambridge, or anywhere else where young physicists and engineers are being trained? No; but in the peaceful seclusion of a palace in the country, almost equidistant from Cambridge, Oxford, London, and everywhere else. You have established a Meteorological Office, and you have put it in the academic seclusion of Victoria Street. What monastic isolation is good for I do not know. I am perfectly certain it is not good for the scientific progress of Meteorology. How can one hope for effective scientific development without some intimate association with the institutions of the country, which stand for intellectual development and the progress of science?

I could imagine an organisation which by association of the universities with a central office would enable this country, with its colonies and dependencies, to build up a system of meteorological investigation worthy of its unexampled opportunities. But the co-operation must be real and not one-sided. Meteorology, which depends upon the combination of observations of various kinds from all parts of the world, must be international, and a Government department in some form or other is indispensable. No university could do the work. But whatever form Government service takes it will always have some of those characteristics which, from the point of view of research, may be called bondage. On the other hand, research, to be productive, must be free with an academic freedom, free to succeed or fail, free to be remunerative or unremunerative, without regard to Government audits or House of Commons control. Research looks to the judgment of posterity with a faith which is not unworthy of the Churches, and which is not among those excellent moral qualities embodied in the Controller and Auditor General. *Die academische Freiheit* is not the characteristic of a Government department. The opportunity which gave to the world the "Philosophiæ Naturalis Principia" was not due to the State subvention of the Deputy Mastership of the Mint, but to the modest provision of a professorship by one Henry Lucas, of whose pious benefaction Cambridge has made such wonderful use in her Lucasian professors.

The future of Meteorology lies, I believe, in the association of the universities with a central department. I could imagine that Liverpool or Glasgow might take a special interest in the meteorology of the sea; they might even find the means of maintaining a floating observatory; and when I say that we know practically nothing of the distribution of rainfall over the sea, and we want to know everything about the air above the sea, you will agree with me that there is room for such an enterprise. Edinburgh might, from its association with Ben Nevis, be desirous of developing the investigation of the upper air over our land; in Cambridge might be found the author of a book, on the principles of atmospheric physics, worthy of its Latin predecessor; and for London I can assign no limited possibilities.

If such an association were established I should not need to reply to Prof. Schuster's suggestion for the suppression of observations. The real requirement of the time is not fewer observations, but more men and women to interpret them. I have no doubt that the first expression of such an organisation would be one of recognition and acknowledgment of the patience, the care, the skill, and the public spirit—all of them sound scientific characteristics—which furnish at their own expense those multitudes of observations. The accumulated readings appal by their volume, it is true, but they are, and must be, the foundation upon which the scientific structure will be built.

So far as this country is concerned when one puts what is in comparison with what might be it must be acknowledged that the tendency to pessimistic complaisance is very strong. Yet I ought not to allow the reflections to which my predecessor's Address naturally gave rise to be too depressing. I should remember that, as Dr. Hellmann said some years ago, Meteorology has no frontiers, and each step in its progress is the result of efforts of various kinds in many countries, our own not excluded. In the presence of our guests to-day, some of whom know by practical experience the advantages of the association of academic liberty with official routine, remembering the recent conspicuous successes in the investigation of the upper air in France, Germany, Austria, and the United States, and the prospect of fruitful co-operation of meteorology with other branches of cosmical physics, I may well recall the words of Clough:—

Say not, the struggle nought availeth . . .
  And as things have been, things remain.

If hopes were dupes, fears may be liars;
  It may be, in yon smoke concealed
Your comrades chase e'en now the fliers,
  And, but for you, possess the field.

For while the tired waves, vainly breaking,
  Seem here no painful inch to gain,
Far back, through creeks and inlets making,
  Comes silent, flooding in, the main.

And not by eastern windows only,
  When daylight comes, comes in the light;
In front, the sun climbs slow, how slowly,
  But westward, look, the land is bright.

Official meteorologists are not wanting in scientific ambitions and achievements. It is true that Prof. Hann, whose presence here would have been so cordially welcomed, left the public service of Austria to continue his services to the world of science by the compilation of his great handbook, and Snellen is leaving the direction of the weather service of the Netherlands for the more exclusively scientific work of directing an observatory of terrestrial physics; but I am reminded by the presence of Prof. Mascart of those services to meteorological optics and terrestrial magnetism that make his place as President of the International Committee so natural and fitting; and of the solid work of Angot on the diurnal variation of the barometer and the reduction of barometric observations for height that form conspicuous features among the many valuable memoirs of the Central Bureau of Paris.

Of the monumental work of Hildebrandsson in association with Teisserenc de Bort on clouds, which culminated quite recently in a most important addition to the pure kinematics of the atmosphere, I hope the authors will themselves speak. Prof. Willis Moore's presence recalls the advances which Bigelow has made in the kinematics and mechanics of the atmosphere under the auspices of Prof. Moore's office, and reminds us of the debt of gratitude which the English-speaking world owes to Prof. Cleveland Abbé, of the same office, for his treatment of the literature of atmospheric mechanics.

If General Rykatcheff had only the magnificent climatological Atlas of the Russian Empire to his credit he might well rest satisfied. Prof. Mohn's contributions to the mechanics of the atmosphere are examples of Norwegian enterprise in the difficult problems of Meteorology, while Dr. Paulsen maintains for us the right of meteorologists to share in the results of the newest discoveries in physics. Davis's enterprise in the far south does much to bring the southern hemisphere within our reach, while Chaves places the meteorology of the mid-Atlantic at the service of the scientific world. Need I say anything of Billwiller's work upon the special effect of mountains upon meteorological conditions, or of the immense services of the joint editors of the *Meteorologische Zeitschrift*, Prof. Pernter, of Vienna, and Dr. Hellmann, of Berlin; of Palazzo's contributions to terrestrial magnetism? The mention of Eliot's Indian work, or of Russell's organisation of Australian meteorology, will be sufficient to show that the dependencies and colonies are prepared to take a share in scientific enterprise. And if I wished to reassure myself that even the official meteorology of this country is not without its scientific ambitions and achievements, I would refer not only to Scott's many services to science but also to Strachey's papers on Indian and British Meteorology and to the official contributions to Marine Meteorology.

There is another name, well known in the annals of the British Association, that will for ever retain an honoured place among the pioneers of meteorological enterprise—that of James Glaisher, the intrepid explorer of the upper air, the Nestor of meteorologists, who has passed away since the last meeting of the Association.

I should like especially to mention Prof. Hergesell's achievements in the organisation of the international investigation of the upper air by balloons and kites, because it is one of the departments which offers a most promising field for the future, and in which we in this country have a good many arrears to make up. I hope Prof. Hergesell will later on give us some account of the present position of that investigation, and I am glad that Mr. Rotch, to whose enterprise the development of what I may call the scientific kite industry is largely due, is present to take part in the discussion.

Yet with all these achievements it must be confessed that the progress made with the problems of general or dynamical Meteorology in the last thirty years has been disappointing. When we compare the position of the subject with that of other branches of Physics it must be allowed that it still lacks what astronomy found in Newton, sound in Newton and Chladni, light in Young or Fresnel, heat in Joule, Kelvin, Clausius, and Helmholtz, and electricity in Faraday and Maxwell. Above all, it lacks its

Kepler. Let me make this clear. Kepler's contribution to physical astronomy was to formulate laws which no heavenly body actually obeys, but which enabled Newton to deduce the law of gravitation. The first great step in the development of any physical science is to substitute for the indescribably complex reality of nature an ideal system that is an effective equivalent for the purposes of theoretical computation. I cannot refrain from quoting again from Plato's "Republic" a passage which I have quoted elsewhere before. It expresses paradoxically but still clearly the relation of natural philosophy to natural science. In the discussion of the proper means of studying sciences Socrates is made to say "We shall pursue astronomy with the help of problems just as we pursue geometry: but we shall let the heavenly bodies alone if it is our design to become really acquainted with astronomy." What I take to be the same idea is expressed in other words by Rayleigh in the introduction to his "Sound." He there points out as an example that the natural problem of a sounding tuning-fork really comprises the motion of the fork, the air, and the vibrating parts of the ear; and the first step in sound is to simplify the complex system of nature by assuming that the vibrations of the fork, the air, and the ear can be treated independently. Frequently this step is a most difficult one to take. What student of nature, contemplating the infinity of heavenly bodies and unfamiliar with this method of idealism, would imagine that the most remarkable and universal generalisation in physical science was arrived at by reducing the dynamics of the universe to the problem of three bodies? When we look round the sciences each has its own peculiar ideals and its own physical quantities: astronomy has its orbits and its momentum, sound its longitudinal vibration, light its transverse vibration, heat its energy and entropy, electricity its "quantity" and its wave, but meteorology has not yet found a satisfactory ideal problem to substitute for the complexity of nature. I wish to consider the aspect of the science from this point of view and to recall some of the attempts made to arrive at a satisfactory modification of reality. I do not wish to refer to such special applications of physical reasoning as may be involved in the formation of cloud, the thermodynamics of a mixture of air and water vapour, the explanation of optical or electrical phenomena, nor even Helmholtz's application of the theory of gravitational waves to superposed layers of air of different density. These require only conventions which belong already to physics, and though they may furnish suggestions they do not themselves constitute a general meteorological theory.

The most direct efforts to create a general theory of atmospheric circulation are those which attempt to apply Newtonian dynamics, with its more recent developments on the lines of hydrodynamics and thermodynamics. Attempts have been made, mathematical or otherwise, to determine the general circulation of the atmosphere by the application of some form of calculation, assuming only the sun and a rotating earth, with an atmosphere, as the data of the problem. I confess that these attempts, interesting and ingenious as they are, seem to me to be somewhat premature. The "problem" is not sufficiently formulated. When Newton set to work to connect the motions of the heavenly bodies with their causes, he knew what the motions of the heavenly bodies were. Mathematics is an excellent engine for explaining and confirming what you know. It is very rarely a substitute for observation, and before we rely upon it for telling us what the nature of the general circulation of the atmosphere really is, it would be desirable to find out by observation or experiment what dynamical and elastic properties must be attributed to an extremely thin sheet of compressible fluid rotating about an axis with a velocity reaching 1000 miles an hour, and subject to periodic heating and cooling of a very complicated character. It would be more in consonance with the practice of other sciences to find out by observation what the general circulation is before using mathematics to explain it. What strikes one most about the mathematical treatises on the general circulation of the atmosphere is that what is true about the conclusions is what was previously known from observation. It is, I think, clear that that method has not given us the working ideal upon which to base our theory.

Consider next the attempts to regard atmospheric phenomena as periodic. Let me include with this the correlation of groups of atmospheric phenomena with each other or with those of the sun, when the periodicity is not necessarily regular, and the scientific process consists in identifying corresponding changes. This method has given some remarkable results by the comparison of the sequence of changes in the meteorological elements in the hands of Pettersen and Meinardus, and by the comparison of the variation of pressure in different parts of the globe by Sir Norman Lockyer and Dr. W. J. S. Lockyer; as regards the earth and the sun the subject has reached the stage of productive discussion. As a matter of fact, by continuing this Address I am preventing Sir Norman Lockyer from telling you all about it.

For the purpose of dealing with periodicity in any form we substitute for nature an ideal system obtained by using mean values instead of individual values, and leaving out what, from this point of view, are called accidental elements. The simplification is perfectly legitimate. Passing on to the consideration of periodicity in the stricter sense the process which has been so effective in dealing with tides, the motions of the liquid layer, is very attractive as a means of attacking the problems of the atmosphere, because, in accordance with a principle in dynamics, to every periodic cause there must correspond an effect of the same period, although the relation of the magnitude of the effect to the cause is governed by the approximation of the natural period of the body to that of the cause.

There are two forms of the strict periodic method. One is to examine the generalised observations for periodicities of known length, whether it be that of the lunar rotations or of sunspot frequency, or of some longer or shorter period. In this connection let me acknowledge a further obligation to Prof. Schuster for tacking on to his Address of last year a development of his work on the detection of hidden periodicities by giving us a means of estimating numerically what I may call the reality of the periodicity. The other method is by harmonic analysis of a series of observations with the view of finding causes for the several harmonic components. I may say that the Meteorological Office, supported by the strong opinion of Lord Kelvin, has favoured that plan, and on that account has for many years issued the hourly results for its observatories in the form of five-day means as representing the smallest interval for which the harmonic analysis could be satisfactorily employed. Sir Richard Strachey has given some examples of its application, and the capabilities of the method are by no means exhausted, but as regards the general problem of dynamic meteorology harmonic analysis has not as yet led to the disclosure of the required generalisation.

I ought to mention here that Prof. Karl Pearson, with the assistance of Miss Cave, has been making a most vigorous attempt to estimate the numerical value of the relationship, direct or inverse, between the barometric readings at different places on the earth's surface. The attempt is a most interesting one as an entirely new departure in the direction of reducing the complexity of atmospheric phenomena. If it were possible to find coordinates which showed a satisfactory correlation it might be possible to reduce the number of independent variables and refer the atmospheric changes to the variations of definite centres of action in a way that has already been approached by Hildebrandsson from the meteorological side.

Years ago, when Buys Ballot laid down as a first law of atmospheric motion that the direction of the wind was transverse to the barometric gradient and the force largely dependent upon the gradient, and when the examination of synchronous charts showed that the motion of air could be classified into cyclonic and anticyclonic rotation, it appeared that the meteorological Kepler was at hand, and the first step towards the identification of a working meteorological unit had been taken—the phenomena of weather might be accounted for by the motion and action of the cyclonic depression, the position of the ascending current, the barometric minimum. The individual readings over the area of the depression could be represented by a single symbol. By attributing certain weather conditions to certain parts of the cyclonic area and supposing that the depression travelled with more or less unchanged characteristics the vagaries of weather changes can be accounted for. For thirty years or more the depression has been closely watched, and thousands of successful forecasts have been based upon a knowledge of its habits. But unfortunately the travelling depression cannot be said to preserve its identity in any sense to which quantitative reasoning can be applied. As long as we confine ourselves to a comparatively small region of the earth's surface the travelling depression is a real entity, but when we widen our area it is subject to such variations of path, of speed, of intensity, and of area that its use as a meteorological unit is seriously impaired, and when we attempt to trace it to its source or follow it to its end it eludes us. Its origin, its behaviour, and its end are almost as capricious as the weather itself.

Nor if we examine other cases in which a veritable entity is transmitted can we expect that the simple barometric distribution should be free from inexplicable variations. We are familiar with ordinary motion, or, as I will call it, astronomical motion, wave motion, and vortex motion. Astronomical motion is the motion of matter, wave motion the motion of energy, vortex motion the motion of matter with energy, but the motion of a depression is merely the transmission of the locus of transformation of energy; neither the matter nor the energy need accompany the depression in its motion. If other kinds of motion are subject to the laws of conservation of matter and conservation of energy, the motion of the depression must have regard also to the law of dissipation of energy. An atmospheric disturbance, with the production of rainfall and other thermal phenomena, must comply in some way with the condition of maximum entropy, and we cannot expect to account for its behaviour until we can have proper regard to the variations of entropy. But the conditions are not yet in a form suitable for mathematical calculation, and we have no simple rules to guide us. So far as Meteorology is concerned, Willard Gibbs unfortunately left his work unfinished.

When the cyclonic depression was reluctantly recognised as too unstable a creature to carry the structure of a general theory Mr. Galton's anticyclones, the areas of high pressure and descending currents, claimed consideration as being more permanent. Prof. Köppen and Dr. van Bebber have watched their behaviour with the utmost assiduity and sought to find therein a unit by which the atmospheric changes can be classified; but I am afraid that even Dr. van Bebber must allow that his success is statistical and not dynamical. "High pressures" follow laws on the average, and the quantity we seek is not an average but an individual.

The question arises, whether the knowledge of the sequence of weather changes must elude us altogether, or will yield to further search. Is the man in the street right after all? But consider how limited our real knowledge of the facts of atmospheric phenomena really is. It may very well be that observations on the surface will never tell us enough to establish a meteorological entity that will be subject to mathematical treatment; it may be that we can only acquire a knowledge of the general circulation of the atmosphere by the study of the upper air, and must wait until Prof. Hergesell has carried his international organisation so far that we can form some working idea therefrom of general meteorological processes. But let us consider whether we have even attempted for surface meteorology what the patience of astronomers from Copernicus to Kepler did for astronomy.

Do we yet fully comprehend the kinematics of the travelling depression; and if not, are we in a satisfactory position for dealing with its dynamics? I have lately examined minutely the kinematics of a travelling storm, and the results have certainly surprised me and have made it clear that the travelling depressions are not all of one kinematical type. We are at present hampered by the want of really satisfactory self-recording instruments. I have sometimes thought of appealing to my friends the professors of physics who have laboratories where the reading of the barometer to the thousandth of an inch belongs to the work of the "elementary class," and of asking them to arrange for an occasional orgy of simultaneous readings of the barometer all over the country with corresponding weather observations for twenty-four consecutive hours, so that we might really know the relation between pressure, rainfall, and temperature of the travelling depressions; but I fear the area covered would even then hardly be large enough, and we must improve our self-recording instruments.

Then, again, have we arrived at the extremity of our knowledge of the surface circulation of the atmosphere? We know a great deal about the average monthly distribution, but we know little about the instantaneous distribution. It may be that by taking averages we are hiding the very points which we want to disclose.

Let me remind you again that the thickness of the atmosphere in proportion to the earth's surface is not unsatisfactorily represented by a sheet of paper. Now it is obvious that currents of air in such a thin layer must react upon each other horizontally, and therefore we cannot *a priori* regard one part of the area of the earth's surface as meteorologically independent of any other part. We have daily synoptic charts for various small parts of the globe, and the Weather Bureau extended these over the northern hemisphere for the years 1875 to 1879; but who can say that the meteorology of the northern hemisphere is independent of that of the southern? To settle that primary question we want a synchronous chart for the globe. As long as we are unable to watch the changes in the globe we are to a certain extent groping in the dark. A great part of the world is already mapped every day, and the time has now arrived when it is worth while to consider what contributions we can make towards identifying the distribution of pressure over the globe. We may idealise a little by disregarding the local peculiarities without sacrificing the general application. I have put in the exhibition a series of maps showing what approximation can be made to an isochronous chart of the globe without special effort. We are gradually extending the possibility of acquiring a knowledge of the facts in that as in other directions. With a little additional enterprise a serviceable map could be compiled; and when that has been reached, and when we have added to that what the clouds can tell us, and when the work of the Aëronautical Committee has so far progressed that we can connect the motion of the upper atmosphere with the conditions at the surface, when we know the real kinematics of the vertical and horizontal motion of the various parts of a travelling storm, we shall, if the universities will help us, be able to give some rational explanation of these periodic relations which our solar physics friends are identifying for us, and to classify our phenomena in a way that the inheritors of Kepler's achievements associated with us in this Section may be not unwilling to recognise as scientific.

