THURSDAY, AUGUST 9, 1900.

PRACTICAL NAVIGATION.

Self-instruction in the Practice and Theory of Navigation. By the Earl of Dunraven, Extra Master. Two volumes. Pp. xxv + 354 + 388. (London: Macmillan and Co., Ltd., 1900.)

THE science of navigation, apart from the practical art of seamanship, stands on a very curious footing. Based mainly on mathematical results, it presents probably the only, certainly the most conspicuous, instance of the adaptation of pure science to practical ends. As a consequence nautical astronomy, or those portions of it which are indispensable to navigation, has been systematised to such a pitch of perfection that a mechanical system has been substituted for a reasoning process. Many regard this result with satisfaction as a triumph of scientific simplicity, and pride themselves on the production of navigators capable of producing a definite practical result with the least possible expenditure in training. Perhaps it would be unjust to say that this view is shared by the Earl of Dunraven, the author of the latest book on the theory and practice of navigation. But he is not prepared to throw his known experience as a sailor and his great popularity as a successful yachtsman on the side of those who would make the Board of Trade Regulations more stringent, and would demand from applicants for the various certificates some proof that they have acquired more than a rule-of-thumb acquaintance with the various methods and formulæ that they will have to put into practice. The effect, if not the object, of his book is to show with how little knowledge one may pass the Board of Trade Examinations, and be legally entitled to assume positions of enormous responsibility. But admitting that it is desirable to give the practical seaman every chance in the examination room, and that the accurate solution of a problem is the only point to be regarded, is it easier to teach once for all the ordinary methods for the solution of a spherical triangle, or to burden the memory with a variety of rules which are available only for the solution of the particular family of problems to which these rules have been adapted? Take, for example, the case of the determination of an hour angle from the observation of an altitude in a known latitude. The candidate for a certificate, taught on the lines that Earl Dunraven approves and encourages, has to remember first of all a series of rules about declination and latitude being of the same or different names; then he has to write certain quantities down in a particular order, perform sundry acts of legerdemain, take out four different logarithmic functions of angles, add them up, and is landed in a quantity which his lordship calls "the log. of the hour angle." It is the log. sine squared of half the hour angle, but this is a detail, and if one happens to possess the particular table in which some obliging genius has given this quantity, with argument hour angle, the work is done and it may be, so far as the result is concerned, satisfactorily. To trust to the memory rather than the rigorous process of demonstration is a plan Earl Dunraven thinks admirably adapted to meet the difficulties introduced by "a wet, slippery, and tumbling deck" and the inconveniences "of a dimly-lit cabin, full of confusion and noise." We fail to perceive the particular advantages of this system, but would express any doubts on this point very modestly, for the author speaks from an actual experience, which we can very inadequately apprehend.

But if our methods of teaching are as far asunder as the poles, it is impossible to escape the influence of the cheerful, breezy style in which the book is written—a model for those who attempt to substitute teaching by written description for oral explanation. The author appears to be sitting at the same table with the student, giving him of his best, and actually pushing him through the examination. If any one has failed to satisfy the examiner that he is competent to do "a day's work," let him take Earl Dunraven for his guide, and he will become fully persuaded of the easiness of the problem, rather than of its difficulty, and will pass the ordeal with success.

The author supposes his pupil to be conversant with the multiplication table, but with practically nothing else, so he gives first a chapter on arithmetic, followed by one on the application of logarithms; the theory is dismissed in a page, and of this short summary the student is told "don't bother to read it unless you have a mind to." This is the keynote of the whole book, only those problems which can have an immediate practical significance, or can be broached in the examination room, are pressed on the student's notice. But to make amends for the lack of theory, on the practical side, the detail is very full and complete. From logarithms we pass to the description of the instruments used at sea, and so arrive at the "sailings" and that troublesome problem of the "day's work," which proves such a stumbling block for so many aspirants for certificates. At this point the author thinks it time to introduce a little algebra and trigonometry, though he advises only extra masters to read it, and we must admit that it contains some hard things, and that we should have some difficulty in solving some of the simple equations proposed by following the rules laid down for our guidance. The author is not seen at his best in these chapters, which are better taught in the schoolroom than on the ship's deck. Tides and charts, so far as their investigation and construction are needed for the examination room, are fully explained. The first volume concludes with the solution of simple problems connected with the determination of latitude, longitude, and azimuth.

We cannot get very far into the second volume without some knowledge of spherical trigonometry, and here, again, we do not find the chapters devoted to this subject altogether satisfactory. Spherical trigonometry covers a very small but well recognised subject of inquiry, and can without much difficulty be made complete. The methods are simple and easily applied, except in one point, and that is the determination of the quadrant in which the various arcs fall. Earl Dunraven has not much assistance to offer on this vexed point. He pins his faith to Haversines, and as a rule keeps free from the employment of auxiliary angles. In this he is no doubt well advised, for the advantages of the method so long insisted upon in elementary treatises are by no means so apparent in actual work. Through the intricacies of the ingenious method known as Sumner Lines, Earl Dunraven conducts us with care, especially dwelling on the use of the various tables that have been introduced to facilitate the process and hasten the result. After one or two further applications of spherical trigonometry, we are brought face to face with that curious survival, known as a Lunar Distance, and we are quite sure that the author did some violence to his sense of practical utility when he devoted so many wearisome pages to the consideration of this obsolete problem. In the examination room of the Board of Trade, the thorny difficulties of "clearing the distance" may exercise a wholesome effect on the extra master, whose fate it is to attack this problem, and induce him to acquire a greater knowledge of nautical astronomy than he would otherwise do; but we imagine in the great majority of cases the applicant endeavours to forget all about the intricacies of the problem as soon as he is possessed of his qualifying "ticket." The skill of the mechanician has done much to remove the necessity of the ingenious device, but the rapid transit of vessels from port to port, and the numerous time signals in known longitudes, give to the mariner Greenwich Time more accurately than it was ever determined by the method of lunar distances. But for some reason known only to the authorities, an acquaintance with the method is demanded, though the necessary facility in manipulating the sextant cannot so well be required. The whole process affords an interesting case of the resources of analysis outrunning in accuracy the observations to which it is applied.

"Problems," says Earl Dunraven, "will be given you in the examination room on the infernal subject of magnetism and deviation," so he has much to say about the coefficients A to E. To many, we are afraid these coefficients will remain a matter of intricate manipulation, carrying no definite meaning; but if they follow the author's guidance, they ought to issue triumphantly from the examination ordeal. His rules are admirably arranged, and, from a purely mechanical point of view, leave nothing to be desired. We could have wished that the theory had been a little fuller, but we remember, a little regretfully, that the author's object is not to teach magnetism, but to pass the reader or student through an examination of a strictly limited character. We cannot but think that the book is eminently calculated to effect this object. Admirably printed, well and lavishly illustrated, furnished with numerous examples and written in a free and easy, but lucid style, we should imagine that this work is destined to become the most popular book on the subject, and that it will be the one guide and text-book to which the young officer will apply, to help him to meet and defy the terrors of Her Majesty's examiners. W. E. P.