SECTION B.

CHEMISTRY.

OPENING ADDRESS BY PROF. W. N. HARTLEY, D.Sc., F.R.S., F.R.S.E., PRESIDENT OF THE SECTION.

THE ofttimes laborious method of investigating the relationship of substances by ascertaining how one form of matter can operate upon another, in other words by chemical reactions, has of late been supplemented by the examination of their physical properties, and has been extended to compounds, both organic and inorganic. In several directions this has led to results of very uncommon interest. Accordingly I propose to offer a brief account of twenty-five years' experimental work in that branch of chemical physics which deals with the emission and absorption of rays of measurable wave-length, and to review its present position chiefly in relation to the theory of chemistry, indicating where it may be usefully and profitably extended.

According to Davy ("Chemical Philosophy," vol. i., 1812, p. 211), Ritter observed chemical action on moist chloride of silver to be different in different parts of the spectrum, slight in the red, greater towards the violet, and entending into a space beyond the violet where there is no sensible light or heat. Wollaston discovered that chemical action was exerted by refracted rays in a region where they were of a higher refrangibility than any rays that were visible. Young showed that the invisible rays are liable to the same affections as visible rays. Hence we have the beginnings of spectrum analysis in its chemical relations to terrestrial matter, in the infra-red, the visible, and the ultra-violet regions.

Everyone is more or less familiar with the subject of spectrum analysis. This was defined by Tait as an optical method of making a diagnosis of the chemical composition of either (*a*) a self-luminous body, or (*b*) an absorbing medium, whether self-luminous or not. It has now become necessary to enlarge this definition, and I would suggest that it is the study of the composition and the constitution of matter by means of radiant energy, and recording in the order of their refrangibilities the rays emitted and absorbed by matter. By this modified statement the infra-red or so-called "invisible heat rays," the visible or "colour rays," and the ultra-violet or "chemical rays" are included.

Spectra are of two kinds, emission and absorption spectra. It will be convenient if the latter are considered first.

ABSORPTION SPECTRA.

The Infra-red Region.

Abney (1880) by the preparation of a particularly sensitive form of collodion emulsion containing silver bromide was successful in obtaining very extraordinary results. Such films as he prepared were so sensitive to invisible radiations of long wave-length as to be capable of forming a representation of even a kettle of boiling water, standing in an absolutely dark room. This picture could not of course be properly referred to as a photograph, though the process by which it was obtained was such as we are accustomed to term a photographic process. It may with greater propriety be termed an actinograph, the result not of light, but of dark rays. The least refrangible of the visible rays lies about wave-length 7800 ten-millionths of a millimetre, or Ångström units; but these rays extend as far as wave-length 12,000, while Becquerel has measured lines in the spectra of metals of as low a refrangibility as wave-length 18,000.

Abney and Festing (1881) investigated the influence of atomic groupings in the molecules of organic substances by measuring their absorption in the infra-red region of the spectrum.

They studied such simply constituted substances as water, hydrochloric acid, chloroform, carbon tetrachloride, and cyanogen, besides many hydrocarbons with their hydroxyl, haloid, and carboxyl derivatives. Characteristic groups of lines or very narrow bands were observed in carbon compounds, but they are absent from carbon compounds containing no hydrogen, and do not all appear in some of the hydrogen compounds. The facts observed led to the conclusion that they belonged to hydrogen, but are subject to some occasional modifications. Oxygen in hydroxyl, for instance, modifies two of the lines, since it obliterates by absorption the rays which lie between them. Oxygen in aldehyde, or when it forms part of the carbon nucleus of some such compound, presents bands which are bounded by well-defined lines, or are inclined to be linear. These appear to be characteristic bands indicating the carbon nucleus of a series of substances. Alkyl radicals, such as ethyl, exhibit absorption bands, and so does the benzene nucleus. It is a remarkable fact that bands appear in the solar spectrum which correspond with those of benzene (1881).

Julius (1893) has investigated the absorption in the infra-red caused by many carbon compounds by means of the bolometer, combined with a prism, and also with a diffraction grating. He showed that the molecules of compound substances absorbed the rays which were emitted at the time of their formation. Thus, to take the simplest case, the emission spectrum of hydrogen burning in air corresponds with the absorption bands of water vapour, that is to say, the absorption spectra of the compounds are the counterpart of the emission spectra of the flames which yield these compounds during combustion. The emission spectrum of carbon dioxide is found in the spectrum of burning carbon monoxide, cyanogen, methane, and carbon disulphide; and that of water-vapour in various hydrocarbons. As early as 1888 Julius, in an Inaugural Dissertation, quoting Tyndall, recognised that the absorption and emission of rays measured with the thermopile were manifestations of the molecular vibrations.

The various absorption spectra examined included those of the alcohols, such as isopentylic, isobutylic, normal butylic, propylic, ethylic, and methylic, as well as hydrocarbons, chloroform, and benzene. The study of the maxima of radiation and the maxima of absorption offers us a means of arriving at a knowledge of a series of new and valuable physical constants, namely, the vibration periods characteristic of the molecules. (Tyndall discussed this subject in his usually luminous style on pp. 391 to 402 of his work "Heat as a Mode of Motion.")

Puccianti (1900) has examined the infra-red absorption spectra of liquids, including aromatic compounds and alkyl derivatives, while Donath has examined in the same region various essential oils. Carbon combined with hydrogen shows a maximum of absorption with a wave-length about (1·71 μ mm.) 17,100 Ångström units.

Benzene and pyridine have two other maxima of absorption in common. The alcohols have very similar maxima of absorption at wave-length 21,000.

The three isomeric xylenes show absorption spectra which are almost identical. At or about wave-length 23,200 another maximum of absorption is shown.

Julius refers to Langley's observation that at a wave-length of 27,000 there is an abrupt termination to the solar spectrum, probably caused by the water vapour in the atmosphere; but a band extends to 273,000, and at no very great elevation above the earth's surface there are rays with a wave-length of 45,700 Ångström units. All radiations of longer wave-length—and Julius has measured down to 149,000 Ångström units—are likely to be absorbed by the carbon dioxide in the atmosphere.

The Visible Rays or Colour Region.

J. L. Schönn (1879) examined the absorption spectra of substances usually considered to be colourless in layers from 1·6 to 3·7 metres in thickness and observed narrow bands in the spectra of methyl, ethyl, and amyl alcohol, lying in the red, orange, and yellow; methyl alcohol showed two bands, ethyl and amyl alcohol each three. Gerard Krüss (1888) calculated the wave-lengths of these bands, and it appears that the higher members of the homologous series have the bands displaced towards the red end of the spectrum. Russell and Lapraik (1879) made similar observations on columns of liquid from two to eight feet in length. All the substances gave well-defined absorption bands lying between wave-lengths 6000 and 7000.

The bands of the different substances differed altogether from the bands of water. Alcohols give a band which is similar in different alcohols, but the higher the alcohol stands in the homologous series, that is to say, the larger the number of carbon atoms it contains, the nearer is the band to the red end of the spectrum (1881).

It was definitely established that for each CH_3 introduced into a molecule of ammonia or benzene there is a shifting of the absorption bands towards the red end of the spectrum.

It will, of course, be understood that the liquids examined were perfectly colourless in the ordinary acceptation of the term; and that they appear so is owing to the bands of absorption being very narrow, so that the percentage of luminous rays withdrawn by absorption is but a very small fraction of the whole spectrum emitted by a source of light when viewed under ordinary conditions.

Numerous observations were made by Melde, Burger, Magnus, H. W. Vogel, and Landauer (1876–78), which showed that changes in the absorption spectra of solutions are partly physical and partly chemical, that is to say, they are caused by changes in the constitution of the solution. Vogel mentions cases where no chemical change was believed to take place, as, for instance, where naphthalene red shows different spectra according to whether it is dissolved in alcohol, water, resin, or is solid or used to colour paper (1878).

This points to some difference in the constitution of the solution. A well-known instance is that of iodine in alcohol, chloroform, or carbon disulphide.

It must be observed that Vogel's work referred merely to phenomena observable in the visible spectrum, to small thicknesses of the absorbing medium, and was not applied quantitatively. Two solutions may give spectra which are apparently identical at one concentration, but spectra quite different when submitted to varying degrees of dilution.

In order to ascertain in what way absorption spectra are related to the chemical constitution of organic substances, it is necessary to examine a wider range of spectrum than that included in the merely visible region, and this may be done by extending the observations into the ultra-violet.

The Ultra-violet Region.

Stokes in preparing his experiments for a Friday evening discourse at the Royal Institution observed that the spectrum of electric light when a prism and lenses of quartz were used extended no less than six or eight times the length of the visible spectrum. In 1862 he studied the ultra-violet spectra of metals and executed drawings of the lines exhibited by aluminium, zinc, and cadmium. He discovered the fact that certain solutions show light and dark bands in the spectrum of rays transmitted by them, the solutions being colourless; the bands are invisible unless they fall on a fluorescent screen. It was under such conditions that they exhibited light and darkness. The screen used was of plaster of Paris saturated with a fluorescent substance, such as uranium phosphate.

William Allen Miller in 1863, simultaneously with Stokes, described his method of examining the photographic transparency of various saline solutions and organic substances and of depicting metallic spectra. A sensitised photographic plate was used for the reception of the rays of the spectrum, so that they were made to register their own position and intensity. L. Soret invented the fluorescent eye-piece for the purpose of investigating the ultra-violet rays and ascertained the best media for the transmission of rays of high refrangibility. Colourless fluor-spar, a rare mineral, was found to answer best, and quartz lenses were achromatised with this. Iceland spar was found to absorb some of the more refrangible rays, and a pure spectrum was difficult to obtain with quartz prisms owing to double refraction, which caused the lines in metallic spectra to be duplicated. Struck by the fact that Miller had examined many organic substances without obtaining evidence of a connection between their constitution and their absorption spectra—the actual words used by Miller were, "I have not been able to trace any special connection between the chemical complexity of a substance and its diactinic power" (*Journ. Chem. Soc.*, vol. xi. p. 68)—it appeared to me desirable that this point should be systematically reinvestigated. L. Soret had already proceeded with work in this direction, by examining and drawing a great variety of organic substances and diagrams of absorption curves. But it was deemed necessary to make a large number of examinations of substances of a comparatively simple constitution, and according to theory closely related, and afterwards gradually to proceed to the study of substances of greater complexity. For such purposes a photographic method alone appeared a practicable one, particularly when comparisons had to be made between substances observed at different times, for the reason that none but photographic records could be absolutely relied upon and stored away for future reference.[1]

The plan of the proposed investigation was to photograph the rays transmitted by molecular proportions of hydrocarbons, alcohols, acids, and esters, either alone as vapour or liquid, or dissolved in some neutral and, in comparison with the substances to be examined, an optically non-absorbent solvent.

It was considered that the metameric esters would afford much information if a sufficient number of them were examined and their spectra compared, and if the acids themselves were not responsive the sodium and potassium salts in solution would serve the purpose, since the alkalies did not affect the spectrum. The general deductions (1879) are now well known, but two points not generally taken into account were well established. First, the extraordinary delicacy of the ultra-violet spectrum in detecting traces of impurities. For instance, pyridine, an invariable impurity in commercial ammonia, is present in the proportion of about 1/30000th. It was proved that the absorption spectra of the normal paraffins prepared with the greatest care by Schorlemmer contained traces of impurities which could not be separated. Secondly, some of the normal alcohols could not be rendered pure by the ordinary methods employed, and great care was necessary in their preparation. It may well be asked that, if such were the case, upon what grounds was it concluded that impurities were present? How was it possible to distinguish between a normal and an abnormal absorption spectrum when no standards of comparison existed? It may be of interest if this question be now answered, as no adequate account of it has been made public. All the substances in any one homologous series were shown to vary in the extent to which the rays at the more refrangible end of the spectrum were absorbed, and the different terms of the series differ solely by the number of CH_2 groups in the molecule; and the greater the number of these the greater the absorption. The extent of the absorption should be proportional to the molecular weight of the substance. Accordingly if repeatedly purifying and fractionally distilling a considerable quantity of material failed to give spectra which were constant and identical, but gave instead spectra which were variable, even in a slight degree, it was evident that the absorption due to the molecule of the substance was interfered with by some impurity.

When, however, it became evident that successive quantities of methylic alcohol, for example, prepared in a certain manner yielded spectra which were practically identical under different conditions, such as thickness of liquid, and that they differed but slightly from that of pure water after the type of which the alcohol is constituted, the conclusion was inevitable that we were dealing with a pure preparation. In short, the longest spectrum obtained in all circumstances and under every reasonable condition could not possibly be the result of accident, more particularly if it could be repeatedly obtained from different specimens of the same substance. The same reasoning applies to the acids and their salts in the investigation of which similar difficulties arose.

Soret and Rilliet pointed out that in the rectification and prolonged desiccation of the alcohols there is often slight oxidation which leads to the production of impurities which affect the spectra transmitted by them.

They found that ethyl alcohol is not appreciably less diactinic than methyl alcohol, and both transmitted a spectrum nearly as long as that of water. This was shown by Huntington and me when the usual 25 mm. of thickness of the layer of liquid were tested. By taking columns of liquid 100 mm. in length the differences are greater, and they increase with columns of increased length.

The influence of each additional CH_2 in the molecule causes a shortening of the spectrum. This was shown to be due to the carbon atoms and not to the hydrogen. The acids, containing the same number of carbon atoms as the alcohols, have a much greater absorptive power, which is due to the carboxyl group ($C:O\cdot OH$). By the examination of a number of various substances, such as polyhydric alcohols, as glycol, glycerol, mannitol, and various sugars, it was found that, no matter what its complexity, no open-chain compound causes selective absorption, *i.e.* absorption bands.

Shortly it may be stated that in the examination of organic substances we have three variations in absorption

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[1] Clerk Maxwell had calculated for Miller the best focal length of lenses of quartz which would give an approximately flat field. His computation made this something over a length of three feet. All Miller's photographs were taken with the plate placed normal to the axis of the lens, but Stokes had shown that the locus of the foci of the different rays formed an arc of a curve or nearly a straight line, lying very obliquely to the axes of the pencils coming through the lens.

It was obvious from Miller's photographs that only one or two rays on each plate were even approximately in focus. To obtain spectra in focus from end to end it was evidently necessary to incline the plate so that the end upon which the red rays would fall, which are of longest wave-length, should be farther off than that upon which the ultra-violet fall, which are of shortest wave-length. It was also found experimentally that lenses of much shorter focal length (ten or twelve inches) could be used, giving perfect definition, and, what is still more important, it was found a positive advantage not to have them corrected by fluor-spar or calcite. The plate carrier was adjusted at an inclination of approximately 22° to the normal; in such a position the rays from the yellow sodium line to the extreme ultra-violet of the spark spectrum of cadmium were simultaneously in focus on a plane surface.

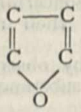
The prism was of quartz cut on Cornu's plan, the method of construction designed to get rid of all double refraction being communicated to me by M. Cornu in a very kindly written letter. The first instrument was constructed in 1878 and the description of it published in 1881. It has been the model for several others. One with two prisms and lenses of 12 inches focus was exhibited by me in the Inventions Exhibition in 1882. At the Jubilee meeting of the British Association at York the spark spectra of iron, cobalt, and nickel, enlarged to twenty-five diameters and printed by the Autotype Company, were exhibited. They are more than 8 feet in length, and have proved very useful for reference. The photographic process is a point of great importance; the then newly invented gelatine bromide films made by Kennet were alone quite suitable.

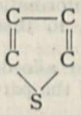
spectra: First, those of substances the rays of which are freely transmitted, the absorption being at the more refrangible end of the spectrum, and the spectrum of which is readily increased in length by dilution; secondly, those in which the spectra are of the same kind, but the absorptive power is greater, so that they withstand dilution to a much greater extent; thirdly, those spectra which exhibit selective absorption, and which at the same time exert great absorptive power, or, in other words, can undergo great dilution before the absorption bands are rendered visible, and still further dilution before they are extinguished or obliterated.

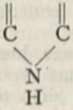
Spectra of the First Variety belong to substances which are constructed on an open chain of carbon atoms, thus: C·C·C·C·C or C═C·C·C·C and C≡C·C·C·C.

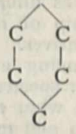
The introduction in place of one or more atoms of hydrogen—of hydroxyl, OH, carboxyl, COOH, methoxyl, OCH_3, CO, COH, or NH_2, or of side chains such as CH_3, C_2H_5, &c.—does not affect the character of the spectra, but merely the absorptive power, which is increased when oxygen or an oxygenated radical is introduced.

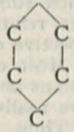
Spectra of the Second Variety are spectra of substances so constituted that the carbon atoms form a closed chain. It is immaterial whether the closed chains are homocyclic or heterocyclic; thus:—

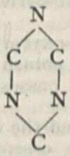

Furfurane

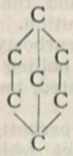

Thiophene

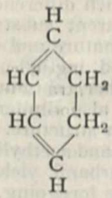

Pyrrol

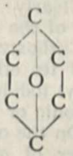

Diketohexamethylene Hydro-aromatic compounds


Piperidine


Cyanuric Acid

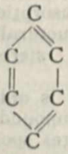

Camphor

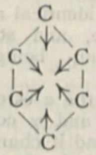

Dihydrobenzene

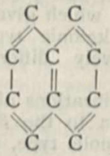

Cineol

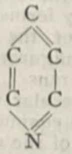
They possess greater absorptive power than open-chain compounds, but do not exhibit absorption bands. It is manifestly the chain or ring structure of the compounds that gives them greater absorptive power, and not the number of carbon atoms in the molecules.

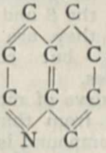
Spectra of the Third Variety.—These show absorption bands, and the substances yielding them are generally constituted on the type of benzene, naphthalene, anthracene, phenanthrene, &c.; but the rings may be either homocyclic or heterocyclic without the character of the spectra being altered; thus:—


Benzene


Benzene


Naphthalene


Pyridine


Quinoline


Pyrazine

If we say that the compounds which are homocyclic are constituted of at least three pairs of carbon atoms doubly linked, which are themselves singly linked together, we may make use of the formula of Kekulé for benzene as the simplest expression of their constitution; if we assume that each of the six atoms is linked to at least other two atoms we adopt what is practically the prism formula of Ladenburg, or the same idea expressed in space of two dimensions. It is difficult to express the physical condition by the Armstrong-Baeyer formula or centric arrangement because this does not clearly suggest to one's mind what is manifestly the fact, namely, that the carbon atoms in the nucleus of benzene are much more closely condensed or combined together than those of the hydroaromatic series. This condensed condition of the carbon atoms is evident from the higher molecular refractive energy of aromatic compounds and of the specific refractive energy of the carbon in such combinations.

Side chains such as do not exert selective absorption have no influence on the character of the spectra, but they slightly increase the general absorption.

Heterocyclic compounds possess greater absorptive power, both as regards the general and selective absorption, than those which are homocyclic.

The point which I particularly desire to direct attention to here is, that for the first time Kekulé's remarkable benzene theory was supported by definite physical measurements, and the closed-ring formula represented a veritable actuality.

Of Molecular and Intra-molecular Vibrations.

Johnstone Stoney was the first to show that the cause of the interrupted spectra of gases is to be referred to the motions within the individual molecules, and not to the irregular journeys or encounters of the molecules with each other; and this applies to the absorption as well as to emission spectra. He further advised the use of oscillation frequencies instead of wave-lengths in describing the measurements of spectra. Johnstone Stoney and Emerson Reynolds subsequently examined the extraordinary absorption exhibited by chlorochromic anhydride, the bands in which are evidently harmonically related.

It has already been shown that the hydrocarbons of the aromatic series exert two kinds of absorption, a general and a selective absorption. All the evidence we possess warrants the belief that the general absorption is caused by the motion of the molecules, while the selective absorption is due to the motion within the molecules.

When the molecule of a substance is capable of vibrating synchronously with a radiation, the ray received on this substance is absorbed. The absorption is complete if the direction of the vibration of the molecule and of the ray is the same but the phase opposite, and if the number of molecules in the path of the rays is sufficient to damp all the vibrations.

When the quantity of substance in the path of the rays is reduced, the number of molecules present is not sufficient to damp all the vibrations and some of the rays are transmitted. If, however, certain carbon atoms within the molecule are vibrating synchronously with certain rays, we shall have selective absorption of these rays after the general absorption has been so weakened by dilution or otherwise as to allow them to pass.

It is evident, then, that general absorption exerted by carbon compounds is due to the vibration of the molecules because the absorption increases with the number of carbon atoms in the molecule; or, in other words, in any homologous series the greater the molecular mass the lower the rate of vibration of the molecule.

It has not been found possible to associate any of the absorption bands of the substances examined with any particular carbon atoms; but the bands in benzene are six in number, or the same in number as the carbon atoms. It has, however, been shown that the rapidity of the intramolecular vibrations was dependent upon the rate of vibration of the molecules. From numbers representing approximately the mean wave-lengths of the four chief bands of rays absorbed by benzene, naphthalene, and anthracene, and from the velocity of light, the mean rate of the vibrations within the molecules was calculated (1881), the numbers being as follows:—

	Molecular Vibrations
Benzene	1248^{10}
Naphthalene	1177^{10}
Anthracene	910^{10}

The mean rate of vibration of the rays absorbed by naphthalene is less than that absorbed by benzene, and those of anthracene less than those of naphthalene. It follows from this that the vibrations within the molecules are not independent, but are a consequence, of the fundamental molecular vibrations, like the harmonics of a stretched string or of a bell.

The term absorptive power has generally been used with respect to the extent of rays of the spectrum absorbed, but there is intensity of absorption to be considered. In the case of a vibrating string or tuning-fork greater amplitude of vibration means a louder note; in the case of molecules greater intensity of absorption may be caused by a greater amplitude of vibration in the molecules of the absorbing medium, the number of molecules being constant. But by greater amplitude it is not to be understood that the rate of vibration is increased.

If this be so then, as the absorption intensity of anthracene and naphthalene is, molecule for molecule, greater than that of benzene, the amplitude of vibration of the molecules of these substances is greater, but the rate of vibration is slower.

From the foregoing it will be observed that where λ is the wave-length $1/\lambda$ is the inverse wave-length, omitting the correction for the refraction of air which is a very small value, it is the oscillation frequency of the ether in a small unit of time, and the most convenient measurement for use in describing spectra. Seven years after the publication of these views Gerard Krüss (1888) dealt with the subject of coloured substances in a similar manner. From the undulatory theory of light, deductions may be drawn regarding the inner molecular movements or inter-atomic movements within the molecules, inasmuch as the vibrations of the ether, which fills the intra-molecular space, are a resultant within that space of the velocity and amplitude of the molecular vibrations.

Thus, if λ be the wave-length of a ray emitted by a substance, and v the velocity of light, the number of vibrations, n, which a molecule sends forth by movements of it as a whole and of its parts can be determined by the equation $n = v/\lambda$.

G. Krüss made a series of calculations for coloured substances similar to those which I had made for colourless substances and for ozone.

Curves of Molecular Vibrations.

Observations on absorption spectra should, whenever it is possible, be made with reference to the quantity of substance which produces a given measurable effect. A molecular weight in milligrams or a milligram-molecule is a convenient quantity which may be dissolved in 20 c.c., 40 c.c., or 100 c.c. of any non-absorbent liquid, and observed through thicknesses of the solution varying from 25 mm. to 1 mm. in thickness. When a series of photographs has been measured a curve is plotted, which shows the general and the selective absorption of the substance. The oscillation frequencies of the absorbed rays are taken as abscissæ, and the proportional thickness in millimetres of the weakest of a series of solutions as ordinates. The curves are as often as possible made continuous, and they are called *curves of molecular vibrations*.

The curves of the molecular vibrations present very striking features: they are valuable physical constants which enable one to classify and identify substances.

Position Isomerism.

Isomerides of the *ortho-*, *meta-*, and *para-*positions in aromatic substances yield spectra with the absorption bands, differing in position, in width, and in intensity. There is no distinguishing character to be observed in the different isomerides. Isomerism in the pyridine, quinoline, and naphthalene derivatives has not yet been completely studied. In such cases as have already passed under review there is nothing that indicates the positions of the substituted hydrogens.

Stereo-isomerism.

Where isomerism is not due to differences in structure, but simply to the distribution of the atoms in space, we have no means of distinguishing isomeric substances from an examination of their spectra; for instance, benz-*syn*-aldoxime and benz-*anti*-aldoxime yield curves of molecular vibrations which are identical.

Tautomerism.

The possibility of an atom of hydrogen occupying alternative positions in a compound

$$(\mathrm{NH \cdot C : O \rightleftarrows N : C \cdot OH})$$

so that it may be united to an atom of nitrogen or of carbon in one instance, or to an atom of oxygen in another, easily gives rise to substances with different characters, the one that of a phenol, the other that of a ketone. One interpretation of the facts observed which has been very commonly received may be stated thus. Certain compounds have in their constitution an atom of hydrogen of a "roving disposition" which at one time will attach itself to an atom of oxygen, or to an atom of nitrogen, and anon it will forsake one of these and unite itself to an atom of carbon. The consequence of this "instability of character" is that when a derivative of the compound is being prepared or sought for by a chemical process, which according to all previous knowledge ought to yield it, the substance brought forth is of a different class, but withal of the same composition; it is, in fact, an isomeride.

According to another theory, the two isomeric derivatives of the parent substance are present in equal proportions in a solution in a state of equilibrium, and upon crystallisation one or other of these assumes the solid form. Taking those cases where a substance has a constitution which it is believed has been correctly ascertained by chemical reactions, and which yields two isomeric alkyl derivatives, it becomes a question as to which of these the parent substance has directly given birth to. The evidence from chemical reactions has in many cases failed to give a satisfactory answer, but the curves of molecular vibrations of such substances afford the desired information concerning the relationship of their constitution to that of their respective derivatives.

Most convincing evidence has been afforded by observations on their spectra, that several of the parent substances are really not what they seem to be.

Thus, isatin and methyl pseudo-isatin yield curves which are almost identical, the sole difference between them being due to the substitution of the alkyl radical for hydrogen, the nature of which difference might have been predicted.

Clearly the parent substance and the pseudo-derivative are of the same nature and constitution.

Carbostyril and methyl-pseudo-carbostyril, *o*-oxycarbanil and its ethyl ether, obtained by boiling with potash and ethyl iodide, are also similarly related, and they possess the ketonic or lactam structure.

On the other hand methylisatin, carbostyril, and the other ether of *o*-oxycarbanil yield curves which are essentially different from the foregoing, and are enolic or of the lactim type. Generally speaking, the ketonic are more stable than the enolic forms. Dibenzoyl-methane is ketonic, and the tautomeric substance oxybenzal-acetophenone is enolic, and in this instance the enolic form is that with the greatest stability. The two substances yield different curves, and the gradual change of the less stable into the more stable form can be traced by photographing the spectra of the solutions at intervals.

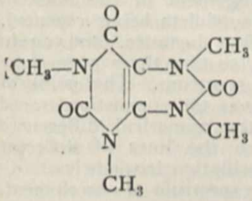
The ethyl esters of dibenzoyl succinic acid are of interest in this connection. There are three isomers known out of the thirteen which are possible, and the spectra of these have been studied. Knorr has given three formulæ for what he designates the α, β, and γ esters. Of these there are two, the β and γ forms, which give identical absorption curves: they are of the ketonic type, and structurally identical, but configuratively different, being stereo-isomerides.

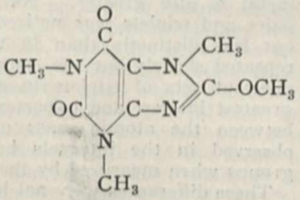
The curve of molecular vibrations of the α ester is quite different from that common to the β and γ compounds. The α compound is of the enolic type, and it changes spontaneously at ordinary temperatures into the ketonic, thus showing that in this case also the latter is the more stable. The transition from the one form into the other was seen to be in progress, and after an interval of only three hours the absorption band of the enolic ester had almost entirely disappeared. In three weeks the transformation had become complete, as was shown by the molecular vibration curve of the α ester being almost exactly coincident with that of the β and γ forms.

Another interesting example is afforded by the study of phloroglucinol, it being a substance with a constitution of a somewhat doubtful character, for owing to the ambiguity of its behaviour towards chemical reagents it is impossible to arrive at a decision from chemical evidence whether the oxygen atoms are present in enolic or ketonic groups. Towards some substances it behaves as a phenol, towards others as a ketone. The doubt also presented itself as to whether phloroglucinol from various sources had the same constitution, and, further, whether there might not be two isomeric forms of the compound present in equal proportions in a solution of the substance. Specimens of phloroglucinol prepared in five different ways from different materials gave curves of molecular vibrations which were identical: this decided the question absolutely; they are one and the same substance. If the constitution of the substance is that of a trihydroxybenzene or phenol, then the trimethyl ether should exhibit an absorption curve differing but slightly in detail from that of the parent substance; and, furthermore, the latter should exhibit a general resemblance to the curves of pyrogallol and phenol. This was found actually to be the case in both particulars.

Finally, with regard to tautomerism, it may be considered as decided that no evidence has been obtained based upon either physical measurements or chemical reactions of, first, the presence of a "wandering" atom of hydrogen as a characteristic of compounds which exhibit tautomerism; secondly, that solutions of tautomeric compounds do not contain equal quantities of the two substances, or enolic and ketonic forms in equilibrium, and that if both are present one so greatly preponderates over the other that no trace of any but the one compound can be detected; thirdly, it has been observed that some substances do change spontaneously from one form to another, and that this change sets in very quickly after the substance has been dissolved; fourthly, that substances change from one form to another under the influence of different reagents, as, for instance, cotarnine, as Dobbie and Lauder (1903) have shown, in presence of methyl alcohol or of caustic soda, and again in presence of potassium cyanide. In fact it appears that under the influence of different reagents one or other of the two compounds is the more stable, and the more stable substance is then formed.

A reaction is recorded in the researches of Emil Fischer where it appears that two tautomeric forms are produced simultaneously from oxycaféine. When the silver salt of this substance is heated with methyl iodide it yields a mixture of tetramethyl uric acid and methoxycaféine, the characteristic groupings in which are $-NH-CO-$ and $-N=COH-$, the hydrogens being methylated. This is a singular reaction which has not yet been studied spectrographically.


Tetramethyluric Acid.


Methoxycaféine.

The Absorption Spectra of Alkaloids.

The interest attached to an examination of the absorption spectra of the alkaloids is not alone the fact that a means of recognising, detecting, and estimating such substances was devised, but still more that we may learn something of their chemical constitution. Many of the poisonous alkaloids give no distinctive chemical reactions, and in certain cases the means of recognising them are restricted to observations on their crystalline form and their physiological action. The physiological action of certain alkaloids of an extremely deadly character is remarkable enough to prove a means of their identification when the effect on the human subject is under observation. The first experimental work on the absorption spectra of the alkaloids arose out of a celebrated trial for murder, which engaged much attention in the year 1882. It was proved that the lethal drug administered was aconitine.

To identify this substance, of which there are several varieties, it was necessary at that time to resort to physiological tests made upon small animals.

Such a course always affords an opportunity for forensic arguments based upon the evidence adduced. To substitute absolute physical measurements for physiological tests seemed to present facilities for securing justice by removing any doubt of the identity of an unknown substance with the nature of one which is known. Alkaloids yield spectra of two kinds, those which do not and those which do exhibit absorption bands, the difference between the two classes of substances being one dependent on the constitution of the nucleus or ultimate radical of the compound. It is possible not only to identify substances, but also to determine the quantity present in a mixture or solution, and this has actually been done.

Alkaloids which are derived from benzenoid hydrocarbons, pyridine, quinoline, or phenanthrene give evidence of their origin by their spectra. It is therefore advantageous to make a careful study of the absorption spectra of the substances themselves and of the various products derived from them when studying their constitution. It was remarked while the work was in progress that the quinine spectrum curve was probably due to the conjugation of four pyridine or two quinoline nuclei. It is known now to be a substance of a complicated structure containing one quinoline nucleus. It differs from cinchonine only by one methoxyl group in the *para*-position. Observations made on simple bases differ from those made on substitution products, such as alkyl derivatives, in this respect, that the bases are the more diactinic, while addition products, such as hydrogenised compounds, and also salts of the alkaloids such as hydrochlorides, are more diactinic than the simple bases. It was shown by the researches of Alder Wright that different preparations of aconitine can yield substances slightly differing in constitution. On examining them it was shown that these preparations yielded different absorption curves the variations in which were due to differences in the constitution of the different preparations. To state a particular case of a well-defined character, the aconitine from *aconitum napellus* and japaconitine from a Japanese aconite prepared by Alder Wright had practically the same absorption spectrum and yielded similar curves; but that of japaconitine was just what might be expected from a substance with a nucleus of a similar constitution, but about twice the molecular weight of aconitine; in other words, a condensation of two molecules of aconitine into one—namely, what was observed in the spectra of morphine and apomorphine, a much greater absorptive intensity with a similar absorption curve.

It was shown that japaconitine has a constitution modified in such a manner; it being, in fact, what was termed by Alder Wright a sesquiapoaconitine; and the formulæ given for these substances are respectively: Aconitine, $C_{34}H_{47}NO_{11}$; japaconitine, $C_{66}H_{88}N_2O_{21}$, which is in agreement with the spectrum observations. It has, however, been supposed by Freund and Beck that the two substances are identical.

Strychnine and brucine are two alkaloids evidently closely related, but little is known about their constitution; both seem to contain a pyridine nucleus united to what is probably a pyrrolic nucleus, the two constituting a conjugated nucleus resembling that of quinoline. The difference between brucine and strychnine is said to be simply that the former contains two methoxyls. The absorption curves show a wider difference than this, and it was predicted that strychnine appears to be a derivative of pyridine, but brucine is more probably a derivative of tetrahydroquinoline, or an addition product of quinoline of the same character, since there is a remarkable similarity between the curves of the two substances. I would suggest that for the future evidence from their spectra be taken into account in studying their constitution.

Stereo-isomerism in the Alkaloids.

Many alkaloids having the same formula are stereoisomerides, and those related in this manner exhibit molecular absorption curves which are identical. The following examples are quoted by Dobbie and Lauder (1903) as the result of their investigations: dextro-corydaline and inactive corydaline; narcotine and gnoscopine; tetrahydroberberine and canadine. Where two compounds are known to have the same formula, and one of these is optically active, the other inactive, it may be inferred, as Dobbie and Lauder have pointed out, that they are not optical isomerides if their absorption curves are different; thus canadine and papaverine have the same formula, but their absorption curves show that they are structurally different.

It is a general rule that substances which agree closely in structure exhibit similar series of absorption spectra, while those which differ essentially in structure show absorption curves which are different; and to this rule neither aromatic compounds, alkaloids, nor dyes and coloured substances form any exceptions. That this is so is easily understood from the theory of absorption spectra. It must, however, be distinctly understood that the essential feature of importance in all such investigations is the quantitative relation of the substance to its spectra, whether these relations are based upon equal weights of material or equimolecular proportions in solutions of given volume and thickness.

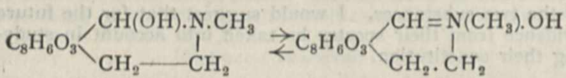
The relationship of morphine, $C_{17}H_{17}NO(OH)_2$, and codeine, or methylmorphine, $C_{17}H_{17}NO.(OH)(OCH_3)$, was shown by their spectra, the latter being a homologue of the former. A similar instance has been investigated recently by Dobbie and Lauder. The resemblance between the spectra of laudanine, $C_{20}H_{25}O_4N$, and laudanosine, $C_{21}H_{27}O_4N$, confirms the view that they are homologous bases. The close agreement of their absorption curves with those of corydaline and tetrahydropapaverine clearly indicates a similarity in structure to that of these alkaloids, but the relationship of laudanosine to corydaline is probably closer than to tetrahydropapaverine, and may be best explained by the formulæ

$$\underset{\text{Corydaline}}{C_{22}H_{27}O_4N - CH_2 + H_2} \quad = \quad \underset{\text{Laudanosine}}{C_{21}H_{27}O_4N}$$

The removal of a methyl group from such a compound would scarcely cause any appreciable change in the curve of molecular vibrations, and very many cases are known where, when two atoms of hydrogen are introduced into a compound without altering the close linking of the carbon atoms of the ring formation in the compound, the alteration in the spectrum is insignificant.