THE CULTIVATION AND PRODUCTION OF COFFEE.

Le Café, Culture—manipulation—production. Par Henri Lecomte, Agrégé de l'Université, Docteur es Sciences, &c. Pp. vi + 342. (Paris: Georges Carré et C. Naud, 1899.)

COFFEE in its various commercial aspects, whether from the point of view of the planter, the broker, the retail dealer, or the consumer, has from time to time commanded a great deal of attention. Occupying as it does a large and extended area of cultivation within the tropics, and being an important branch of industrial culture in many of the British possessions, as Jamaica, Ceylon, Southern India, and Borneo, it is but reasonable to expect that treatises on the cultivation, best means of improvement of yield and quality, prevention of disease, &c., would be numerous. In the English language many such works are available, and if this be so, bearing on a culture which though large and important is small in comparison with that of Brazil, Central America, Mexico, Java, and Sumatra, we might also expect to find a large number of books in the languages of the nations to which these extensive coffee growing countries belong.

The work before us is the latest contribution to the French literature of the subject, and extensive as that literature is and for the most part carefully worked out, M. Lecomte's handbook will be a useful and valuable addition not only for its arrangement, but also for the concise character of the information given and the various items of intelligence regarding production in the several countries referred to and exports therefrom.

The first chapter is devoted to the early history of the coffee plant. The botany of the genus *Coffea* is treated of in the second chapter occupying twenty-five pages, and is illustrated by a figure of the so-called Arabian coffee (*Coffea arabica*) in flower and in fruit, and a figure is also given of *C. stenophylla*, the tree which furnishes the wild coffee of Sierra Leone, as well as of the new species from the Congo, *C. canephora*, Pierre. In the enumeration of species given in this chapter thirty-three are referred to, prominence, of course, being given to *C. arabica* and *C. liberica*, the two most important coffee yielding species. The best varieties of *C. arabica* cultivated in various parts of the world are also enumerated. Referring to *Coffea stenophylla* the specific name of which, by the way, is spelt with a capital initial letter, the author gives the following interesting account of it: In 1894 some plants of this new species were received at the Royal Gardens, Kew, from Sierra Leone, and these plants produced flowers in 1895. Seeds were afterwards sent to most of the English colonies where it was thought the plant might flourish. In Ceylon, however, the results have not been satisfactory; but in Dominica, Jamaica, and Trinidad, the case has been different. In the Botanic Garden of Port of Spain, Trinidad, there are some fine fruiting examples of this tree quite free of disease. The author further regrets that this coffee has not yet been introduced into the French colonies. On the climate and elevation suitable for the success of coffee plantations the great coffee-growing country of Brazil has the first consideration. The remaining chapters are devoted to the consideration of soils, the choice of seeds, transplanting, manures, shade trees, &c. The use of simple diagrams showing the different positions in which the coffee plant and its shade trees may be placed will be found useful, as will also the list of trees suitable both for shade and shelter, amongst which we notice such well-known trees as *Albizzia Lebbek*, *A. stipulata*, and *Exythrina indica.*

On the subject of harvesting or gathering the crop it is pointed out how extremely variable in the period of ripening its seeds the plant is in different countries. Thus in Cuba, Guadaloupe, and other islands of the Antilles, the harvest commences in August and is carried on through

November, while in Brazil it commences in May and ends in September.

Though the broad principles of the preparation of coffee for market are well known, the description here given, especially aided as it is by the practical illustrations, will be of especial value. No book on coffee could possibly be complete without a reference to the diseases to which the plant is subject, whether the disease belongs to the vegetable or animal kingdom. Consequently we find thirty-one pages devoted to this part of the subject. Substitutes for coffee also come under consideration. occupying, however, a comparatively small space, and though no doubt sufficient is said about them, their number might be considerably increased. Perhaps one of the most interesting parts of the book is that treating on production, in which each country is considered separately, the first chapter being devoted to the American Continent, and naturally leading off with Brazil. British, Dutch and French Guiana are also considered, and comparisons made with product and export, as are also those of Paraguay, Venezuela, Columbia, Costa Rica, Mexico and other places. The West Indies, including Jamaica, Porto Rico, Trinidad and other important coffee growing countries, as well as the Eastern countries and Africa, are also referred to. This part of the subject is practically illustrated by a map of the world, showing at a glance the geographical distribution of the coffee plant, together with the production of each country in kilogrammes, and the date to which the figures refer. A comparison of the produce of each country is readily gained by a series of disks of different sizes, with the names of the country beneath each, and the total in figures; from this it will be seen that Brazil is far ahead of any other individual country. An interesting table is also given showing the consumption of coffee in the principal countries of the world, from which it seems that of the European countries Germany consumes by far the largest quantity. The figures in tons for 1897 standing thus—Germany 136,390, France 77,310, England 12,420, while the consumption in the U.S. of America in the same year amounted to 318,170 tons. The book concludes with a table of subjects of the several chapters, but lacks that most necessary adjunct of all books—a good index.

THE BIRDS OF SURREY.

The Birds of Surrey. By J. A. Bucknill. Pp. lvi + 374, illustrated. (London: R. H. Porter, 1900.)

FROM its great extent of open moorland and the presence of several large sheets of water, Surrey occupies an unusually favourable position among the metropolitan counties for the development of a large bird-fauna; and since a very considerable portion of the county is now undergoing a metamorphosis under the hands of the builder as the area of the metropolis and its suburbs increase, it is most important that a full record should be secured of the species of birds which are fast disappearing from its limits. The compiling of such records, and the careful working out of the past history of locally distributed species within the limits treated of, seem, indeed, to be the chief justification for the publication of county ornithologies. And in this respect, as well as in the careful collection of local bird-names, the author of the work before us appears to have discharged his task in a thoroughly satisfactory manner. An instance of this is afforded by his account of the occurrence of the black-grouse in Surrey. To many of our readers it will probably come as a surprise to learn that black-cock shooting was a recognised sport on the Surrey moors during the forties, and even to a considerably later date. At the present day there is, however, scarcely a single genuine wild bird of this species to be met with in the county; and the excellent history of its gradual extermination given by Mr. Bucknill should, therefore, be read with the greatest interest alike by sportsmen and by ornithologists. The raven, the buzzard, the marsh-harrier, and the dotterel are other species which have disappeared from the county, either totally or as nesting birds; the last record of the occurrence of the dotterel being 1845, when a couple of specimens were purchased from the landlord of an inn at Hindhead.