A particularly interesting example of tautomerism already mentioned has been observed by Dobbie and Lauder in studying the constitution of cotarnine, a substance prepared from narcotine. Three formulæ have been proposed for it: one represents it as an aromatic aldehyde in which one hydrogen is replaced by an open change containing nitrogen; a second gives it the character of a carbinol base; while a third that of an ammonium base. It has been supposed that in solution it is a mixture of two or all three such substances in a state of equilibrium, but as to what is the formula to be assigned to solid cotarnine the data are insufficient to determine. There are, however, two different solutions of the substance obtainable; that in ether or chloroform is quite colourless, like the solid; but a solution in water or alcohol is yellow. From the molecular absorption spectra of these solutions and of certain derivatives with which they are compared there is very distinct evidence that a solution in alcohol or water contains the ammonium base, while under the influence of sodium hydroxide it assumes the condition of the carbinol form. Moreover, the rate of transformation and the conditions which influence this isomeric change have been studied. It suffices here to state that a solution containing entirely the one form may be converted wholly into the other.

The two formulæ referred to are given below:—



$$C_8H_6O_3\begin{cases} CH(OH).N.CH_3 \\ \qquad\qquad\; | \\ CH_2\text{———}CH_2 \end{cases} \rightleftarrows C_8H_6O_3\begin{cases} CH{=}N(CH_3).OH \\ \qquad\quad | \\ CH_2.CH_2 \end{cases}$$

Carbinol Form   Ammonium Base

EMISSION SPECTRA.

Spark Spectra and their Constitution.

As it became necessary to make accurate measurements of absorption spectra in the ultra-violet, the work of obtaining the wave-lengths of lines in twenty metallic spectra was undertaken. They were for the most part in a region which, except in the case of two or three elements, had not been previously explored. A small Rutherford grating was employed, combined with quartz lenses with a focal length of three feet. Experience has shown that it was advisable in describing these spectra to give measurements in hundredths of an inch of the positions of the lines on the published photographs of the prismatic spectra in the *Journal* of the Chemical Society (March, 1882), and to follow Lecocq de Boisbaudran by giving a description of the character of each of the lines. In this way they are easily identified, and the value of the measurements for practical purposes is greatly enhanced. Prior to the publication of the work (1882), in the prosecution of which Dr. Adeney was associated with me, Liveing and Dewar, who had been engaged on a similar investigation, but operating in a different manner, published an account of the spectra of the metals of the alkalies and alkaline earths, and subsequently the lines of iron, nickel, and cobalt. They showed a rhythmic grouping of the lines to be characteristic of the spectra of the alkali metals.

In connection with the prismatic spectra which were photographed some remarkable facts were noticed; for instance, the character of the lines belonging to different groups of elements was a noticeable feature, as well also their disposition or arrangement, more particularly in the ultra-violet. Similarities in the visible spectra of zinc and cadmium, of calcium, strontium, and barium, and in those of the alkali metals had been observed by Mitscherlich, by Lecocq de Boisbaudran, and also by Ciamician. As to the grouping of the lines as observed on the photographs, it appeared that the spectra of well-defined groups of elements had characteristics in common which were different from those of other groups. For instance, the alkali metals differed from the alkali earth metals which appeared to form a group by themselves. Then in marked contrast to these simple spectra were those of iron, nickel, and cobalt, which though very complicated were seen to be much alike. Nearest to these but differing from them in certain respects were the palladium, gold, and platinum spectra.

It was observed how these elements with certain chemical and physical properties in common could be recognised as being relations owing to their family likeness when their spectra were photographed. Then it was remarked that the spectra of magnesium, zinc, and cadmium, had distinctive characters in common; for instance, the individual lines in these spectra were marked by similar characteristics, such as a great extension of the strong lines above and below the points of the electrodes. This extension was increased with the atomic mass of the metal, and with the greater atomic mass in this group the volatility of the metal is also greater. An arrangement of the lines in pairs and triplets was noticed, the triplets being repeated, but less distinctly than in the first instance, and again repeated sharply but less strongly, so that there were three different sets of triplets in each spectrum. The point of greatest interest and importance was the connection traced between the atomic mass and the numerical differences observed in the intervals between the lines of different groups when measured by their oscillation frequencies.

These differences were not in the spectrum of one element, but were in the lines of each metal of the group, and were clearly associated with the atomic mass and chemical properties in each case.

The arrangement of the lines, which was common to all the metals in the magnesium, zinc, cadmium group, may shortly be described as follows:—Three isolated lines and one pair of lines in magnesium, with four sets of triplets; one isolated line and one pair of lines in zinc, with three sets of triplets; one isolated line and one pair of lines in cadmium, with three sets of triplets.

Besides the arrangement of these lines there were in the spectrum of each element two groups of the most refrangible lines, consisting one of a quadruple group and the other of a quintuple group, the groups and the lines composing them being similarly disposed in each spectrum. It was, however, not distinctly proved that these particular groups were strictly homologous, the most refrangible lines in the zinc spectrum being very difficult to photograph even on specially prepared plates, though the lines are strong. It was furthermore observed that with an increase in the atomic mass the distances between the lines both in pairs and triplets were greater. The same was the case with the quadruple and quintuple groups. In the magnesium spectrum, if we compare the first with the second group of triplets, we find the intervals extending from the first line in the first group to the first line in the second group, and from the second line in the first group to the second line in the second group, and from the third line in the first group to the third line in the second group, when measured in terms of oscillation frequencies to be 677·1, 677·0, and 677·4. Similarly taking the second and third groups it is 391·2, 391·1, and 391·1. Between the third and fourth groups in like manner it is 230·9, 233, and 233; so that the intervals diminish with increase of refrangibility of the lines.

In the zinc spectrum the intervals between the lines in the first and second groups are 910, 910, and 910; in the second and third groups 582, 581, and 583.

In the cadmium spectrum the corresponding intervals are 801·5, 800, and 800; in the second and third groups 588, 589, and 587. The more accurately the lines are measured the more exactly do these differences correspond. It is scarcely necessary to point out that the differences in the atomic masses of the elements are in round numbers where H = 1, Mg 24, Zn 65, and Cd 112.

The *Law of Constant Differences* rendered it evident that the spectra of the elements were subject to a law of homology, which was closely connected with the atomic mass and with their chemical and physical properties.

It was, in fact, found, in accordance with the periodic law, that the spectra of definite groups were spectra similarly constituted, from which it was deduced that they are produced by similarly constituted molecules. It is evident that there is periodicity in their spectra. The metals studied being all monatomic in their molecular condition, the conclusion was inevitable that the atoms were of complex constitution, and that not only was the complex nature of these atoms disclosed, but it was also shown that groups of elements with similar chemical and physical properties, the atomic weights of which differed by fixed definite values, were composed of the same kind of matter, but the matter of the different elements was in different states of condensation, as we know it to be in different members of the same homologous series of organic compounds. If this were not the case, the mass or quantity of matter in the atom would not affect in the same manner its rate of vibration—which the facts observed lead us to conclude that it does—and the chemical properties of the substances would differ more widely from one another, and the differences between them would not be gradational, which in fact they are. It was thus impossible to believe that the atoms were the ultimate particles of matter, though so far as chemical investigations had proceeded they were parts which had not been divided. Here the conviction was forced upon one that matter might exist in a state which had hitherto been unrecognised by those who accepted the atomic theory without searching beneath it. All that the atomic theory enabled the chemist to take account of were the laws of combination and decomposition of the forms of matter that are ponderable and of sufficient mass to be weighable on the finest balances, which after all are but crude and imperfect instruments for the study of matter, since they are capable only of determining differences between masses of tangible size. It became conceivable that matter in the state of gas or vapour might become so attenuated that repulsion of the molecules would be greater than the attraction; that they would then no longer form aggregates, and in consequence would cease to be weighable. In such a condition they may be imagined to constitute the ether, and in view of this conception there may be recognised four physical conditions of material substances, namely, solid, liquid, gas, and ether.

It is more than twenty years ago since the study of homology in spectra led me to the conviction that the chemical atoms are not the ultimate particles of matter, and that they have a complex constitution.

That the atoms of definite groups of chemically related elements are composed of the same kind of matter in different states of condensation is not a dream or a view of a visionary character, for it is based upon definite observations controlled by exact physical measurements, and is therefore in the nature of a theory rather than an hypothesis. Batchinski (1903) regards the atoms as being in a state of vibration, and the periods of vibration of related elements appear to stand in a simple relation to their properties. The mass of an atom is proportional to the square of its period of vibration, and conversely the vibration period of the atom may be calculated from the square root of the atomic weight. These values have been calculated and arranged according to Mendeléeff's classification, whereby it is shown that there is a decided tendency to form harmonic series in the vertical columns. The deviations are probably capable of explanation, as the author believes, on the ground that the atom is not to be regarded as a material point, but as a material system. It is well to remember that the precursor of the Periodic Law was Newland's Law of Octaves.

I have always experienced great difficulty in accepting the view that because the spectrum of an element contained a line or lines in it which were coincident with a line or lines in another element it was evidence of the dissociation of the elements into simpler forms of matter. In my opinion, evidence of the compound nature of the elements has never been obtained from the coincidence of a line or lines exclusively belonging to the spectrum of one element with a line or lines in the spectrum exclusively belonging to another element. This view is based upon the following grounds:—First, because the coincidences have generally been shown to be only apparent, and have never been proved to be real; secondly, because the great difficulty of obtaining one kind of matter entirely free from every other kind of matter is so great that where coincident lines occur in the spectra of what have been believed to be elementary substances they have been shown from time to time to be caused by traces of foreign matter, such as by chemists are commonly termed impurities; thirdly, no instance has ever been recorded of any homologous group of lines belonging to one element occurring in the spectrum of another, except and alone where the one has been shown to constitute an impurity in the other; as, for instance, where the triplet of zinc is found in cadmium and the triplet of cadmium in zinc; the three strongest lines in the quintuple group of magnesium in graphite, and so on. The latest elucidation of the cause of coincidences of this kind arises out of a tabulated record from the wave-length measurements of about three thousand lines in the spectra of sixteen elements made by Adeney and myself. The instances where lines appeared to coincide were extremely rare; but there was one remarkable case of a group of lines in the spectrum of copper which appeared to be common to tellurium; also lines in indium, tin, antimony, and bismuth which seemed to have an origin in common with those of tellurium.

It is difficult to separate tellurium from copper, and copper from tellurium, by ordinary chemical processes. Dr. Köthner, of Charlottenburg, has succeeded in obtaining very pure tellurium from the spectrum of which these lines and also several others have been almost entirely eliminated, which shows that they are foreign to the element, and that his specimen of tellurium is probably purer than any previously obtained. For determining the atomic weight of tellurium it is of course necessary to obtain it in the greatest possible state of purity; and it may be mentioned that the material which Staudenmaier employed for this purpose was found, from Köthner's photograph of its spectrum, to be a very pure specimen.

The prosecution of researches in connection with the constitution of spectra was initiated by Johnstone Stoney, by Balmer with respect to hydrogen, and continued by Rydberg, Deslandres, Ames, and, above all, by Kayser and Runge, who by an elaborate and exhaustive investigation of the arc spectra of the elements have given us formulæ by which the wave-lengths of lines in the spectra of different elements in certain definite groups may be calculated. They also showed the spectra to be constituted of three series of lines, the principal series and two subordinate series, one sharp and the other diffuse.

Ramage, however, has given us a simpler formula, depending on the atomic weight, which applies to several groups, and he has co-ordinated the spectra of several of the elements with the squares of their atomic masses, and also their atomic masses with other of their physical properties.

It may here be remarked that the homology of the spark spectra in the magnesium, zinc, and cadmium series was at first called in question by Ames, though he proved the arc spectra of zinc and cadmium to be strictly homologous.

Preston decided the question by demonstrating by means of beautiful photographs that corresponding lines such as the pairs, triplets, and the quadruple groups in the spark spectra of the three metals when under the influence of a very powerful magnetic field underwent the same kind of change; for instance, each quadruple group changed to sextuple, the second and fourth lines in each group becoming double. Lines in spectra which have not the same constitution behave differently. Recently Runge and Paschen have arrived at the same conclusion; and, furthermore, have established homology in the spectra of sodium, copper, and silver; also between aluminium and thallium. Indium is almost certainly homologous with aluminium and thallium, but it was probably not investigated on account of its rarity. Marshall Watts has pointed out that a relationship exists between the lines in the spectra of some elements and the squares of their atomic weights, from which it is possible to calculate the atomic weight of an element if that of another in the same homologous series is known, and the oscillation frequencies of corresponding lines are known.

The knowledge of spectra we now possess enables the determination of atomic weights to be controlled with quite as much efficiency and certainty in many instances as by specific heat or vapour-density determinations.

The first application of the observed homology in spectra was directed towards the question of the atomic mass of beryllium, for which purpose the lines in the ultra-violet spark spectrum of this element were first photographed and measured. The nature of the evidence on the subject adduced at the time was in outline as follows:—

"If, as Nilson and Petterson suggest, the position of beryllium is at the head of a series of triad rare earth metals, the element scandium (at. wt. 44) and yttrium (at. wt. 89) must be members of the same group. If this be the case the spectra of the three elements must have certain characters in common, for the series of which aluminium and indium are the first and third terms yield strictly homologous spectra. As a matter of fact no two spectra could be more dissimilar than those of beryllium and scandium."

Having compared the photographs and wave-length measurements of a large number of spectra of the elements, I felt justified in making the following remarks:—

"The spectrum of beryllium exhibits no marked analogy with the calcium, the magnesium, or the aluminium spectra, all of which are members of well-defined homologous series. There is nothing similar in it to the boron, silicon, or carbon spectra, nor to those of the scandium, yttrium, or cerium. The spectrum of lithium is most closely analogous to that of beryllium in the number, relative positions, and intensities of the lines. This leads to the conclusion that beryllium is the first member of a dyad series of metals, to which in all probability calcium, strontium, and barium, as a sub-group, are homologous, its atomic mass being 9·2, its place is above magnesium." Subsequently Nilson, and also Humpidge, by chemical evidence and from vapour-density determinations of certain compounds, substantiated the conclusion previously arrived at by Emerson Reynolds, that the atomic mass of beryllium was not 13·8 but 9·2.

The next practical application of the spark spectra was to the analysis of rhabdophane, a mineral found many years ago in Cornwall and described by Heuland in 1837 as a zinc blende of a peculiar character.

This mineral I found to contain neither zinc nor sulphur, and therefore it is not a blende. It is, in fact, a phosphate of the formula $R_2O_3.P_2O_5.2H_2O$, in which the oxides of cerium, didymium, lanthanum, and yttrium may wholly or in part replace each other. The didymium absorption spectrum is well seen both by reflection from the surface and transmission through thin sections of the mineral. The spark spectrum of the yttrium chloride obtained from rhabdophane was compared with that observed by Thalén and ascribed to yttrium. Of the fifty-one lines in the spectrum of yttrium thirty-eight were absent from the yttrium obtained from rhabdophane, and it was concluded that the purest yttrium was that which yielded the simplest spectrum. This was the first occasion of the finding of yttrium in any British mineral. Quite recently a confirmation of this view has been obtained by comparing this spectrum with lists of the arc lines of yttrium and ytterbium which have just been published by Kayser (1903).

Penfield analysed a mineral found in the United States which he named scovellite: it proved to be identical in species with rhabdophane.

Flame Spectra at High Temperatures.

What are commonly known in the chemical laboratory as flame spectra are chiefly those of the metals of the alkalies and alkaline earths; also of gallium, indium, and thallium. The researches of Mitscherlich and Lecocq de Boisbaudran first showed that copper, manganese, and gold gave flame spectra. Lockyer, Gouy, and Marshall Watts also investigated flame spectra.

In 1887 I used iridium wires one millimetre thick, twisted into loops upon which fragments of minerals were heated in the oxygen blowpipe flame. Natural silicates yielded spectra not only of alkalies but of the alkaline earths, and also distinct manganese spectra. Baryta, strontia, and lime gave spectra when insoluble compounds such as the sulphates were thus examined at high temperatures. Iron, cobalt, and nickel gave spectra even when compounds such as the oxides were heated strongly. But iridium, though infusible, is somewhat volatile, and contributes a line spectrum to the flame. In 1890 thin slips of the mineral kyanite and even pieces of tobacco pipe were used instead. Experience with this method of working went to show how the flame spectra of oxides of calcium, strontium, and barium could be separated from those of lithium, sodium, potassium, rubidium, and cæsium, as observed in the Bunsen flame. Furthermore, that even the most volatile of these substances could be made to yield a continuous coloration from a single bead of salt for a period exceeding fifteen minutes, and extending to one or two hours, so that measurements of the lines might be made with some degree of certainty.

In order to study the flames emitted from furnaces during metallurgical operations, and particularly from the mouth of Bessemer vessels, it became necessary to ascertain what really were the lines of the elements observed under different conditions at a high temperature, and accordingly systematic methods of study were developed from the previous somewhat tentative experiments.

In all the flame spectra obtained by the oxyhydrogen blowpipe the ultra-violet line spectrum emitted by water vapour which had been discovered by Huggins and by Liveing and Dewar was visible on the photographs by reason of the combustion of the hydrogen in the hydrocarbon, or the hydrogen gas itself, when burnt along with oxygen. The flame spectra are always shorter than those obtained from the arc or from condensed sparks. After an extended examination of spectra produced by the oxyhydrogen blowpipe from solid substances, the knowledge obtained was applied to the examination of the flames coming from the Bessemer vessel during the "blow" during all periods from the commencement to the termination. These observations were made at the London and North-Western Railway Steel Works at Crewe; and at Dowlais, in South Wales. In collaboration with Mr. Ramage, a large number of these complicated spectra were photographed at the North-Eastern Steel Works, where the Thomas-Gilchrist process is carried out. The spectra were fully described and measured, with the result that every one of the lines and bands was accounted for. A new line belonging to potassium was discovered to have peculiar properties. Gallium was proved to be present in the Cleveland ore from Yorkshire, in the finished metal, in clays and in all aluminous minerals, even in corundum. Also, by very accurate determinations of the wave-lengths of its principal lines, gallium was proved to be a constituent of the sun. Moreover it was found in several meteorites. Pure gallium oxide was separated, by analytical methods, from iron ores and other materials; and the proportion of the metal in the steel rails made by the North-Eastern Steel Company, of Middlesbrough, was determined and found to be one part in thirty thousand. This Yorkshire steel is richer in gallium than any other substance from which it has been extracted; for instance, the Bensburg blende, supposed hitherto to be the richest ore, contains only one part in fifty thousand.

By observations on the spectra, the thermo-chemistry of the Bessemer process of steel manufacture was studied, and the temperatures attained under varying conditions were estimated. The demonstration of the great volatility of most metals, and of many metallic oxides in an undecomposed condition, at the temperature of the oxyhydrogen blowpipe and of the Bessemer flame was of special interest.