Of the numerous rare birds that have been noticed from time to time in the county, the great majority have been visitors to the well-known Frensham ponds, the larger of which extends into Hampshire. Here we are practically in Gilbert White's country; and in these favoured haunts have been seen the osprey, the spoonbill, several of the rarer kinds of duck, the goosander, and the purple heron. Sad to say, the arrival of these wanderers has for the most part been speedily followed by their slaughter; and, as the author remarks, hundreds of other avian rarities have doubtless been killed and eaten without record. Unhappily, the great increase in game preservation which has taken place of late years in the county appears to have been the cause of the diminution in the numbers of many of the rarer species of birds. But there are many country gentlemen, on the other hand, who are lovers of natural history, and who veto as much as possible the bird-slaying propensities of their gamekeepers. It is to such, and to the laws now in force for the protection of wild birds, that we have to look for the commencement of a better state of things in the wilder parts of the county. And the fact that the golden oriole and the hoopoe have been observed of late years on several occasions indicates the probability that these beautiful birds would once more nest in the Surrey groves if only they received adequate protection.

A feature of the book is the beautiful series of illustrations of Surrey scenery; the views of Frensham Great Pond and of the Surrey Weald being some of the best examples of landscape photogravure that have come under our notice. Although primarily intended for residents in the county (among whom we are glad to see that a long list of subscribers has been enrolled), the book is full of interest to all bird-lovers living in the south of England.

R. L.

OUR BOOK SHELF.

Untersuchungen ueber d. Vermehrung d. Laubmoose durch Brutorgane und Stecklinge. Von Dr. Carl Correns, a.ö. Prof. d. Botanik in Tübingen. Pp. xxiv+472; mit 187 abbild. (Jena: Verlag v. Gustav Fischer, 1899.)

FEW people perhaps fully realise how abundantly the mosses are provided with modes of vegetative reproduction, even although they may be fully cognisant of the fact that the protonema—the precursor of the moss-plant—is readily induced to make its appearance from the cut ends of the stems and leaves of these plants. Prof. Correns has done a useful service in bringing together, in a classified manner, the numerous methods employed by mosses to ensure their propagation and dispersal by means less expensive than by the production of spores. The readily friable stems of some species of *Andreaea*, the easily detached branchlets of *Dicranum*, are instances, well known to muscologists, of a large class of propagative bodies. These simpler forms of reproduction are also widely spread amongst plants other than mosses, and in some cases—e.g. *Lycopodium Selago*—the superficial resemblance is rather striking. Less obvious are the subterranean bulbils or buds, such as are met with in *Dicranella*, *Barbula*, or *Funaria*, in which special tuberous bodies are formed. *Dicranella heteromalla* affords a pretty example of a form transitional from the simple to the more complex types, inasmuch as the subterraneous bulbils of this moss are little more than rows of swollen rhizoid-cells arranged somewhat like a string of beads. Many of these bulbils are regarded by Correns rather as of the nature of food reservoirs than as brood bodies; but it is at least certain that they are in most cases able to function in the latter capacity as well as in that of mere storehouses of food-reserves.

Other and very common cases of brood bodies are afforded by the so-called "*folia fragilia*"—leaves which readily become detached from the parent plant, and with greater or less intervention of protonematal filaments give birth to new individuals. Oftentimes the leaves destined to this end undergo considerable contraction in size, and, indeed, may assume a totally rudimentary appearance.

Again, as in some species of *Orthotrichum*, cells grow out from the ends of leaves, and the sausage-shaped proliferations, after detachment from the parent plant, grow out to filaments, on which new plants arise.

The above are only a few of the many forms cited by Correns of gametophytic reproductions in the mosses by vegetative means. But as Pringsheim long ago pointed out, it is also possible to reproduce these plants from the sporophyte generation, especially from cut fragments of the seta or stalk of the moss-capsule. These are far more interesting, as they resemble the curious aposporic development met with in a number of ferns. Indeed, these latter offer, perhaps, a means of attacking the details of the phenomena of apospory with a greater chance of success than in the case of the ferns, since they seem more easily induced by simpler experimental devices than is the case with the higher plants.

A general synopsis of the various types and forms of brood-bodies forms a useful adjunct to the main descriptive part of a book on which the author has evidently expended much labour, and which should earn for him the gratitude of all those muscologists who are not merely describers of species, as well as of botanists who seem too often rather to be disposed to ignore an important section of the vegetable kingdom.

Village Notes, and Some Other Papers. By Pamela Tennant. Pp. xii + 204; 13 plates. (London: William Heinemann, 1900.)

THESE notes reveal some of the humour and pathos of rural life in South Wilts, and here and there they lightly touch natural scenes and objects other than human. The plates, which are reproductions from original photographs of Wiltshire views, are excellent, and the book itself is a dainty volume suitable for a drawing-room table. Reference is made to the "pernicious habit of 'underlining' in their letters" which some people adopt, yet we notice an abundance of italicised words in the book, and they are equivalent to the underlined words so severely condemned.

LETTERS TO THE EDITOR.

[*The Editor does not hold himself responsible for opinions expressed by his correspondents. Neither can he undertake to return, or to correspond with the writers of, rejected manuscripts intended for this or any other part of* NATURE. *No notice is taken of anonymous communications.*]

The Conductivity produced in Gases by the Motion of Negatively-charged Ions.

RECENT researches have shown that gases are rendered conductors of electricity when negatively-charged ions move through them with a high velocity. Thus the kathode rays and the Lenard rays possess the property of ionising gases through which they pass (J. J. Thomson, "The Discharge of Electricity through Gases"). Becquerel (*Comptes rendus*, March 26, 1900) also has recently shown that the conductivity produced by radium is due to small negatively-charged particles given off by the radio-active substance. In these cases the charged particles which ionise the gas move with velocities nearly equal to the velocity of light.

Some experiments which I have recently made show that ions which are produced in air by the action of Röntgen rays will produce other ions when they move through the gas with a velocity which is small compared with the velocity of light.

When Röntgen rays are sent through a gas, at atmospheric pressure, the current between two electrodes immersed in the gas increases in proportion to the electric force, when the force is small. For large forces the current attains a value which is practically constant.

When the pressure of the gas is reduced, the connection between conductivity and electromotive force is more complicated. The accompanying tables show the connection between current and electric force for air at 2 and ·8 mm. pressure. At these pressures the current is practically constant for forces of about 10 volts per centimetre, and when forces of this order are acting, all the ions are produced directly by the rays. When the electric force is increased these ions produce others, so that the current again increases.

It appears from the following investigation that the new ions are produced by the collisions between negatively-charged ions and the molecules of the gas.

Let us suppose that n negative ions are moving in a gas between two parallel plates at a distance d apart. Let X be the electric force between the plates $\left(=\frac{V_1 - V_2}{d}\right)$, and p the pressure of the gas. In going a distance dx the n ions produce $\alpha \times n \times dx$ others, where α is a constant depending on X, p, and the temperature, which is constant in these experiments. (The coefficient α is practically zero for small values of X, unless p is also small).

$$\therefore \quad dn = \alpha n dx$$
$$\text{and } n = n_0 \mathrm{E}^{\alpha x}$$

Hence n_0 ions starting at a distance x from one of the plates will give rise to $n_0(\mathrm{E}^{\alpha x} - 1)$ others. When the ions arrive at the plate, the formation of new ions ceases and the current stops, although the electromotive force is kept on. Let n_0 be the number per unit volume produced by the rays. The total number of ions produced will therefore be

$$\int_0^d n_0 \mathrm{E}^{\alpha x} dx = \frac{n_0}{\alpha}(\mathrm{E}^{\alpha d} - 1)$$

per unit area, $n_0 d$ being the number produced by the rays. Hence

$$\frac{c}{c_0} = \frac{1}{\alpha d}(\mathrm{E}^{\alpha d} - 1)$$

where c is the current for a large force X, and c_0 the current composed of ions produced by the rays.