The metals chiefly referred to are copper, silver, lead, tin, manganese, chromium, iron, cobalt, nickel, palladium, gold, and iridium. Several of these, such as silver and gold, have lately been distilled *in vacuo* by Krafft.

Banded Flame Spectra.

Well-defined groups of elements yield banded flame spectra which have a similar constitution; thus magnesium, zinc, and cadmium yield bands composed of fine lines, degraded towards the violet, while fluted band spectra of beryllium, aluminium, and indium were found to be degraded towards the red. Thallium also yields a fluted spectrum; gallium gives a line spectrum; lanthanum gives bands degraded towards the red; palladium gives bands in the nature of flutings composed of fine lines; germanium gave very faint indications of bands; rhodium and iridium both lines and bands. It became manifest that elements belonging to the same group in the periodic system of classification exhibited banded spectra which are similarly constituted, and hence similarly constituted molecules of the elements have similar modes of vibration, whether at the lower temperature of the flame or at the higher temperature of the arc or spark. Banded spectra are thus shown to be connected with the periodic law.

A great advantage is to be derived from an investigation of banded spectra from a theoretical point of view, as well as from the application of this method to the analysis of terrestrial matter. While the spectra are easily obtained, they can be applied in a very simple manner to the chemical analysis of minute quantities of material, and may readily be made quantitative.

M. Armand de Gramont has described a method of obtaining spectra of metals and metalloids by means of a spark, and has given the analysis of eighty-six mineral species. The novelty and importance of his work lies in the method of obtaining spectra of such constituent substances as chlorine, bromine and iodine, sulphur, selenium and tellurium; also phosphorus and carbon when in a state of combination, as sulphates, phosphates, carbonates, &c.

There is a possibility of utilising this method for the quantitative determination of carbon, sulphur, and phosphorus in iron and steel during the process of manufacture.

Definition of an Element.

In a discussion on the question of the elementary character of argon in 1895 it was pointed out by me that argon gave a distinct spark spectrum by the action of condensed sparks, and therefore, on this evidence alone, it must be regarded as an element. The fact that it gave two spectra under different conditions was not opposed to, nor did it invalidate, this evidence, because such an element as nitrogen not only emits two spark spectra, but the two spectra can be readily photographed simultaneously from the same spark discharge.

It was proposed by M. de Gramont at the International Congress in Paris in 1900, and agreed, that no new substance should be described as an element until its spark spectrum had been measured and shown to be different from that of every other known form of matter.

This appears to me to have been one of the most important transactions of the Congress. The first application of this rule has resulted in the recognition of radium as a new element: it is characterised by a special spark spectrum of fifteen lines which have been fully studied and measured by Demarçay. It shows no lines of any other element.

Another application of this rule has recently been made by Exner and Haschek with preparations of the oxide of an element obtained by Demarçay, and named europium. It exhibits 1193 spark lines and 257 arc lines.

I have already mentioned that one feature strikingly shown in the spectra of chemically related elements was the wider separation of the lines in pairs, triplets, or other groups; was in some way related to the atomic mass, since the separation was greater in those elements the atomic weights of which were greater. Kayser and Runge, and also Rydberg, have shown that in the series of alkali metals the differences between the oscillation frequencies of the lines are very nearly proportional to the squares of the atomic weights. Runge and Precht have recently shown that in every group of elements that are chemically related the atomic weight is proportional to some power of the distance separating the two lines of the pairs of which the spectrum is constituted. In other words, if the logarithms of the atomic weight and distance between the lines be taken as coordinates the corresponding points of a group of elements which are chemically related will lie on a straight line. Applying this law to the determination of the atomic weight of radium they find that the strongest lines of the new element are exactly analogous to the strongest barium lines, and to those of the closely related elements magnesium, calcium, and strontium. The intervals between the two lines of each pair in the principal series, and in the first and second subordinate series, if measured on the scale of oscillation frequencies, are equal for each element, and the same law holds good for the spectrum of radium. From this the value 257·8 was found for the atomic mass of the element. This does not quite accord with the number obtained by Madame Curie, who found it to be 225. It will be interesting to see which number will eventually be proved to be the more correct.

It is now many years since I first pointed out that the absolute wave-lengths of the lines of emission spectra of the elements are physical constants of quite as great importance in theoretical chemistry as the atomic weights; in the light of recent discoveries this statement may be said to be now fully justified.

Radio-active Elements.

From the study of rays of measurable wave-lengths we have lately sailed under the guidance of M. Henri Becquerel into another region where it is doubtful whether all the rays conform to the undulatory theory. In fact some of the rays are believed to be charged particles of matter, charged, that is to say, with electricity. Beyond doubt they are possessed of very extraordinary properties, inasmuch as they are able to penetrate the clothing, celluloid, gutta percha, glass, and various metals. They are, moreover, endowed with a no less remarkable physiological action, producing blisters and ulcerations in the flesh which are difficult to heal. It is an established fact that such effects have been caused by only a few centigrams of a radium compound contained in a glass tube enclosed in a thin metallic box carried in the pocket.

From this we can quite understand that there is no exaggeration in the statement attributed to the discoverer, Prof. Curie, by Mr. W. J. Hanmer, of the American Institute of Electrical Engineers, that he would not care to trust himself in a room with a kilogram of pure radium, because it would doubtless destroy his eyesight, burn all the skin off his body, and probably kill him.

It remains for me to express regret that without an undue extension of the time devoted to this Address it would have been scarcely possible to afford adequate treatment to the absorption spectra of inorganic compounds, particularly those of the rare earths, and such also as afford evidence of the chemical constitution of saline solutions; or of organic compounds closely related to coloured substances and dyes, the investigation of which leads to the elucidation of the origin of colour, and serves to indicate the nature of the chemical reactions by which coloured substances may be evolved from those which are colourless.

Chemistry is popularly known as a science of far-reaching importance to specific arts, industries, and manufactures; but it occupies a peculiar position in this respect, that it is at one and the same time an abstract science, and one with an ever-increasing number of practical applications. To draw a line between the two and say where the one ends and the other begins is impossible, because the theoretical problem of to-day may reappear upon the morrow as the foundation of a valuable invention.

SECTION C.

GEOLOGY.

OPENING ADDRESS BY PROF. W. W. WATTS, M.A., M.Sc., PRESIDENT OF THE SECTION.

THERE are two circumstances which invest the fact of my presidency of the Section this year with peculiar pleasure to myself. The first public lecture I ever gave was in the Town Hall at Birkdale in 1882, and the first of the fifteen meetings of the British Association which I have attended was that held in Southport in 1883.

There is still a third reason, that this meeting is in many respects a geological meeting. A palæobotanist is presiding over Section K, and the Council has invited, for the first time for many years, one geologist to deliver an evening discourse and another to give the address to artisans. I need hardly say that we are all looking forward to the lectures of Dr. Rowe and Dr. Flett with keen anticipation. To the one for his successful use of new methods of developing fossils and his scientific employment of the material thus prepared in stratigraphic research; to the other for his prompt, daring, and businesslike expedition to the scene of recent volcanic activity in the West Indies, during which he and his colleague, Dr. Tempest Anderson, collected so many important facts and brought away so much new knowledge of the mechanism of that disastrous and exceptional volcanic outbreak.

The Functions of Geology in Education and in Practical Life.

At the meeting in 1890, at Leeds, my old friend Prof. A. H. Green delivered an address to the Section which has generally been regarded as expressing an opinion adverse to the use of the Science of Geology as an educational agent. Some of the expressions used by him, if taken alone, certainly seem to bear out this interpretation. For instance, he says: "Geologists are in danger of becoming loose reasoners"; further he says: "I cannot shut my eyes to the fact that when Geology is to be used as a means of education there are certain attendant risks that need to be carefully and watchfully guarded against." Then he adds: "Inferences based on such incomplete and shaky foundations must necessarily be largely hypothetical."

Such expressions, falling from an accomplished mathematician and one who was such an eminent field geologist as Prof. Green, the author of some of the most trustworthy and most useful of the Geological Survey Memoirs, and above all one of the clearest of our teachers and the writer of the best and most eminently practical text-book on Physical Geology in this or any other language, naturally exercised great influence on contemporary thought. And I should be as unwise as I am certainly rash in endeavouring to controvert them but for the fact that I think he only half believed his own words. He remarks that "to be forewarned is a proverbial safeguard, and those who are alive to a danger will cast about for a means of guarding against it. And there are many ways of neutralising whatever there may be potentially harmful in the use of Geology for educational ends."

After thus himself answering what is in reality his main indictment, Prof. Green proceeds with the rest of an address crammed full of such valuable hints as could only fall from an experienced and practical teacher, showing how much could be done if the science were only properly taught.

And then he concludes by asking for "that kindly and genial criticism with which the brotherhood of the hammer are wont to welcome attempts to strengthen the cornerstones and widen the domain of the science we love so well."

I think the time has now come to speak with greater confidence, and, although the distance signal stands at danger, to forge ahead slowly but surely, keeping our eyes open for all the risks of the road, with one hand on the brakes and the other on the driving gear, secure at least in the confidence that Nature, unlike man, never switches a down train on to the up track.

Those of us who have been teaching our science for any considerable time have come to realise that there are many reasons why Geology should be more widely taught than at present; that there are many types of mind to whom this science appeals as no other one does; and that there are abundant places and frequent circumstances which allow of the teaching of it when other sciences are unsuitable.

To begin with, there is no science in which the materials for elementary teaching are so common, so cheap, and everywhere so accessible. Nor is there any science which touches so quickly the earliest and most elementary interests. It was for this reason that Huxley built his new science of Physiography on a geological basis. Hills, plains, valleys, crags, quarries, cuttings, are attractive to every boy and girl, and always rouse intelligent curiosity and frequent inquiry; and although the questions asked are difficult to answer in full, a keen teacher can soon set his children to hunt for fossils or structures which will give them part of the information they seek. Of course the teaching cannot go very far without simple laboratory and museum accommodation, and without a small expenditure on maps and sections; but the former of these requirements can soon be supplied from the chemical laboratory and by the collection of the students themselves, while the latter are every day becoming cheaper and more accessible and useful. The bicycle and the camera, too, are providing new teaching material and methods, while at the same time they are giving new interests. The bicycle has already begun to create a generation to whom relief maps are not an altogether sealed book, and for whom the laws which govern the relief of a country are rapidly finding practical utility; and the camera, at the same time that it quickens the appreciation of natural beauty, must give new interest to each scrap of knowledge as to the causes, whether botanical or geological, to which that beauty is due. And it is this new knowledge which in turn develops the æsthetic sense. *Mente, manu, et malleo* sums up most of what is required in the early stages of learning; but to round off the motto we still require words to express the camera and bicycle.

Another reason is the open-airness of the practice of the science. The delight of the open country comes with intense relief after the classroom, the laboratory, or the workshop. In education generally, and especially in geological education, we have reached the end of the period when

> "all roads lead to Rome
> Or books—the refuge of the destitute."

Of course I realise fully the vital necessity of laboratory and museum work in the stages of both learning and investigation, and quite freely admit that there is an immense amount of useful work being done and to be done in these institutions alone. But what I think I do right to insist upon is that all work in the laboratory and museum must be mainly preparatory to the field-work which is to follow; every type of geological student must be sent into the field sooner or later, and in most cases the sooner the better. I have generally found that students in the early stages have a great repugnance to the grind of working through countless varieties of minerals, rocks, and fossils; but once they have gone into the field, collected with their own hands, and seen the importance of these things, and the inferences to be drawn from them, for themselves—once indeed they have got keen—they come back willingly, even eagerly, to any amount of hard indoor work.

But it is when they leave ordinary excursion work and start upon regular field training that one really feels them spurt forward. As soon as they begin to realise that surface-features are only the reflex of rock-structure and can be utilised for mapping, that to check their lines and initiate new ones they must search for and find new exposures, and that each observation while settling perhaps one disputed point may originate a host of new ones, when above all they can be trusted with a certain amount of individual responsibility and given a definite point to settle for themselves, it is then that their progress is most rapid, and is bounded only by their powers of endurance.

I have often watched my students through the various stages of their field training with the deepest interest as a study of the development of character. At first they look upon it merely as a relief from the tedium of the classroom and laboratory, and as a pleasant country excursion. But gradually the fascination of research comes over them, and as they feel their capacity increasing and their grip and insight into the structure of the country deepening, one can see them growing up under one's eyes. They come into the field a rabble of larky boys; they begin to develop into men before they leave it.

And what is true of students is more than ever true of the working geologist. I hold that every geologist, whatever his special branch may be, should spend a portion of every year in the field. Though a petrologist may have specimens sent to him from every variety, even the common ones, in a rock mass, and have their relations and proportions properly explained to him, it is quite impossible for him to feel and appreciate these proportions and relationships so well as if he had studied and collected in the field and gained a personal interest in them. Besides this the conclusions drawn in the field are the crystalline and washed residuum, so to speak, left on the mind after the handling of dozens of specimens, weathered and unweathered, and the seeing them in a host of different lights and aspects. The rock is hammered and puzzled over and its relations studied until some conclusion is arrived at which bears the test of application to all the facts observed in the field.

Again, once a palæontologist is divorced from the field he loses the significance of minute time variations, the proportion of aberrant to normal forms, and the value of naked-eye characteristics which can be "spotted" in the field. Huxley once asked for a palæontologist who was no geologist; I venture to think we have now had enough of them. What we want above all at the present time is the recognition of such characters as have enabled our field palæontologists to zone by means of the graptolites, the ammonites, and the echinids, so that every rock system we possess may be subdivided with the same minuteness and trustworthiness as the Ordovician, Silurian, and Jurassic systems, and the Chalk.

If this is once done the biological results will take care of themselves, and we may feel perfect confidence that new laws of biological succession and evolution will result from such work, as indeed they are now doing—laws which could never be reached from first principles, but could only come out in the hands of those to whom time and place were the factors by which they were most impressed. It is only by field work that we shall ever get rid of the confusion which has been inevitable from the supposed existence of such so-called species as *Orthis caligramma, Atrypa reticularis*, and *Productus giganteus*.

As for the geological results, it is only necessary to read the excellent and workmanlike Address delivered to this Section at Liverpool in 1896 by Mr. Marr to realise how many problems of succession and structure, of distribution and causation, of ancient geography and modern landscape, are still awaiting solution by the application of minute and exact zonal researches.

On the other hand it goes without saying that the more a field geologist knows of his rocks and fossils the better will his stratigraphical work become; but this is too obvious to require more than stating.

Geology, again, is of value as a recreative science, one which can be enjoyed when cycling, walking, or climbing, even when sailing or travelling by rail. Indeed it is difficult to find a place in which to treat the confirmed geologist if you wish to make him a "total abstainer." There are others than those who must make use of their science in their professions, those in need of a hobby, those interested in natural scenery, veterans who have seen much and now have leisure and means to see more, and those fortunate ones who have not to earn their bread by the sweat of their brain or brow. Many of these have done and are doing good work for us, and many more would find real pleasure in doing so if only they had been inoculated in those early days when impressions sink deep. Mr. A. S. Reid, who has had much and fruitful experience in teaching, tells me that he has often seen seed planted in barren ground at school spring up and grow and blossom as a country-holiday recreation after schooldays, or bear the good fruit of solid research after lying dormant for many years.

We may next look upon Geology as an educational medium from quite a different point of view. If more than half the work of the man of science is the collection of fact, and of actual fact as opposed to the result of the personal equation, Geology is perhaps the very best training-ground. There are such hosts of facts to be still recorded, so many erroneous observations to be corrected, and so much hope of extending observations on already recorded facts, that there is plenty of work even for the man who can snatch but limited leisure from other pursuits and the one who is a collector of fact and nothing else, as well as those

> "under whose command
> Is earth and earth's, and in their hand
> Is Nature like an open book."

But in the collection of facts a wise and careful selection is constantly necessary in order to pick out from the multitude those which are of exceptional value and importance in the construction of hypotheses. Nature, it is true, cannot lie; she is a perfectly honest but expert witness, and it takes an astonishing amount of acute cross-examination to elicit the truth, the whole truth, and nothing but the truth.

There is no science which needs such a variety of observations as Field Geology. When we remember that Sedgwick and Darwin visited Cwm Glas and carried away no recollection of the features which now shout "glaciation" to everyone who enters the Cwm, it is easy to see how alert must be the eyes and how agile the mind of the man who has to carry a dozen problems in his mind at once, and must be on the look-out for evidence with regard to all of them if he would work out the structure of a difficult country; and who is not only looking out for facts to test his own hypothesis, but wishes to observe so accurately that if his hypothesis gives way even at the eleventh hour his facts are ready to suggest and test its successor. There is no class of men so well up in what may be called observational natural history generally as the practised field geologist, because he never knows at what moment some chance observation—a mound, a spring, a flower, a feature, even a rabbit-hole or a shadow—may be of service to him. Not only should he know his country in its every feature and every aspect, but he must have, and in most cases soon acquires, that remarkable instinct, which can only be denoted as an "eye for a country," with which generally goes a naturalist's knowledge of its plants and of its birds, beasts, and fishes.

At the present time many educationists are in favour of teaching only the experimental sciences to the exclusion of those which collect their facts by observation. This attitude may do some good to Geology in compelling us to pay more attention to that side of our science which has been better cultivated hitherto in France than in our own country. But whether we think of education as the equipping of a scientific man for his future career or as the training of the mind to encounter the problems of life, we must admit that it would be as wrong to ignore one of the two ways only of collecting fact as it would be to teach deductive reasoning to the exclusion of that by induction. Indeed this is understating the case, for in the vast majority of the problems which confront us in everyday life the solution can only be reached if an accurate grasp of the facts can be obtained from observation. The training of the mind solely by means of experiments carefully designed to eliminate all confusing and collateral elements savours too much of "milk for babes" and too little of "strong meat for men."

Mr. Teall in his masterly Address to the Geological Society in 1901 pointed out "that the state of advancement of a science must be measured, not by the number of facts collected, but by the number of facts *coordinated*." Theory, consistent, comprehensive, tested, verified, is the life-blood of our science as of any other. It is what history is to politics, what morals are to manners, and what faith is to religion.

It is almost impossible to collect facts at all without carrying a working hypothesis to string them on. It is easy to follow Darwin's advice and speculate freely; the speculation may be right, and if wrong it will be weeded out by new facts and criticism, while the speculative instinct will suggest others. In hypothesis there will always be an ultimate survival of the fittest.

And it is not only easy but absolutely necessary, because in Geology, more perhaps than in any other science, hypotheses are like steps in a staircase: each one must be mounted before the next one can be reached; and if you have no intention of coming back again that way, it does not matter if you destroy each step when you have made use of it. Every new hypothesis has something fresh to teach, and nearly all have some element of untruth to be ultimately eliminated. But each one is a stage, and a necessary stage, in progress.

In physics and in chemistry the chief difficulties are those which surround the making of experiments. When these have been successfully overcome the right theory follows naturally, and verification is not usually a very lengthy process. In Geology, on the other hand, theory is more quickly arrived at from the numerous facts; but the price is paid in the patience required for testing and the ruthless refusal to strain fact to fit theory. Every hypothesis leads back to facts again and again for verification, extension, and improvement.

Many of the leading conclusions of our science have not yet become part of the common stock of the knowledge of the world; indeed they are not even fully realised by many men eminent in their own sciences. The momentum given by Werner and Playfair, Phillips and Jukes, Sedgwick and Lyell, and other pioneers of the fighting science, has died down, and in the interval of hard work, detailed observation, minute subdivision, involved classification, and pedantic nomenclature which has followed, and which I believe to be only the prelude to an epoch of more important generalisation in the immediate future, it has been difficult for an outsider to see the wood for the trees. He has hardly yet realised that facts as vital to the social and economic well-being of the people at large, and conclusions of as great importance in the progress of the science and of as far-reaching consequence in the allied sciences, are being wrung from Nature now as in the past.

"The unimaginable touch of Time," the antiquity of the globe as the abode of life, the absolute proof of the evolution of life given by fossils, the proofs of change and evolution in geography and climate, the antiquity of man, the nature of the earth's interior, the tremendous cumulative effect of small causes, the definite position of deposits of economic value, the *rôle* played by denudation and earth-movement in the development of landscape, the view of the earth as a living organism with the heyday of its youth, its maturity, and its future old age and death, to mention but a few of our great principles, furnish us with conceptions which cannot fail to quicken the attention and inspire the thought of students of history, geography, and other sciences.

Now that these things are capable of definite proof, that they are of real significance in the cognate sciences, and of actual economic value, above all now that the nineteenth century, the geological century, has closed, that the heroic age is over, that we have passed the stages of scepticism and religious intolerance and reached the stage "when everybody knew it before," it might be expected that a fairly accurate knowledge and appreciation of these principles should form part of the common stock of knowledge, and be a starting-point in the teaching of allied sciences.

Another feature which adds to the attractiveness of geological observations is their immediate usefulness from many points of view. The relief and outline of any area are as closely related to its rocky framework as the form of a human being is related to his skeleton and muscles. The geological surveyor recognises how every rise and fall is the direct reflex of some corresponding difference in the underlying rocks; he seeks to observe and explain the ordinary as well as anomalous ground-features, every one of which conveys some meaning to him.

A geological basis for the classification and grouping of surface-features is the only one which is likely to be satisfactory in the end, because it is the only one founded on a definite natural principle, the relation of cause to effect. It is not without good reason that the topographic and geological surveys of the United States are combined under one management, and nowhere else are the topographic results more accurate and satisfactory. Landscape is traced back to its ultimate source, and consequently sketched in with more feeling for the country and greater accuracy of knowledge than would otherwise be possible. Geologists were among the first to cry out for increasing accuracy and detail in our Government maps, and they have consistently made the utmost use of the best of these maps as fast as they appeared. With the publication of each type of map, hachured, contoured, six-inch, twenty-five inch, the value and accuracy of geological mapping have advanced step by step. Wherever the topography is better delineated than usual, the facilities are greater for accurate geological work, and the best geological maps, and those in greatest demand, are always those based on the most minute and detailed topographic work. On the other hand geologists are training up a class of men who can read and interpret the inner meaning of these maps, and make the fullest use of the splendid facilities given by the minute accuracy of the ordnance work.

Lord Roberts has recently complained that the cadets at Woolwich are unable to read and interpret maps, and he "strongly advised them to set about improving themselves in this respect, or they would find themselves heavily handicapped in the future." I believe that the only training in this subject before entering the Royal Military Academy and the Royal Military College has been that given to those candidates who have taken up Geology for their entrance examination. By encouraging these students to study and draw maps and sections of their own districts, and to explain and draw sections across geological maps generally, thus accounting for surface-features, the examiners have compelled this small group of candidates to see deeper into a map than ordinary people. If only this training had been encouraged and advanced and made use of later, the Commander-in-Chief would have had no cause of complaint with regard to these particular men. Looking at a map is one thing; working at it, seeing into it, and getting out of it what is wanted from the vast mass of information crammed into it, is quite another; and Geology is the very best and perhaps the only means of compelling such a close study of maps as to enable students to seize upon the salient features of a country from a map as quickly and accurately as if the country itself were spread out before them. The geologist is compelled to work out and classify for himself the features he observes on his maps, such as scarps and terraces, crags and waterfalls, streams and gorges, passes and ridges, the run of the roads, canals, and railways, the nature and accessibility of the coast, and all those features which make the difference between easy-going and a difficult country. When he has worked his way over a map in this fashion that map becomes to him a real and telling picture of the country itself.

Experience, bitter experience, in South Africa has shown the necessity not only for good maps and map-reading, but for that which is the most priceless possession alike of the best field geologists and of the best strategists, a good "eye for a country." It has been said that the Boer war was a geographical war; but it was even more, and, especially in its later stages, a topographic war. Again and again the Boers aroused our astonishment and admiration by the way in which their topographic knowledge and instinct enabled them to fight, to defend themselves, and to secure their retreat by the most consummate ability in utilising the natural features of their country. This was due to two things. In the first place they took care to have with them in each part of the country the men who knew that particular district best in every detail and in every aspect. But in the second place there can be no doubt that they made the utmost use of that hunter-craft by which the majority of them could take in at a glance the character of a country, even a new one, as a whole, guided by certain unconscious principles which each man absorbed as part of his country life and hunter's training. They possessed, and had of necessity cultivated to a very high degree, an "eye for a country."

Now the study of the geology of any district, and especially the geological mapping of it, goes a long way towards giving and educating the very kind of eye for a country which is required, partly by reason of the practice in observation and interpretation which it is continuously giving, and partly because it deliberately supplies the very kinds of classification and the principles of form which a hunter-people have unconsciously built up from their outdoor experience.

Any geologist who thinks of the Weald, the wolds and downs of Eastern England, the scarps and terraces of the Pennine, the buried mountain structure of the Midlands, even the complicated mountain types of Lakeland and Wales, will remember how often his general knowledge of the rock-structure of the region has helped him as a guide to the topography; and as his geological knowledge of the area has increased he will recall how easy it has become to carry the most complicated topography in his mind, or to revive his recollection of it from a glance at the map, because the geological structure, the anatomy, is present in his mind throughout, and the outside form is the inevitable consequence of that structure. Indeed the reading of a good geological map to the geologist is like the reading of score by a musician.

Surely it would be most unwise if the Committee on Military Education were to cut out of their curriculum the one subject which has exercised and educated this faculty, and one which is at the same time doing a great deal to counteract that degeneration of observing faculties inseparable from a town life. Some cadets at least ought to be chosen from amongst those men who have been trained by this method to see quickly and accurately into the topographic character and possibilities of a country, and provision should be made for educating their faculties further until they become of genuine strategic value.

Then I believe it would be correct to say that no class of men get to know their own country with anything like the minuteness and accuracy of the geological surveyor. The mere topographer simply transfers his impressions on the spot as quickly as may be to paper, and has no further concern with them. The geologist must keep them stored in his mind, watching the variation and development of each feature from point to point for his own purposes. He must traverse every inch of his ground, he must know where he can climb each mountain and ford every brook, where there are quarries or roads, springs or flats; what can be seen from every point of view, how the habitability or habitations vary from point to point; in short, he must become a veritable walking map of his own district. Why not scatter such men in every quarter of the globe, particularly where any trouble is likely to arise? They are cheap enough, they will waste no time, and they will be so glad of the chance for research that they will not be hard to satisfy in the matter of pay and equipment. Thus you will acquire a corps of guides, ready wherever and whenever they are wanted; and when trouble arises they may do a great deal by means of their minute knowledge of topography to save millions of money and thousands of lives, and to prevent the irritating recurrence of the kind of disaster with which we have become sadly familiar within the last five years.

In dealing with the relationship of Geology to Geography geologists are frequently charged with claiming too much. On this point at least, however, there can be no difference of opinion, that the majority of geological surveyors and unofficial investigators have kept their eyes open to this relationship, and have often contributed new explanations to old problems. They have been compelled to observe, and often to explain, surface-features before making use of them in their own mapping, and in doing so have often hit upon new principles. It is hardly needful to mention such examples as Ramsay's great conception of plains of marine denudation, Whitaker's convincing memoir on subaërial denudation, Jukes's explanation of the laws of river adjustment, Gilbert's scientific essay on erosion, Heim's demonstration of the share taken by earth-movement in the modelling of landscape features, and the exceedingly valuable proofs of the relation of human settlement and movement to underground structure, worked out with such skill and diligence by Topley in his masterly memoir on the Weald—the jumping-off place, if I may so term it, of the new geography.

No one is more pleased than geologists that geographers have ceased to draw their knowledge of causation solely from history, and that they have turned their attention to the dependence and reaction of mankind on nature as well. But while hoping that geographers will continue to study, so far as they logically can, the relationship of plants, animals, and mankind to the solid framework of the globe on which they live, we must draw the line at the invention of new geological hypotheses to explain geographic difficulties on no better evidence than that furnished by the difficulties themselves; on the other hand, we must insist that each new geological principle must take its place amongst geographic explanations as soon as it is freely admitted to be based on a sound substratum of fact.

I must confine myself to a few instances of what I mean. Mr. Marr's geological work on the origin of lake-basins has led to some remarkable and unexpected conclusions with regard to the history and origin of the drainage of the Lake district. Some of the very difficult questions raised by the physical geography of the North Riding of Yorkshire have received a new explanation from the researches of Prof. Kendall and Mr. Dwerryhouse, an explanation which is the outcome of purely geological methods of observation of geological materials. Again, the simple geological interpretation of a well-known unconformity between Archæan and Triassic rocks has made it extremely probable that many of the present landscapes, not only in the Midlands but elsewhere, may be really fossil landscapes, of great antiquity and due to causes quite different from those in operation there at the present day. In mountain regions, too, it can only be by geological observation that we shall ever determine what has been the precise direct share of earth-movement in the production of surface relief. Such examples seem to indicate that many of the principles must be of geological origin but of geographic application.

While Geology has been of direct scientific utility in topography and geography there is another domain, that of Economic Geology, which is entirely its own. The application of Geology extends to every industry and occupation which has to do with our connection with the earth on which we live. Agriculture, engineering, the obtaining of the useful and precious metals, chemical substances, building materials, and road metals, sanitary science, the winning and working of coal, iron, oil, gas, and water, all these and many more pursuits are carried on the better if founded on a knowledge of the structure of the earth's crust. Indeed a geological map of this country, showing rocks, solid and superficial, of which no economic use could be made, would be nearly blank. Yet so much has this side of the science been neglected of recent years that our only comprehensive text-books on it are altogether out of date.

But in teaching Geology as a technical science, or rather as one with technological applications, one of the greatest difficulties before us is to steer between two opposing schools, the so-called theoretical school and the practical school.

There are those who say that there is but one geology, the theoretical, and that a thorough knowledge of this must be obtained by all those who intend to apply the science. Others think that this is too much to ask—that the time available is not sufficient—and that it is only necessary to teach so much of the subject as is obviously germane to the question in hand.

The best course appears to me to be the middle one between the two extremes. If the engineer or miner, the water-finder or quarryman, has no knowledge of principles, but only of such facts as appear to be required in the present position of his profession, he will be incapable of making any improvement in his methods so far as they depend upon geology. If, on the other hand, he is a purely theoretical man without a detailed practical and working acquaintance with the facts which specially concern him, he will be put down by his colleagues as unpractical; he will have to learn the facts as quickly as he can and buy his experience in the dearest market.

It seems to me that there is certain common ground which must be acquired by all types of professional men. The general petrographic character of the common rocks, enough of their mode of origin to aid the memory, the principle of order and age in the stratified rocks, the use of fossils and superposition as tests of age, the nature of unconformities, the relation of structure to the form of the ground, the occurrence of folds and faults, and above all the reading of maps and sections, and sufficient field work to give confidence in the representation of facts on maps—these things are required by everybody who makes any use of geology in his daily life.

But when so much has been acquired it should be possible to separate out the students for more special treatment. The coal-miner will require especially a full knowledge of the coal-bearing systems, not in our own islands merely, but all over the world; a special acquaintance with the effects of folds and faults, and an advanced training in the maps and sections of coal-bearing areas. The vein-miner should be well up in faulting and all the geometrical problems associated with it, and he should have an exhaustive acquaintance with the vein and metalliferous minerals.

The water engineer needs to know especially well the porous and impervious rock types, the texture and composition of these rocks, the nature of their cements and joints, and the distribution of water levels in them. Further, he must know what there is to be known on the problems of permeability and absorption, the relation of rain to supply, the changes undergone by water and the paths taken by it on its route underground, and the varying nature of rocks in depth. He must also realise the effects of folds and faults on drainage areas and on underground watercourses, the special qualities of water-yielding rocks, of those forming the foundation of reservoir sites, and those suitable for the construction of dams.

The sanitary engineer will need to be acquainted with the same range of special knowledge as the water engineer, but will naturally be more interested in getting rid of surface water without contaminating it more than he can help than in obtaining it; he will also need a more detailed acquaintance with superficial deposits than any other class of professional men.

The quarryman and architect ought to know the rocks both macroscopically and microscopically, in their chemical and mineralogical character, their grains and their cements. But he ought to be well acquainted with the laws of bedding, jointing, and cleavage, with questions of outcrop and underground extent, and all those other characters which make the difference between good and bad stone, or between one desirable and undesirable in the particular circumstances in which a building is to be erected. Further, he should make a particular study of the action of weight and weather on the rocks which he employs.

The road engineer and surveyor, now that it has been discovered that it is cheaper and better to use the best and most lasting road-metal instead of any that happens to be at hand, requires to have an extensive acquaintance with our igneous and other durable rocks. He needs, however, not only petrographic and chemical knowledge, but also a type of information not at present accessible in England, the relative value of these rocks in resisting the wear and tear of traffic, the cementing power of the worn material, and the surface characters of roads made from them, in order that he may in each case select the stone which in his particular circumstances gives the best value for money. It would surely pay the county councils to follow, with modifications, the example of the French and Americans, and carry out a deliberate and well-planned series of experiments on all the material accessible to them in their respective districts.

The teaching of the application of Geology should therefore take some such form as the following:—First, the principles should be thoroughly taught with the use for the most part of examples drawn from the economic side; thus cementing might be illustrated on the side of water percolation, jointing from the making of mine roads and from quarry sites, faulting from effects on coal outcrops and veins, unconformity from its significance to the coal-miner; while in teaching the sequence of stratified rocks the systems and stages could be mainly individualised by their economic characters. When this is done the class must be divided into groups, each paying special attention to the points which are of essential importance to them.

The teaching at all stages should be practical and, so far as can be, experimental, and in all cases where possible a certain amount of field work should be attempted. For the field after all is the laboratory of the geologist, where he can observe experiments being made on a gigantic scale under his eyes.

The aim of the teaching should be to give to students the equipment necessary to deal with the chief geological problems that they will meet with in their varied professions; it should show them where to go for maps, memoirs, or descriptions of the areas with which they are dealing; and in cases of great difficulty should enable them to see where further geological assistance is required, and to weigh and balance the expert evidence given them against the economic and other factors of the problem before them.

From men educated thus Geology has the right to expect a valuable return. There is a vast amount of knowledge on economic subjects in existence but not readily accessible. It has been obtained by experts, and after being used is locked up or lost. And yet it is the very kind of knowledge which is wanted to extend our principles further into the economic side of the subject. So well is this recognised that many geologists are attracted to economic work mainly because of the wide range of new facts that they can only thus become acquainted with. It is possible to make use of many of these facts for scientific induction without in any way betraying confidence or revealing the source from which they are obtained; and even if they cannot be used directly they are often of great service in giving moral support, or the contrary, to working hypotheses founded on other evidence.

The knowledge of our mineral resources is of such vital consequence to ourselves and to our present and future welfare as a nation, and yet it is a matter of so much popular misconception, that I feel bound to dwell on this subject a little longer. To anyone who studies the growth and distribution of population in any important modern State the facts and reasons become as clear as day.

It is easy to construct maps showing at a glance the density of population in any country. Perhaps the most effective way to do so is to draw a series of isodemic lines and to gradually increase the depth of tint within them as the number of people per square mile increases until absolute blackness represents, say, more than 2000 people per square mile. Such maps are the best means of displaying the geography of the available sources of energy in a country at any particular period. Population maps of England and Wales in the early part of the eighteenth century would be pale in tint with a few rather darker patches, and would show a distribution dependent solely upon food as a source of energy working through the medium of mankind and animals. Such maps would be purely agricultural and maricultural, dependent upon the harvests of the land and sea. Maps made at a later period would show a new concentration round other sources of energy, particularly wind and water, but would not be perceptibly darker in tint as a whole; for although we are apt to think that we have in this country too much wind and water, they are not in such a form that we can extract any appreciable supply of energy directly from them.

But maps representing the present population, while still mainly energy maps, at once bring out the fact that our leading source of energy is now *coal* and no longer food, wind, or water. The new concentrations, marked now by patches and bands of deepest black, have shifted away from the agricultural regions and settled upon and around the coalfields. The map has now become geological.

The difference between the old and the new map is, however, not only in kind; it is even more remarkable in degree. The population is everywhere much denser. Not only are the mining and manufacturing areas on the new map more than eight times as densely populated as any areas on the older map, not only is the average population five times greater throughout the country, but the lightest spot in the new map is nearly as dark as the darkest spot on the old one. The sparsest population at the present day is as thick on the ground as it was in the densest spots indicated on the older map, while at the same time the standards of wages, living, and comfort, instead of decreasing, have increased.

The discovery of this new source of energy, coal, immediately gave employment to a much larger number of people; it paid for their food and provided the means of transporting it from the uttermost parts of the earth. Under agricultural conditions the map shows that the population attained a given maximum density, and no further increase was possible, the density being regulated by the food supply raised on the surface of the land. Our dwelling-house was but one story high. Under industrial conditions our mineral resources can support five times the number. Our dwelling-house is of five stories—one above ground and four below it.

At the same time the type of distribution is altered. The agricultural areas are now covered by a relatively scanty population, and the dense areas are situated on or near to the coal and iron fields, the regions yielding other metals, those suitable for industries which consume large supplies of fuel, and a host of new distributing centres, nodal points on the new lines of traffic, either inside the country or on its margins where the great routes of ocean transport converge, or where the sea penetrates far in towards the industrial regions.