The following experiments were made in order to test the accuracy of this formula for currents produced between two parallel plates whose distance apart could be varied.

The rays fell normally on one of the plates, which was made of thin aluminium, and after passing through the air between the plates, the rays were completely stopped by the second plate, which was of brass. The plates were 10 centimetres in diameter, and the rays were allowed to fall on a circular area at the centre 4 centimetres in diameter. The conductivity was thus confined to a region where the force was constant. A large part of the conductivity (c_0) arises from the secondary radiation from the brass disc. At high pressures the secondary effect is principally confined to a layer of gas near the surface (John S. Townsend, *Camb. Phil. Proc.*, vol. x. Part iv.), but when the pressure is low the secondary rays are not so rapidly absorbed by the gas, and the ionisation (n_0) between the plates is nearly uniform.

The ratios of $\frac{c}{c_0}$ were determined for different forces, the air being at a pressure of two millimetres. When the strength of the rays was reduced to $\frac{1}{3}$ of its original value it was found that the ratios $\frac{c}{c_0}$ were unaltered. This shows that α is independent of n_0 and is some function of X and p.

The plates were then set at one centimetre apart, and the values of c were determined for different forces. The results, corresponding to a pressure 2 and ·8 mm., are given in the second columns of the accompanying tables. The numbers given are the mean between the currents in opposite directions. With this form of apparatus, however, there were only very small differences found in the conductivity when the electromotive forces were reversed. The plates were then set at two centimetres apart, and the currents found in this case for pressures 2·14 and ·8 mm. are given in the third columns of the tables.

The force X is given in volts per centimetre.

TABLE I.—*Air at pressure* 2 *mm.*

X	$c(d=1)$	$c(d=2)$	Calculated values of $c(d=1)$
20	28	49·5	28
40	28·2	51	28·4
80	29·5	55	29·5
120	36	81	35·5
160	51	173	50
180	64·5	293	63

TABLE II.—*Air at pressure* ·8 *mm.*

X	$c(d=1)$	$c(d=2)$	Calculated values of $c(d=1)$
10	10	17·7	10
20	10·5	19	10·5
40	12	24·5	12
80	17	53·5	17
120	31	190	29
165	61	990	62·5
186	82	2180	84

The tables show that the current increases more rapidly with X when the plates are two centimetres apart than when they are one centimetre apart. This effect cannot be attributed to a surface action which would be independent of d when X remains constant.

From the formula $\frac{c}{c_0}=\frac{1}{\alpha d}\left(E^{\alpha d}-1\right)$ we can deduce the values of α from the third columns of the tables, by making $d=2$ and c_0 the smallest value of c. From values of α thus obtained, the ratios $\frac{c}{c_0}$ for the different forces corresponding to plates 1 centimetre ($d=1$) were calculated. The values of c found in this manner are given in the fourth columns, and they show a good agreement with the experimental determinations.

Other experiments for different pressures have also been made, and they all show an agreement with the present theory.

For the purpose of deciding whether it is the positive or negative ions which produce other ions by their rapid motion through the gas, we may mention the following experimental results. When the lines of force in the gas are not parallel, large differences in current were obtained on reversing the electromotive force. Thus, when the conductivity takes place between two electrodes one inside the other, it was found that for high electromotive forces the current is much greater when the ions go towards the inner electrode.

Thus, with an apparatus consisting of a small spherical electrode surrounded by a large electrode made of thin aluminium, the currents, when the outside electrode was positive, were 14 for a potential difference of 40 volts, and 34 for a potential difference of 300 volts; when the outside electrode was negative the currents were 14 and 174 for the same voltages. In these experiments the pressure was about 2 mm. The positive and negative ions produced by the rays are generated nearly uniformly throughout the area between the electrodes. When the large electrode is positive only a few of the negative ions pass through the region round the small electrode where the force is big, and the current only increases from 14 to 34. When the electromotive force is reversed all the negative ions produced by the rays come into the region where the force is big, and the current is thereby increased from 14 to 174. It is therefore evident that the increase of conductivity must be attributed to the rapid motion of the negative ions.

I hope in a future paper to give a fuller account of the above experiments, and also to point out some of the applications of this theory to the passage of electricity through gases. I may mention that the high conductivities obtained with ultra-violet light (Stoletow, *Journal de Physique* (2), 9, pp. 463-473, 1890), at pressures of about 1 millimetre, may be explained by this theory.

Approximate values of the energy of translation of the negative ion when producing another ion by a collision can also be obtained from the coefficients α. J. S. TOWNSEND.

Trinity College, Cambridge.

A Remarkable Hailstorm.

I HEREWITH enclose you prints, from untouched negatives, of hailstones which fell at Northampton on Friday, July 20.

The drawing board measures 19½" by 17", and the average circumference of the hailstones upwards of five inches. These are by no means the largest that fell, according to the statements of trustworthy persons, but were typical of what fell in my garden.

FIG. 1.—Group of hailstones which fell at Northampton on July 20. Size of board 19½ in. by 17 in.

The majority of the stones were somewhat flattened, as shown in the front of the photograph, but many were nearly spherical like those in my hand (Fig. 1).

The stones were extremely dense and well frozen, and buried themselves in the garden soil. Where they fell on hard surfaces, they usually broke into fragments which rebounded to considerable heights, while glass roofs suffered enormous damage all over the area, some twelve miles by six, covered by the storm. I have a piece of glass 5/16ths of an inch in thickness many hundred square feet of which were broken at the various factories in the town.

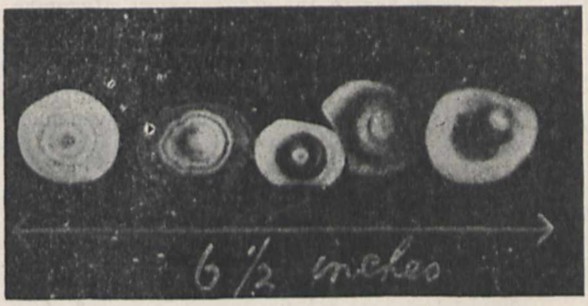

FIG. 2.—Sections of hailstones (Northampton, July 20).

The sections (Fig. 2) were an afterthought and show the structure exceptionally well in two instances.

J. G. ROBERTS.

Northampton and County School, July 30.

THE PHOTOGRAPHY OF SOUND-WAVES AND THE DEMONSTRATION OF THE EVOLUTIONS OF REFLECTED WAVE-FRONTS WITH THE CINEMATOGRAPH.

Introduction.

In a paper published in the *Philosophical Magazine* for August 1899, I gave an account of some experiments on the photography of sound-waves, and their application in the teaching of optical phenomena. Since writing this paper I have extended the work somewhat and at a meeting of the Royal Society on February 15, 1900, gave an account of this work, and demonstrated certain features of wave motion with the cinematograph.

In the present article I propose to give a somewhat more extended account of the work, paying especial attention to the analogies between the sound-waves and waves of light.

In teaching the subject of optics we are obliged to resort to diagrams when dealing with the wave-front, and in spite of all that we can do, the student is apt to form the opinion that the rays are the actual entities, and that wave-fronts are after all merely conceptions.

The set of photographs illustrating this article will, I think, be of no small use to teachers in ridding the minds of students of the obnoxious rays, and impressing the fact that all of the common phenomena of reflection, refraction and diffraction are due simply to changes wrought on the wave-front.

Sound-waves in air were first observed and studied by Toepler, by means of an exceedingly sensitive optical contrivance for rendering visible minute changes in the optical density of substances. A very full description of the device will be found in Toepler's article (*Wied. Annalen*, cxxxi.), while a brief account of it will be given presently.

The waves in question are the single pulses of condensed air given out by electric sparks. A train of waves would complicate matters too much, and for illustrating the optical phenomena which we are to take up would be useless.

The snap of the spark gives us just what we require, namely, a single wave-front, in which the condensation is considerable.

When seen subjectively, as was the case in Toepler's experiments, the wave-fronts, if at all complicated, as they often are, cannot be studied to advantage, as they are illuminated for an instant only, and appear in rapid succession in different parts of the field. By the aid of photography a permanent record of the forms can be obtained and studied at leisure. The first series of photographs, published in the *Philosophical Magazine*, were made with an apparatus similar to the one to be presently described; while most of those illustrating this article were made on a much larger scale by employing a large silvered mirror in place of the lens, an improvement due to Prof. Mach, of Prague, who has given much attention to the subject.

As it is a matter of no trouble at all to set up in a few minutes, in any physical laboratory, an apparatus for showing the air-waves subjectively, and as the method does not seem to be as well known as it deserves to be, a brief description of the "Schlieren" apparatus, as Toepler named it, may not be out of place.

The Apparatus.

The general arrangement of the "Schlieren" apparatus is shown in Fig. 1. A good-sized achromatic lens of the finest quality obtainable, and of rather long focus, is the most important part of the device. I have been using the object-glass of a small telescope figured by the late Alvan Clarke. Its diameter is five inches, and the focal length about six feet. I have no doubt but that a smaller lens could be used for viewing the waves, but one of at least this size is desirable for photographing them.

The lens is mounted in front of a suitable source of light (in the present case an electric spark), which should be at such a distance that its image on the other side of the lens is at a distance of about fifteen feet.

The image of the spark, which we will suppose to be straight, horizontal, and very narrow, is about two-thirds covered with a horizontal diaphragm (*a*), and immediately behind this is placed the viewing-telescope. On looking into the telescope we see the field of the lens uniformly illuminated by the light that passes under the diaphragm, since every part of the image of the spark receives light from the whole lens. If the diaphragm be lowered the field will darken, if it be raised the illumination will be increased. In general it is best to have the diaphragm so adjusted that the lens is quite feebly illuminated, though this is not true for photographic work. Let us now suppose that there is a globular mass of air in front of the lens of slightly greater optical density than the surrounding air (*b*). The rays of light going through the upper portion of this denser mass will be bent down, and will form an image of the spark below the diaphragm, allowing more light to enter the telescope from this particular part of the field; consequently, on looking into the instrument, we shall see the upper portion of the globular mass of air brighter than the rest of the field. The rays which traverse the under part of "*b*," however, will be bent up on the contrary, forming an image of the spark higher up, and wholly covered by the diaphragm; consequently this part of the field will appear black. It will be readily understood that, with the long path between the lens and the image a very slight change in the optical density of any portion of the medium in front of the lens will be sufficient to raise or depress the image above or below the edge of the diaphragm, and will consequently make itself manifest in the telescope.

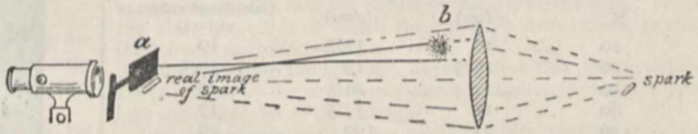

Fig. 1.

The importance of using a lens of first-class quality is quite apparent, since variations in the density of the glass of the lens will act in the same way as variations in the density of the medium before it, and produce unequal illumination of the field. It is impossible to find a lens which will give an absolute even, feeble illumination, but a good achromatic telescope objective is perfect enough for every purpose. A more complete discussion of the operation of the apparatus will be found in Toepler's original paper in the *Annalen*. The sound-waves, which are regions of condensation, and consequent greater optical density, make themselves apparent in the same way as the globular mass of air already referred to. They must be illuminated by a flash of exceedingly short duration, which must occur while the wave is in the field of view.

Toepler showed that this could be done by starting the sound-wave with an electric spark, and illuminating it with the flash of a second spark occurring a moment later, while the wave was still in the field. A diagram of the apparatus used is shown in Fig. 2. In front of the lens are two brass balls (*a*, *a*), between which the spark of an induction coil passes, immediately charging the Leyden-jar *c*, which discharges across the gap at *e* an instant later. The capacity of the jar is so regulated that the interval between the two sparks is about one ten-thousandth of a second. The field of the lens is thus illuminated by the flash of the second spark before the sound-wave started by the first spark has gone beyond the edge of the lens.

To secure the proper time-interval between the two sparks it is necessary that the capacity of the jar be quite small. A good-sized test tube half full of mercury standing in a jar of mercury is the easiest arrangement to fit up. This limits the length and brilliancy of the illuminating-spark, and with the device employed by Toepler I was unable to get enough light to secure photographs of the waves. After some experimenting I found that if the spark of the jar was passed between two thin pieces of magnesium ribbon pressed between two pieces of thick plate-glass, a very marked improvement resulted. With this form of illuminator I found that five or six times as much light could be obtained as by the old method of passing the spark between two brass balls.

The spark is flattened out into a band, and is kept always in the same plane, the light issuing in a thin sheet from between the plates. By this arrangement we secure a light source of considerable length, great intensity, and bounded by straight edges, the three essentials for securing good results. The glass plates, with the ribbon terminals between them, must be clamped in some sort of a holder and directed so that the thin sheet of light strikes the lens: this can be accomplished by darkening the room, fastening a sheet of paper in front of the lens, and then adjusting the plates so that the paper is illuminated as much as possible. The image formed by the lens will be found to have very sharp straight edges,[1] on one of which the edge of the diaphragm can be set in such a manner as to allow but very little light to pass when the intervening medium is homogeneous; a very slight change, however, in any portion may be sufficient to cause the entire amount of light passing through that portion to pass below the diaphragm and enter the telescope.