It has been the good fortune of this country to be the first to realise, and with characteristic energy to take advantage of, the new possibilities for development opened up by the discovery and utilisation of its mineral wealth. We were exceedingly fortunate in having so much of this wealth at hand, easy to get and work from geological considerations, cheap to transport and export from geographical considerations. So we were able to pay cash for the products of the whole world, to handle, manufacture, and transport them, and thus to become the traders and carriers of the world.

But other nations are waking up. We have no monopoly of underground wealth, and day by day we are feeling the competition of their awakening strength. Can we carry on the struggle and maintain the lead we have gained?

In answering this question there are three great considerations to keep in mind. First, our own mineral wealth is unexhausted; secondly, that of our colonies is as yet almost untouched; and thirdly, there are still many uncolonised areas left in the world.

The very plenty of our coal and iron, and the ease of extracting it, has been an economic danger. There has been waste in exploration because of ignorance of the structure and position of the coal-yielding rocks; waste in extraction because of defective appliances, of the working only of the best-paying seams and areas, of the water difficulty, and the want of well-kept plans and records of areas worked and unworked; waste in employment because of the low efficiency of the machinery which turns this energy into work. With all this waste our coalfields have hardly yielded a miserable *one* per cent. of the energy which the coal actually possesses when *in situ*.

Engineers and miners are trying to diminish two of these sources of waste, and Geology has done something to reduce that of exploration. This has been done by detailed mapping and study, so that we now know the areas covered by the coal-seams, their varying thickness, the "wants," folds, and faults by which they are traversed, and all that great group of characters designated as the geological structure of the coalfields. It could not have been accomplished unless unproductive as well as productive areas had been studied, the margins of the fields mapped as well as their interiors, and unless the geological principles wrested from all sorts of rocks and regions had been available for application to the coal districts in question. We no longer imagine every grey shale to be an index of coal; we are not frightened by every roll or fault we meet with underground; nor do we, as in the past, throw away vast sums of money in sinking for coal in Cambrian or Silurian rocks.

We cannot afford, hard bitten as we are in the rough school of experience and with our increased knowledge, to make all the old mistakes over again, and yet we are on the very eve of doing it. Up to the present it is our visible coalfields that we have been working, and we have got to know their extent and character fairly well. But so much coal has now been raised, so much wasted in extraction, and so many areas rendered dangerous or impossible to work, that we cannot shut our eyes to the grave fact that these visible fields are rapidly approaching exhaustion. The Government have done well to take stock again of our coal supply and to make a really serious attempt by means of a Royal Commission to gauge its extent and duration; and we all look forward to that Commission to direct attention to this serious waste and to the possibility of better economy which will result from the fuller application of scientific method to exploration, working and employment.

But we still have an area of concealed coalfields left, possibly at least as large and productive as those already explored and as full of hope for increased industrial development. It is to these we must now turn attention with a view of obtaining from them the maximum amount possible of the energy that they contain. The same problems which beset the earlier explorers of the visible coalfields will again be present with us in our new task, and there will be in addition a host of new ones, even more difficult and costly, to solve. In spite of this the task will have to be undertaken, and we must not rest until we have as good a knowledge of the concealed coalfields as we have of those at the surface. This knowledge will have to be obtained in the old way by geological surveying and mapping and by the coordination of all the observations available in the productive rocks themselves and in those associated with them, whether made in the course of geological study or in mining and exploration. But now the work will have to be done at a depth of thousands instead of hundreds of feet, and under a thick cover of newer strata resting unconformably on those we wish to pierce and work. When we get under the unconformable cover we meet the same geology and the same laws of stratigraphy and structure as in more superficial deposits, but accurate induction is rendered increasingly difficult by the paucity of exposures and the small number of facts available owing to the great expense of deep boring. How precious, then, becomes every scrap of information obtained from sinkings and borings, not only where success is met with, but where it is not; and how little short of criminal is it that there should be the probability that much of this information is being and will be irretrievably lost!

Mr. Harmer pointed out in a paper to this Section in 1895 that under present conditions there was an automatic check on all explorations of this kind. The only person who can carry it out is the landowner. If he fails he loses his money and does not even secure the sympathy of his neighbours. If he succeeds his neighbours stand to gain as much as he does without sharing in the expense. The successful explorer naturally conceals the information he has acquired because he has had to pay so heavily for it that he cannot afford to put his neighbours in as good a position as himself and make them his rivals as well; while the unsuccessful man is only too glad to forget as soon as possible all about his unfortunate venture. And yet in work of this kind failure is second only to success in the value of the information it gives as to the underground structure which it is so necessary to have if deep mining is to become a real addition to the resources of the country.

Systematic and detailed exploration, guided by scientific principles, and advancing from the known to the unknown, ought to be our next move forward: a method of exploration which shall benefit the nation as well as the individual, a careful record of everything done, a body of men who shall interpret and map the facts as they are acquired and draw conclusions with regard to structure and position from them—in short a Geological Survey which shall do as much for Hypogean Geology as existing surveys have done for Epigean Geology, is now our crying need. Unless something of this sort is done, and done in a systematic and masterful manner, we run a great risk of frittering away the most important of our national resources left to us, of destroying confidence, of wasting time and money at a most precious and critical period of our history, and of slipping downhill at a time when our equipment and resources are ready to enable us to stride forward.

We do not want to be in the position of a certain town council which kept a list of its old workmen and entered opposite one, formerly sewerage inspector, that he possessed "an extensive memory which is at the disposal of the corporation."

Even supposing the scheme outlined by Mr. Harmer cannot be carried out in its complete form, a great deal will be done if mining engineers can receive a sufficient geological training to enable them to realise the significance of these underground problems, so that they can recognise when any exploration they are carrying out inside their own area is likely to be of far-reaching geological and economic significance outside the immediate district in which they are personally and immediately concerned.

Turning to our colonies it is true that in many of them much is being done by competent surveys to attain a knowledge of mineral resources, but this work should be pushed forward more rapidly, with greater strength and larger staffs, and above all it should not be limited to areas that happen to be of known economic value just at the present moment. It is almost a truism that the scientific principle of to-day is the economic instrument of to-morrow, and it will be a good investment to enlarge the bounds of geological theory, trusting to the inevitable result that every new principle and fact discovered will soon find its economic application. Further, it is necessary that we should obtain as soon as possible a better knowledge of the mineral resources of the smaller and thinly inhabited colonies, protectorates, and spheres of influence. This is one of the things which would conduce to the more rapid, effective occupation of these areas.

With regard to areas not at present British colonies, it seems to me that no great harm would be done by obtaining, not in any obtrusive way, some general knowledge of the mineral resources of likely areas. This at least seems to be what other nations find it worth their while to do, and then, when the opportunity of selection arises, they are able to choose such regions as will most rapidly fill up and soonest yield a return for the private or public capital invested in them.

To sum up, I consider that the time has come when geologists should make a firm and consistent stand for the teaching of their science in schools, technical colleges, and universities. Such an extension of teaching will of course need the expenditure of time and money; but England is at last beginning to wake up to the belief, now an axiom in Germany and America, that one of the best investments of money that can be made by the pious benefactor or by the State is that laid up at compound interest, "where neither rust nor moth doth corrupt," in the brains of its young men.

This knowledge has been an asset of monetary value to hosts of individuals who have made their great wealth by the utilisation of our mineral resources, and to our country, which owes its high position among the nations to the power and importance given to it by its coal and iron. It is surely good advice to individuals and to the State to ask them to reinvest some of their savings in the business which has already given such excellent returns, so that they and we may not be losers through our lack of knowledge of those sources of energy which have made us what we are, and are capable of keeping for many years the position they have won for us.

And in our present revival of education it would be well that its rightful position should be given to a science which is useful in training and exercising the faculty of observation and the power of reasoning, which conduces to the open-air life and to the appreciation of the beautiful in nature, which places its services at the disposal of the allied sciences of topography and geography, which is the handmaid of many of the useful arts, and which brings about a better knowledge and appreciation of the life and growth of that planet which we inhabit for a while, and wish to hand on to our descendants as little impaired in vitality and energy as is consistent with the economic use of our own life-interest in it.

NOTES.

The following have been elected Fellows of the Reale Accademia dei Lincei:—As Ordinary Fellows ("Socî nazionali"), Messrs. J. Dalla Vedova for geography, A. Naccari for physics, C. de Stefani for geology, A. Borzì, J. Fano, A. Maffucci for zoology, pathology, &c. As Corresponding Fellows ("Corrispondenti"), Messrs. P. Pizzetti for mechanics, A. Angeli for chemistry, R. Fusari and A. Stefani for zoology and physiology. As Foreign Fellows, Messrs. D. Hilbert and J. D. van der Waals for mathematics and mechanics, J. Thomson and H. Becquerel for physics, R. Lydekker for geology and palæontology, E. B. Wilson, T. Schlösing, P. Sorauer and F. Marchand for zoology, agronomy and pathology.

The prizes offered by the Reale Accademia dei Lincei for the present year have been allotted as follows:—Royal prizes have been awarded to Prof. Artini for mineralogy and geology, to Prof. Ghino Valenti for social and economic science, and to the late Prof. Contardo Ferrini for jurisprudence and political science. Of the prizes offered by the Minister of Public Instruction, awards have been made for physical and chemical science to Profs. Cicconetti and Pierpaoli (jointly), and to Prof. Baggio Lera, and for philology to Profs. Toldo, G. Tàmbara and V. Ussani. The Carpi prize for botany has been conferred on Dr. Biagio Longo, of Rome. The award of the Royal prize for mathematics has been deferred.

We have received a copy of the programme of prizes to be awarded in 1904 by the Société Industrielle de Mulhouse. The present publication takes the place of all previous issues, and copies of the programme, in which certain changes have been made, can be obtained on application to the secretary of the society. There are no fewer than fifty-six competitions concerned with chemical technology, more than twenty dealing with the mechanical arts, and twelve with natural history and agriculture. Several prizes are offered with the object of improving and stimulating local industries. The programme also contains full particulars of several large prizes of five thousand francs, which are awarded for scientific work at intervals of in some cases ten, and in others five years.

The death is announced, at the age of eighty-one years, of the Rev. Maxwell Henry Close, treasurer of the Royal Irish Academy, and author of numerous contributions to the *Proceedings* of the Royal Irish Academy.

Violent earthquake shocks of seventeen seconds' duration are reported by Reuter to have been experienced in Bucharest, Roumania, at 10 a.m. on Sunday last.

An earthquake is stated in the *Globe* to have taken place in Lisbon at 1.34 p.m. on Monday last. It was of three seconds' duration.

Dr. W. H. Allchin is to deliver the Harveian oration at the Royal College of Physicians of London on Monday, October 19. The Bradshaw lecture (the subject of which will be "Some Observations on Tuberculosis of the Nervous System") will be delivered at the college by Dr. E. F. Trevelyan on Thursday, November 5.

A course of lectures on bacteriology for medical men, veterinary surgeons, agriculturists, brewers, farmers, sanitary inspectors, teachers and others is to be given by Dr. F. Bushnell at Plymouth under the direction of the education authority for that town. The lectures will be illustrated by lantern slides, cultures and demonstrations, and it is hoped to make arrangements for a class of practical bacteriology in the future.

An International Exhibition of Inventions is to be held at Brighton in November next. The object of the exhibition is to afford inventors and patentees an opportunity of bringing their inventions before the notice of capitalists, manufacturers, and users. Awards of gold, silver, and bronze medals will be made for inventions possessing the greatest merit combined with commercial utility.

It has been decided to start a school of colonial medicine at Marseilles, and Surgeon-Major Martine, of the colonial military service, has just been appointed by the French Minister of War to confer with the municipality of Marseilles relative to its establishment.

The U.S. Consul-General at Frankfort is reported by the *Chemist and Druggist* to have stated that "the city of Düsseldorf will soon have the first academy for practical medicine in Germany, and it will be in connection with the new hospital to be erected." Prof. Witzel, of the University of Bonn, is proposed as director of the academy. The establishment of other similar academies is under consideration.

AN exposition is to be held in Baltimore under the auspices of the Maryland Public Health Association and the Tuberculosis Commission appointed by the Governor of that State, the object of which is to arouse public and professional interest in the subject of tuberculosis. The basis for the exposition will, says the *Lancet*, be the investigations of the Tuberculosis Commission into the cause, the prevalence, and the distribution of human tuberculosis in that State, its influence on the public welfare, and the best methods of restricting and controlling the disease. The medical questions involved, the importance of habits, occupation, and housing conditions will receive consideration. The ultimate purpose of the exposition is to determine the proper legislation, municipal, State, and national, to be recommended, some definite line of prophylaxis, as well as measures relating to the care and cure of both advanced and incipient cases of pulmonary tuberculosis.

IT is stated in the *British Medical Journal* that a number of consumptive patients have been taken by Dr. Kuss, of Paris, to the Vallot Observatory, near the summit of Mont Blanc, for the purpose of ascertaining the effect of rarefied air on their lungs. The patients remain in the open for the greater part of the twenty-four hours in every kind of weather.

THE next meeting of the International Congress of Ophthalmology is to take place at Lucerne from September 19 to 21 of next year, under the presidency of Prof. Dufour. According to the official circular which has recently been distributed, no papers are to be read, but such, if written in English, French, German, or Italian, and sent with the admittance fee before May 1 next to Prof. Mellinger, of Basle, will be printed and grouped according to their subjects, and this printed report will be sent to each member with his admission card at least two weeks before the date appointed for the opening of the congress. At the meetings the authors of the papers will have the opportunity of stating the conclusion of their respective papers in a few words, and the discussion will then commence. Members present who are interested in the subject of the paper will, of course, have had the opportunity of reading the paper before the opening of the congress. The discussions will be printed and published at the close of the congress, and possibly papers received too late to be printed before the opening of the congress will also be discussed and printed with the discussions. The afternoons of the congress will be devoted to practical demonstrations.

THE Paris Society of Pharmacy is to celebrate its centenary on October 17, and in connection with it an historical account of the Society has been prepared and will be read by Prof. E. M. Bourquelot, the general secretary, at a public meeting. This history, together with other original matter that may be supplied by members of the Society, will, says the *Chemist and Druggist*, form the material of a book which will be published later. The work will also contain the portraits and biographies of leading pharmacists and chemists who have been connected with the Society, such as Nicolas Houël, the founder, the "Citizen" Trusson, one of the last directors of the Free Society of Pharmacists, Parmentier, Vauquelin, Bouillon-Lagrange, and others.

A MEETING was recently held in America, under the chairmanship of Dr. D. C. Gilman, to promote a proposed memorial to the late Major Reed, M.D., well known for his work in connection with the discovery of the mode by which yellow fever has been spread, and the suppression of the disease. According to *Science* the meeting decided that an effort should be made to raise a memorial fund of 25,000 dollars or more, the income to be given to the widow and daughter of Dr. Reed, and that after their decease the principal shall be appropriated either to the promotion of researches in Dr. Reed's special field, or to the erection of a memorial in his honour at Washington.

PARTICULARS, according to the *Lancet*, have been received of the medical results of the expedition of investigation to the Bahamas which was sent out some time ago by the Johns Hopkins University and the Baltimore Geographical Society, from which we glean the following. Skin diseases, and especially leprosy, were found to be very prevalent. No effort is made to prevent the spread of leprosy, and many instances were noted where persons suffering from that disease were engaged in the sale of provisions, in piloting vessels, and in other pursuits. No cases of yellow fever were discovered, and but two cases of malaria were recognised. Many species of mosquito were secured for subsequent study. A special feature of the work of the medical department was the study of the degenerates of Abaco, descendants of the Torys, who closely intermarry.

ACCORDING to the *Times* a prehistoric British barrow has just been opened at Martinstown, Dorset. The barrow contained worked flints, a quantity of pottery, and a large British urn inverted on a slab of stone, covering some cremated remains which had been wrapped in a rough material of cloth or rushes, the texture of the weaving of which was still traceable. In another barrow close by have been found a vase and a bronze knife with a portion of a willow handle.

ON this day week, September 10, a storm of unusual violence advanced over the central portion of the British Islands, causing enormous damage in its passage over sea and land. The *Daily Weather Report* issued by the Meteorological Office for 8h. a.m. of that day showed that a depression lay to the westward of the Irish coasts; by 6h. p.m. the disturbance reached the Irish Sea, and had advanced at the rate of about fifty miles an hour, while by the evening it had spread over nearly the whole country. So rapid was its rate of progression that the *Daily Weather Report* of the morning of September 11 showed that the centre of the storm had reached the north of Holland. The destruction was so general that it seems somewhat invidious to refer to individual instances. We merely quote two cases to illustrate its violence—the demolition of the solid breakwater at Dover, and the uprooting of trees in the vicinity of London that had withstood the storms of a hundred years. During the passage of the gale the barometer fell at the unusual rate of more than 0·1 inch an hour. The velocity of the wind to the southward of the centre of the storm was much greater than to the northward; near the mouth of the Channel on the evening of September 10 it reached nearly 70 miles an hour. The rainfall measured in the twenty-four hours ending on Friday exceeded an inch and a half in the north-west, and an inch and a quarter in the east of England.

THE September issue of the Meteorological Office pilot chart contains, in addition to the twelve maps showing the tidal streams round the British Isles, a reproduction of Dr. Hermann Berghaus's chart of cotidal lines round our own and the North Sea coasts, with explanatory remarks by Prof. G. H. Darwin. To render the information more complete to the mariner, there is a table giving the times of high water at Dover throughout the month. Another addition deals with a proposal to alter the steamship route between the Bristol Channel and Jamaica. A comparison has been instituted to show the merits and demerits of the Great Circle track, 3524 miles; the Rhumb track, 3603 miles; and the suggested route *viâ* the Azores and the Mona passage, 3722 miles. The conclusion arrived at is that, "taking into consideration the wind direction, the wind force, and the sea-surface currents, it seems safe to assume that the Azores routes will be covered by a vessel at her usual speed in an interval of time certainly not greater than that occupied by the same ship in following either the Great Circle route or the Rhumb track, and probably in less."

THE report of the Meteorological Commission of Cape Colony for the year 1901 shows a considerable falling off as regards the number of stations, compared with that of the previous year, owing to the difficulties of observation and communication under the operation of Martial Law within the colony. Nevertheless, the commission has been able to publish rainfall statistics from 436 stations, excluding those connected with the Kenilworth Observatory, and a large amount of valuable general meteorological observations. Many of the stations destroyed or discontinued were situated in the more sparsely populated districts, and it is estimated that it will take years to recover the lost ground. The commission reports, however, that there is an awakening sense of the importance of meteorology among the governing bodies of the other British South African territories, and that, in spite of the troublous times recently passed through, the prospects of the development of meteorological observations are much brighter now than ever they have been. We wish the commission success in the continuation of its very useful operations.