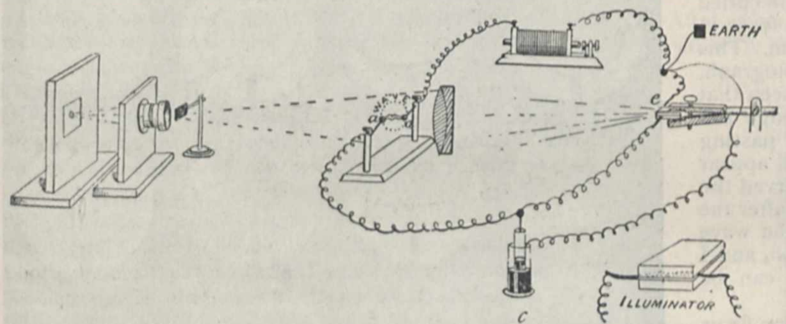

FIG. 2.

The photographs were made by substituting a photographic objective for the telescope, in the focal plane of which a vertical board was mounted to support the plate. The room was darkened, a plate held in position, and a single spark made to pass between the knobs by pulling a string connected with the hammer of the induction coil. The plate was then moved a trifle and a second impression secured in the same way. This obviated several of the difficulties experienced in the earlier work. The images never overlapped, and the hot air from the spark did not appear in the pictures. About thirty-five images were obtained on each plate in less than a minute, from which it was usually possible to pick a series showing the wave in all stages of its development, owing to the variations in the time-interval between the two sparks.

In the first series the pictures were so small that it was necessary to enlarge them several diameters. Those of the new series, owing to the use of an eight-inch mirror in place of the five-inch lens, and an objective of larger aperture and longer focus, required no enlarging.

The Wave-Front Photographs.

In the study of optics we may treat the subject of regular reflection in two ways, by rays and by wave-fronts. When spherical waves of light are reflected from a plane surface, we know that the reflected waves are also spherical in form, the centre of curvature being a point just as far beneath the reflecting surface as the source of light is above it. In the first of the series of photographs we have the reflection of a spherical wave of sound by a flat plate of glass, the wave appearing as a circle of light and shade surrounding the image of the balls between which the spark passed (Fig. 3). The reflected wave or echo from the plate is seen to be spherical, with a curvature similar to the incident wave.

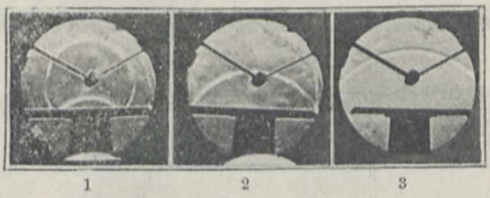

FIG. 3.

When we have a source of light in the focus of a parabolic mirror, the rays leave the mirror's surface parallel to one another, and move out in an intense narrow beam. Treating this case from the wave-front point of view, we ascertain by the usual geometrical construction that the spherical wave is changed by reflection into a plane or flat wave which moves out of the mirror without further divergence. In the picture (Fig. 4), only a portion of the parabolic reflector is shown near the bottom. The sound-wave starts in the focus, and the reflected portion appears quite flat.[1]

What happens now if we use a spherical mirror in the same way?

Owing to the spherical aberration the reflected rays are not strictly parallel, or the reflected wave is not a true plane. Let us start a sound-wave in the focus of such a mirror, and follow the reflected portion out of the mirror (Fig. 5). We notice that near the axis of the mirror the effect is much the same as in the case of the parabola, that is, the reflected front is plane. Thus we are

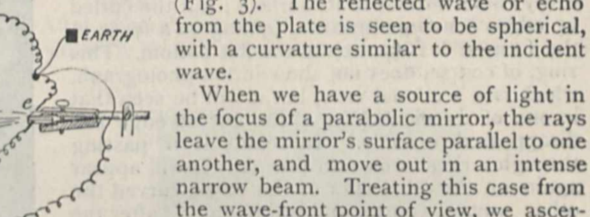

FIG. 4.

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[1] If more than one image appears it means that the plane of the glass plates of the illuminator does not lie parallel to the optical axis of the system. It is of prime importance to secure a single image.

[1] In this series and some others left and right have been inadvertently interchanged by the engraver. The series should be followed by the numbers.

accustomed to say that if we confine ourselves to a small area around the axis, a mirror of spherical form acts almost as well as a parabola. If on the contrary we consider the reflection from the entire hemisphere, we see that the reflected wave curls up at the edges, having a form not unlike a flat-bottomed saucer. The flat bottom moves straight up, travelling everywhere normal to its surface; but the curled up edges converge inwards, coming to a focus in the form of a ring around the flat bottom. This ring, of course, does not show in the photograph, which is a sectional view, but it will be seen that in one of the views (No. 4) the curved edge has disappeared entirely. In reality it is passing through a ring focus, and presently it will appear again on the other side of the focus, curved the other way, of course, and trailing along after the flat bottom. This curious evolution of the wave can be shown by geometrical construction, and I shall show later how its development can be shown with the cinematograph.

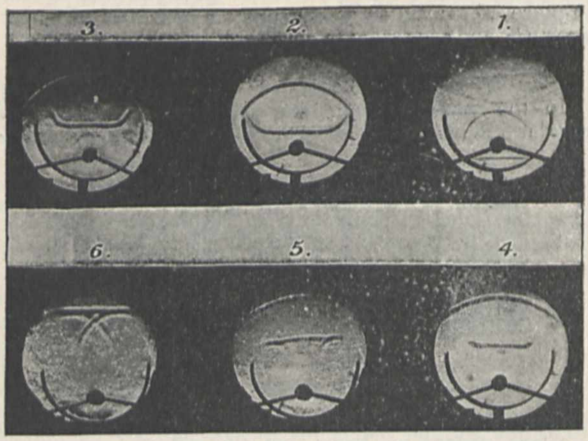

FIG. 5.

When the spherical waves start in one focus of an elliptical mirror, they are transformed by reflection into converging spheres, which shrink to a point at the other focus, the surface being aplanatic for rays issuing from a point. An elliptical mirror was made by bending a strip (Fig. 6) of metal into the required form, and a sound-wave started at one of the foci. The transformation of the diverging into a converging sphere, and the shrinkage of the latter to a point at the other focus, is well shown (Fig. 6).

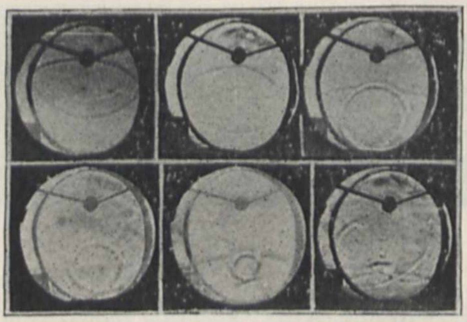

FIG. 6.