PARTICULARS are given in the *Scientific American* of an ingenious invention which has been brought out to notify automatically the outbreak of fire, and to indicate to the fire stations the name and position of the building which is in danger. Of the device, which is the invention of M. Emile Guarini, the essential feature is a thermometer which is so arranged that it is capable of releasing a toothed wheel which serves to transmit the requisite information. When the heat reaches the thermometer and the mercury rises in the tube until it reaches the mark indicated by 42° on the Réaumur scale it touches a small platinum wire inserted in the upper end of the tube, and thereby closes an electric circuit including an electro-magnet. Thus excited the magnet attracts and holds its armature. This motion releases a toothed wheel of peculiar construction, which, by means of a weight or spring, is made to revolve, and produces during each revolution a series of makes and breaks upon a contact piece placed in its path. A connected induction coil describes the exact location of the endangered property to the neighbouring fire station, where the message is registered by a Morse apparatus, and the attention of the attendants is directed by an electric gong to the signal received. An incandescent lamp also glows when the alarm is sounded.

IT will not be owing to want of help from the Imperial Department of Agriculture if West Indian planters fail to get profitable returns from their land. In the last number of the *West Indian Bulletin* the value of ground nuts, Eucalyptus trees, and the bay tree is brought to notice. Mr. W. G. Freeman has collected much practical information on the subject of ground nuts, known also as monkey nuts and pea nuts. Besides furnishing oils of which the best grades are nearly equal to olive oil, the ground nut, *Arachis hypogaea,* offers another source of profit, since it may be manufactured into oil-cake, for which there is evident demand, as at the present time large quantities are imported. For the manufacture of bay oil and bay rum the tree *Pimenta acris* has a considerable value; it is indigenous to many of the islands, but must be distinguished from the tree known as "bois d'Inde citron" in Dominica, the product from which is inferior.

JUDGING from a circular which has been received from the Forestry Bureau of the U.S. Department of Agriculture the lumbermen of the United States of America do not yet thoroughly recognise that their interests coincide with those of the forester. Of the three papers included in the circular, the first is an address delivered by President Roosevelt in which he states that "the forest problem is in many ways the most vital internal problem in the United States." Chief-forester Pinchot discusses the mutual position of the lumberman and the forester.

WE have received a chart of fossil shells found in connection with the seams of coal and ironstone in north Staffordshire, drawn up by Dr. Wheelton Hind and Mr. J. T. Stobbs. There are columns showing the strata met with in the Potteries and Cheadle coal-fields, but the information relates chiefly to the former and more important district. The species figured are chiefly Mollusca, and they are arranged alongside the divisions which they characterise. The chart is published by the North Staffordshire Institute of Mining and Mechanical Engineers, and it should prove of practical use to mining students and to those engaged in sinking for coal.

DR. J. F. WHITEAVES has described some additional fossils from the Cretaceous rocks of Vancouver, and has given a revised list of the species therefrom, in the fifth and concluding part of his first volume on Mesozoic fossils (Geol. Survey of Canada, August). A number of Crustacea, of Cephalopoda and other Mollusca, and Brachiopoda are figured. Echinoderms are represented only by fragments, and corals and Polyzoa by two or three specimens. A few fish-remains occur, including *Lamna appendiculata*, which extends through the Upper Cretaceous strata, and ranges from northern Europe to New Jersey and Queensland.

DR. ERNEST W. SKEATS contributes an essay on the chemical composition of limestones from upraised coral islands, with notes on their microscopic structure (*Bull.* Museum Comp. Zool., Harvard Coll., vol. xlii.). The rocks consist of true coral reefs and of fragmental strata made up of organic débris. The author, after describing the materials, briefly discusses the relation of the distribution of magnesium carbonate in the limestones to the question of the origin of dolomite. It seems probable that the introduction of magnesium into the rocks takes place from the waters of lagoons under certain favourable conditions.

IN addition to his presidential address on the distribution of life in the Antarctic, Dr. H. Woodward contributes a paper on East Anglian geology to the *Transactions* of the Norfolk and Norwich Naturalists' Society for 1902–1903.

WE have received two parts of the *Bulletin International* (Rospravy Ceske Ak. Praze) for 1903. Among their contents, reference may be made to an important article, by Dr. O. Völker, on the development of the pancreas in the amniote vertebrates, and to a second, by Prof. J. Janošík, on that of the blood corpuscles in the same great group.

A LENGTHY illustrated account of the "Bathymetrical Survey of the Fresh-water Lochs of Scotland" appears in the current *Geographical Journal*, the introductory portion of which gives the history of the origin of the survey; this is followed by particulars of some six of the lochs. The *Geographical Journal* is to publish the bathymetrical maps and the other observations of the survey staff, and the series of articles will, it is hoped, when completed, form a worthy memorial of the late Mr. F. P. Pullar.

THE September issue of the *American Journal of Science* contains, as frontispiece, a process portrait of Prof. J. Willard Gibbs, and an obituary notice of Prof. Gibbs by Prof. H. A. Bumstead. The number also contains an article by Mr. J. Stanley Gardiner, of Cambridge, on "The Origin of Coral Reefs as shown by the Maldives."

THE September issue of the *Popular Science Monthly* (New York) is full of interesting matter, and contains, among other contributions, articles on "Palm and Sole Impressions and their use for Purposes of Personal Identification," by Prof. H. H. Wilder; "Theories of Sleep," by Dr. P. G. Stiles; "Mosquitoes and Suggestions for their Extermination," by W. L. Underwood; and part iv. of a series of articles by Prof. J. A. Fleming, F.R.S., on "Hertzian Wave Wireless Telegraphy."

MESSRS. WATTS AND Co. have issued, for the Rationalist Press Association, a reprint, at sixpence, of the first edition of "The Origin of Species." It will be remembered that an edition of the final form of this great classic was brought out not long ago by Mr. Murray in paper covers at one shilling.

THE additions to the Zoological Society's Gardens during the past week include a Sooty Mangabey (*Cercocebus fuliginosus*) from West Africa, presented by Mr. C. Pells; two Masai Ostriches (*Struthio camelus*, var. *massaicus*) from East Africa, presented by Mr. A. Marsden; two Grey-breasted Parrakeets (*Myopsittacus monachus*) from Monte Video, presented by Mr. C. Martin; a Vervet Monkey (*Cercopithecus lalandii*) from South Africa, two Mozambique Monkeys (*Cercopithecus pygerythrus*) from East Africa, a Black-striped Wallaby (*Macropus dorsalis*), a Black-tailed Wallaby (*Macropus walabates*), a Rufous Hare Wallaby (*Lagorchestes hirsutus*) from New South Wales, two Black-headed Caiques (*Caia melanocephala*) from Demerara, an Australian Barn Owl (*Strix delicatula*), a Winking Owl (*Ninox connivens*), a Burton's Lizard (*Lialis burtoni*), a Limbless Lizard (*Pygopus lepidopus*) from Australia, a Javan Loris (*Nycticebus javanicus*) from Java, two Grey Monitors (*Varanus griseus*) from North Africa, two Muricated Lizards (*Amphibolurus muricatus*) from Australia, deposited.

OUR ASTRONOMICAL COLUMN.

SEARCH-EPHEMERIS FOR COMET 1896 V. (GIACOBINI).—Herr M. Ebell contributes to No. 3898 of the *Astronomische Nachrichten* a second portion of the ephemeris for comet 1896 v. which he commenced in No. 3881 of the same journal. This ephemeris takes as the time of perihelion June 22·5, 1903, but Herr Ebell also gives ephemerides in which the time of perihelion passage is taken as June 6·5 and July 8·5 respectively.

Ephemeris 12*h*. *M.T.* (*Berlin*). T = June 22·5 1903.

1903	α h. m. s.	δ ° ′	log *r*	log Δ	Brightness.
Sept. 26	4 4 43	+14 12·2	0·2492	0·0177	2·66
,, 30	4 5 48	+13 29·7			
Oct. 4	4 6 9	+12 45·0	0·2604	0·0111	2·61
,, 8	4 5 47	+11 59·0			
,, 12	4 4 45	+11 12·2	0·2717	9·9973	2·64
,, 16	4 3 4	+10 24·9			
,, 20	4 0 49	+ 9 37·8	0·2831	0·0076	2·39
,, 24	3 58 3	+ 8 51·4			
,, 28	3 54 51	+ 8 6·5	0·2943	0·0130	2·21

INTENSITY OF SPECTRAL LINES.—*Circular* No. 72 of the Harvard College Observatory is devoted to the explanation of a scheme, proposed by Prof. Pickering, for the formation of a uniform universal method of recording the absolute intensities of spectral lines.

Comparative intensities are easily determined, in the case of bright lines by the bolometric method, in the case of dark lines by using the bright background as the standard unity intensity. Absolute values, however, are much more difficult to determine, and two methods offered themselves to Prof. Pickering's choice. First, the determination once for all of the intensities of certain well-known lines; secondly, the construction of an artificial standard with which all lines might be directly compared; he decided to use the second method.

A standard scale was constructed in which each line was 1·26 times as wide as the one next below it, so that the logarithms of their widths differed by 0·1, and the scale was then reduced rather more than twenty times and printed on sensitised paper, the haziness, which is characteristic of real spectral lines, being produced by inserting various thicknesses of white paper between the negative and the sensitive paper.

To standardise this prepared scale the line E of the Fraunhofer spectrum on Higgs's charts was used, and the intensities of thirty-six lines between λ 5261·8 and λ 5276·2 were measured, on the scale, on five different charts, and the five independent scale readings, their mean, the residuals from the mean and the width of each line in Ångström units, are given in the table accompanying Prof. Pickering's paper.

A PROVISIONAL CATALOGUE OF VARIABLE STARS.—No. 3 vol. xlviii. of the Harvard College Observatory *Annals* is devoted to a provisional catalogue of variable stars in which reference is made to some 1227 different variables. The catalogue has been prepared from a card-index of variable stars, commenced by Prof. W. M. Reed in 1888, and carried forward by Miss A. J. Cannon since 1900, which now contains about 34,000 cards referring to observations of variables.

A new notation has been adopted after grave consideration in this catalogue. Each star is designated by a number containing six figures, which are printed in ordinary type if the star is in the northern hemisphere and in italics if it is in the southern. The first two figures give the hours and the second two the minutes in the R.A., whilst the last two give the degrees in the declination; thus the designation of the first star in the catalogue (V. Sculptoris) is *000339* which, when translated, gives the approximate position of the star as R.A. = 0h. 3m., Dec. = −39°.

The catalogue also gives the Chandler number, the name of the star or its constellation, the D.M. number, the exact position for 1900, the chief particulars of the elements, the class of the variable and of its spectrum, and the date of discovery, with the name of the discoverer, for each variable.

MASS OF MERCURY.—In No. 3897 of the *Astronomische Nachrichten*, Prof. T. J. J. See, of Washington, gives the results of his recomputation of the mass of Mercury, and points out, *en passant*, the importance to workers in celestial mechanics of obtaining the truest possible value of this constant.

The latest measurements of the planet's diameter have slightly increased the former values, and Prof. See adopts 6″·00 as the most probable value of the diameter at unit distance; this gives an absolute diameter of 4351 ± 72km. and a resulting mass of $m = 1 : 14868548 \pm 743427$, which Prof. See adopts as the definite value. The mean specific gravity of the planet, with this mass, is 3·09, and this conforms very well with the other densities obtaining in the solar system.

CORRECTIONS TO EXISTING STAR CATALOGUES.—Since the publication of the "Catalogue of Reference Stars in the Zone +46° to +55°," by the Royal Observatory of Catania, Signor G. Boccardi has discovered a number of errors in various existing catalogues. These are set forth and their corrections given in a paper communicated by him to No. 3898 of the *Astronomische Nachrichten*; they include errata in the coordinates and in the precessional corrections.

Twelve catalogues are dealt with, including, among others, "The Radcliffe Catalogue of 6317 Stars (1845·0)," "The Brussels Catalogue of 10,792 Stars (1865·0)," "The Harvard College Catalogue of 8627 Stars, A.G. Zone +50° to +55°" (Leipzig, 1892), and "The Bonn Catalogue of 18,457 Stars (1875·0), A.G. Zone +40° to +50°," published at Leipzig in 1894.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

OXFORD.—An examination for a geographical scholarship of the value of 60*l.* will be held on Wednesday, October 14. Candidates, who must have taken honours in one of the final schools of the university, should send in their names to the reader in geography not later than Thursday, October 1. The scholar elected will be required to attend the full course of instruction at the School of Geography during the academic year 1903–4, and to enter for the university diploma in geography in June, 1904.

DR. F. H. NEWMAN, principal of the Carlisle Technical School and director of higher education in that city, has been appointed principal of the Norwich Technical Institute and organiser of higher education.

IT is stated in *Science* that a gift of ten thousand dollars has been made to Washington and Lee University by Mrs. Cyrus H. McCormick and her three sons, of Chicago, the interest of which sum is to be devoted to the development of the department of physics. A new laboratory of engineering and physics, the gift of an anonymous donor, is expected to be ready for occupation in the summer of next year.

THE evening continuation schools in connection with the School Board for London reopened on September 14. As the School Board will cease to exist after the end of April next the present session will be the last under the Board. Among the numerous classes arranged we notice that doctors and nurses will teach first aid and home nursing in upwards of two hundred schools. There will also be facilities for women and girls to learn practical cookery, dress-cutting and making, and laundrywork, and for men and boys to receive instruction in woodwork. The lantern will, in many cases, be used to illustrate the lessons in geography. The Board has arranged for medical men to give simple lectures on health in twenty schools; the subjects will include the air and ventilation, the house, prevention of consumption, the care of the skin, personal hygiene, how to prevent the spread of infectious disease, the care of infancy and childhood, ill-health in women, &c.; all the lectures will be illustrated by diagrams, and many simple experiments will be shown by the lecturers.

THE Board of Education, South Kensington, has issued the following list of candidates successful in the 1903 competition for the Whitworth scholarships and exhibitions:—Scholarships, 125*l.* a year each (tenable for three years), John S. Nicholson, Alford, Aberdeenshire; Leonard Southerns, Retford, Notts.; Alec J. Simpson, Edinburgh; Alexander Gray, Edinburgh. Exhibitions, 50*l.* (tenable for one year), Frederick G. Turner, Southsea; James Cunningham, Banbury; William Welch, London; Edmund W. Spalding, Lincoln; William E. Hogg, London; Alfred R. Stamford, Plumstead, Kent; Joseph Lloyd, Pembroke Dock; John A. Davenport, Liverpool; Stewart S. Spears, Sheerness-on-Sea; James Lees, Southsea; William H. Powell, London; Edwin C. Trew, Landport, Portsmouth; Frederick W. B. Sellers, Sutton, Surrey; John E. Lister, Doncaster; Richard W. Bailey, Manor Park, Essex; Laurence H. Pomeroy, London; Christopher J. Lees, London; Fred Newell, Plumstead, Kent; Edmund G. Nicholls, Swansea; Maurice K. Pedlar, East Stonehouse, Devon; George F. Sutherland, Aberdeen, N.B.; Charles I. Sutton, Plumstead, Kent; Robert H. Barr, Barrow-in-Furness; William H. Hemer, Devonport; James Nicol, Barrhead, N.B.; Frederick E. Pollard, Eastwood, Notts.; Arnold Sykes, Huddersfield; Wilfred C. Kimber, London; Henry F. Elliott, Plumstead, Kent; David Richardson, Crewe.

THE following list of successful candidates for royal exhibitions, national scholarships, and free studentships (science), 1903, has been issued by the Board of Education, South Kensington:—Frederick G. Turner, Southsea; James M. Mackintosh, Inverness, N.B.; Samuel Lees, Broughton, Manchester; John H. Hugon, Eccles, Manchester; Arthur A. Rowse, Southsea; William E. Hogg, London; William L. Perry, Plymouth, royal exhibitions; Archibald Ward, Sheffield; Alexander Gray, Edinburgh; Edwin S. Crump, Wolverhampton; Leslie G. Milner, New Brompton, Kent; Archibald R. Richardson, London; Francis G. Steed, Devonport, national scholarships for mechanics (group A); Harold H. Broughton, Huddersfield; George F. Sutherland, Aberdeen, N.B., free studentships for mechanics (group A); William H. L. Patterson, Chiswick; Arthur E. Hall, Swindon; William F. G. Swann, Brighton; James Hoggarth, Bath; John Watson, Sunderland, national scholarships for physics (group B); Charles I. Robinson, London, free studentship for physics (group B); Frederick Dewhurst, Middleton Junction, Manchester; William Godden, Canterbury; George S. Whitby, Hull; John F. Stansfield, Morley, Leeds; Henry Holmes, Middlesbrough; Thomas Jackson, Middlesbrough, national scholarships for chemistry (group C); Frederic W. Caton, Hove, Sussex; John Keegan, Burnley, free studentships for chemistry (group C); Edward Hindle, East Bierley, Bradford; Ethel Mellor, Burnley, national scholarships for biology (group D); Ellis L. Jones, Blaenau Festiniog, free studentship for biology (group D); Winifred M. Clune, Bristol; Fred Thistlethwaite, Burnley; Diogo F. de Souza, London, national scholarships for geology (group E).

SOCIETIES AND ACADEMIES.

PARIS.

Academy of Sciences, September 7.—M. Albert Gaudry in the chair.—Parthenogenesis of the larvæ of Asteriæ by the action of carbonic acid, by M. Yves **Delage**. By modifying the conditions, the larvæ develop to the stage when all the essential organs are well marked.—On the production of glycogen in fungi cultivated in weak sugar solutions, by M. Émile **Laurent**. The production of reserve carbohydrates is related both in fungi and in vascular plants to a food supply containing an abundance of sugar or analogous substances. The author has discovered an interesting exception to this rule, four species of moulds, *Mucor racemosus, Sclerotinia Libertiana, Botrytis cinerea*, and *Saccharomyces cerevisiae*, all giving considerable quantities of glycogen when grown in very dilute organic solutions.—Observations of the planet MA (August 24, 1903) made at the Observatory of Besançon, by M. P. **Chofardet**.—On a bacterial disease of tobacco, "chancre" or "anthracnose," by M. G. **Delacroix**. This disease is due to a bacillus, not previously described, and to which the name of *Bacillus aeruginosus* is given, on account of the coloration it develops in certain culture media.

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