We will consider next another case of spherical aberration. When parallel rays of light enter a concave mirror, those reflected from points of the mirror near its axis converge approximately to a point situated halfway between the surface of the mirror and its centre of curvature. The wave-front in the case of parallel rays is, of course, plane, and is changed by reflection into a converging shell of approximately spherical curvature. If we investigate the case more carefully, we find, however, that the reflected rays do not come accurately to a focus, but envelope a surface known as the caustic—in this case an epicycloid. The connection between the wave-front and the caustic is perhaps not at once apparent. Let us examine the changes wrought on a sound-wave entering a concave hemispherical mirror (Fig. 7).

If we follow the wave during its entrance into the mirror, we see that the reflected portion trails along behind, being united to the unreflected part at the mirror's surface. After the reflection is complete, we find the reflected wave of a form not unlike a volcanic cone with a large bowl-shaped crater (No. 4). This bowl-shaped portion we may regard as a converging shell, which shrinks to point at the focus of the mirror. As it shrinks, the steep sides of the cone run in under the bowl, crossing at about the moment when the converging portion is passing through the focus (No. 6). The rim of the crater forms a cusp on the wave-front, and if we follow this cusp we shall see that it traces the caustic surface. Hence we may define the caustic as the surface traced by the cusp of the wave-front.

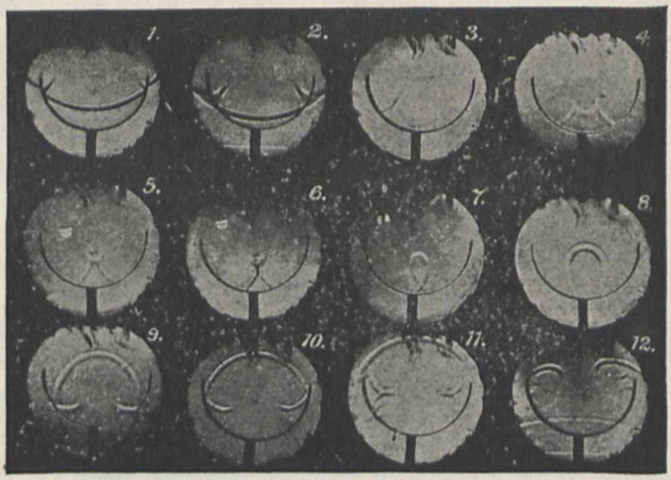

FIG. 7.

The portion of the wave which comes to a focus at once begins to diverge again, uniting with the sides of the crater, the whole moving out of the mirror in a form somewhat resembling a mushroom or the bell of a Medusa jelly-fish. The turned-under edges of the bell are cusped, and these cusps trace the caustic enveloped by the twice-reflected rays. These forms can also be constructed geometrically.

A much more complicated case is now shown (Fig. 8). Here the wave starts within a complete sphere, or rather cylinder. (Cylindrical surfaces have been used in all these cases for obvious reasons, the sectional views shown in the photographs being the same for both forms of surface.) Starting in the principal focus of the closed mirror, the wave is bounced back and forth, becoming more complicated after each reflection, yet always symmetrical about the axis. Only a few of the many forms are shown, and, with the exception of the first three or four, are not arranged in order; for at the time that the series was arranged on the slide this case had not been worked out geometrically, and it was quite impossible to determine the evolution of the different forms. More recently this case has been constructed for five reflections, and all of the forms shown in the photographs found.

We will take up next some cases of refraction, the first being that of a spherical wave at a flat surface of a denser medium. In Fig. 9 we have a rectangular tank with sides made of plane-parallel glass, and covered with a collodion film of soap-bubble thickness made by the method described by Toepler. Ordinary collodion is diluted with about ten parts of ether, poured on a small piece of plate-glass and immediately drained off. As soon as it is quite dry, a rectangle is cut with a sharp knife on the film. Toepler's method of removing the film was to place a drop of water on one of the cuts, and allow it to run in by capillarity; but I have had better success by proceeding in the following manner:—One end of the plate is lowered into a shallow dish of water, and the plate inclined until the water comes up to one of the cuts. By looking at the reflexion of a window in the water, it is possible to see whether the film commences to detach itself from the glass. If all goes well, it will float off on the surface of the water along the line of the knife-cut, and it should be slowly lowered (one end resting on the bottom of the dish) until the rectangular piece detaches itself and floats freely on the surface. The edges of the tank are well greased, and then lowered carefully upon the film, to which they will adhere. The whole must then be lifted from the water in an oblique direction, when the film will be found covering the tank and exhibiting the most beautiful interference-colours. The tank was filled with carbonic acid and placed under the origin of the sound-wave. On striking the collodion film, the wave is partly reflected and partly transmitted, and it will be seen that the reflected component in air has moved farther than the transmitted component in the carbonic acid. The spherical wave-front is transformed into an hyperboloid on entering the denser medium. This is well shown in No. 3 of the series. In No. 4 the wave is seen in air, having been reflected up from the bottom of the tank.

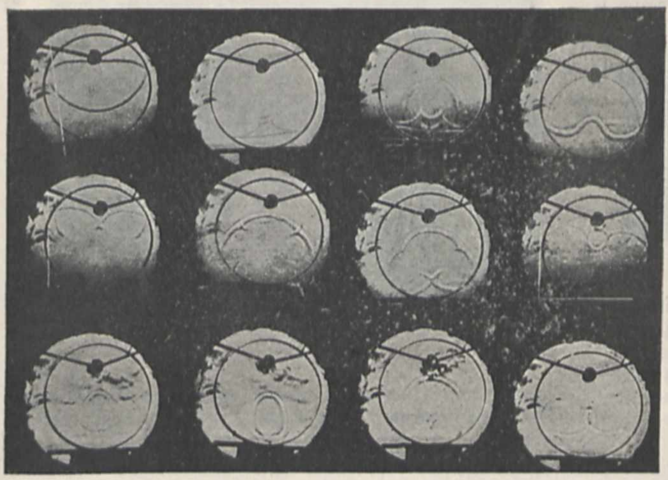

FIG. 8.

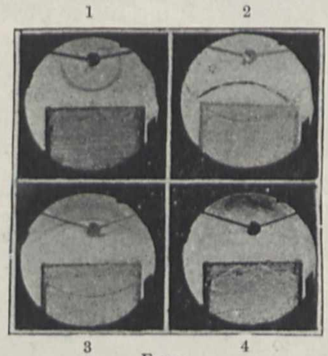

FIG. 9.

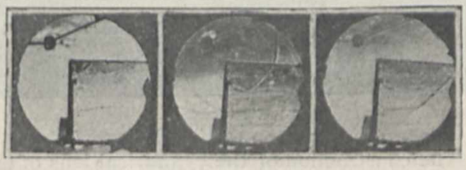

FIG. 10.

In Fig. 10 we have the refraction of the wave in the same tank under oblique incidence. The bending of the wave within the tank is very marked. The wave-fronts reflected from the side which follows the unreflected portion is also interesting in connection with Lloyd's single mirror interference experiment (No. 2 of series).

After several failures I succeeded in constructing a prism with its two refracting faces of this exceedingly thin collodion, which, when filled with carbonic acid, showed the bending of the wave-front, exactly as we figure it in diagrams for light. It was necessary to have the collodion thinner than before, since if we are to photograph the wave after twice traversing the film, we must lose as little energy as possible by reflexion.

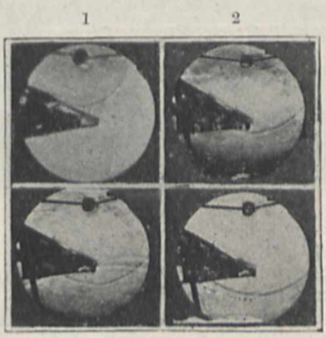

FIG. 11.

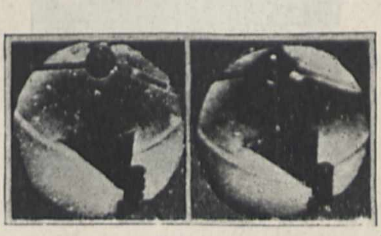

FIG. 12.

Fig. 11 shows the refraction in a carbonic acid prism, the bending being particularly noticeable in No. 4, on which I have, with a pair of dividers, traced out the position which the wave-front would have occupied had it not traversed the prism.

The bending of the wave-front in the opposite direction is shown in Fig. 12, where the same prism is filled with hydrogen gas, in which sound travels faster than in air.

In the next figure we have a very interesting case, though, owing to the experimental difficulties, the photographs are not quite as satisfactory as some of the others. It represents the transformation of a spherical into a plane wave by passage through a double convex lens.

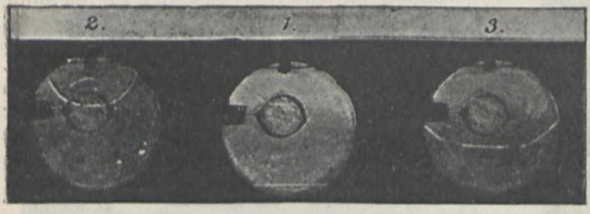

FIG. 13.

The construction of the cylindrical lens of exceedingly thin collodion was a matter of great difficulty. The flat, circular ends were made of thin mica as free from striæ as possible, that the passage of the wave through the lens could be followed. On these discs the collodion film was wound, the whole forming a hollow drum, which was then filled with carbonic acid. The sound-wave, started at the principal focus of this lens, is seen to be quite flat after its emergence (Fig. 13).

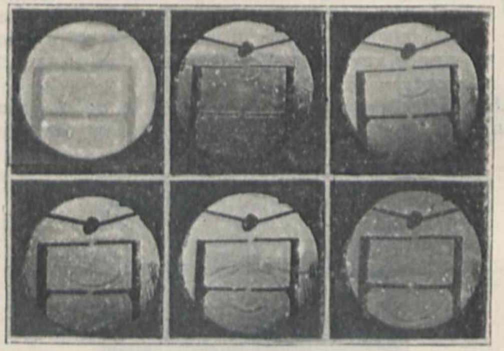

FIG. 14.

We will next take up some cases of diffraction, beginning with the well-known principle of Huygens, that any small portion of a wave-front can be considered as the centre of a secondary disturbance, and that a small portion of this secondary disturbance can act as a new centre in its turn.

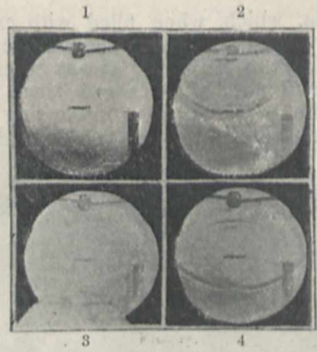

FIG. 15.

In Fig. 14 we have the wave starting above a plate with a narrow slit in it. This slit is seen to be the centre of a secondary hemicylindrical wave which moves down precisely as if the spark were located at the slit. After proceeding a short distance this secondary wave encounters a second slit, and the same thing happens as before, the little slice that gets through spreading out into a complete wave, while the intercepted portion bounces back and forth between the plates.

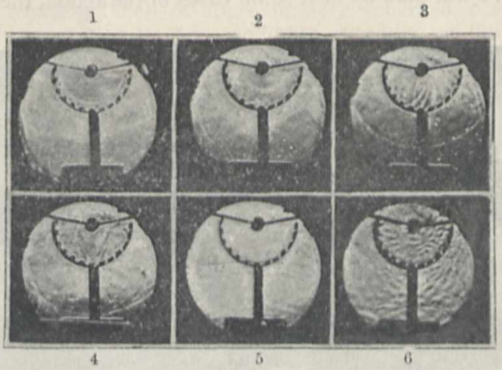

FIG. 16.

Fig. 15 shows the very limited extent to which sound shadows are formed. The wave is intercepted by a small glass plate. Just below the plate in No. 3 of the series a gap in the wave is found, which constitutes a shadow. But presently, by diffraction, the wave curls in, closing up the gap and obliterating the shadow entirely. In the last one of the series it is interesting to note how the diffracted waves have their centres at the edges of the obstacle, the edges acting as secondary sources, as in the case of the diffraction of light.

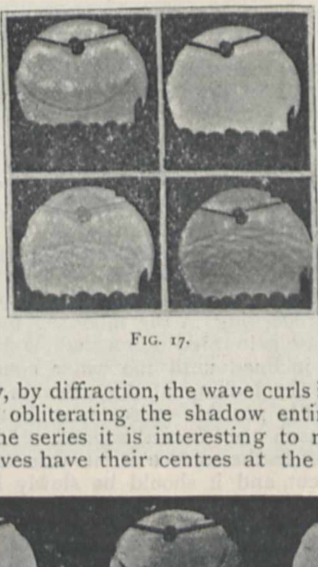

FIG. 17.

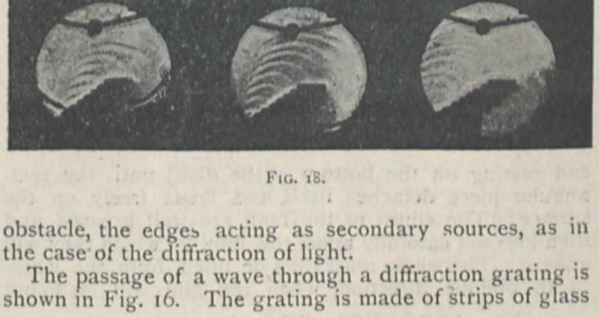

FIG. 18.

The passage of a wave through a diffraction grating is shown in Fig. 16. The grating is made of strips of glass arranged on a cylindrical surface, the wave starting at the centre of curvature. In No. 2 of the series the union of the secondary disturbances coming from the openings

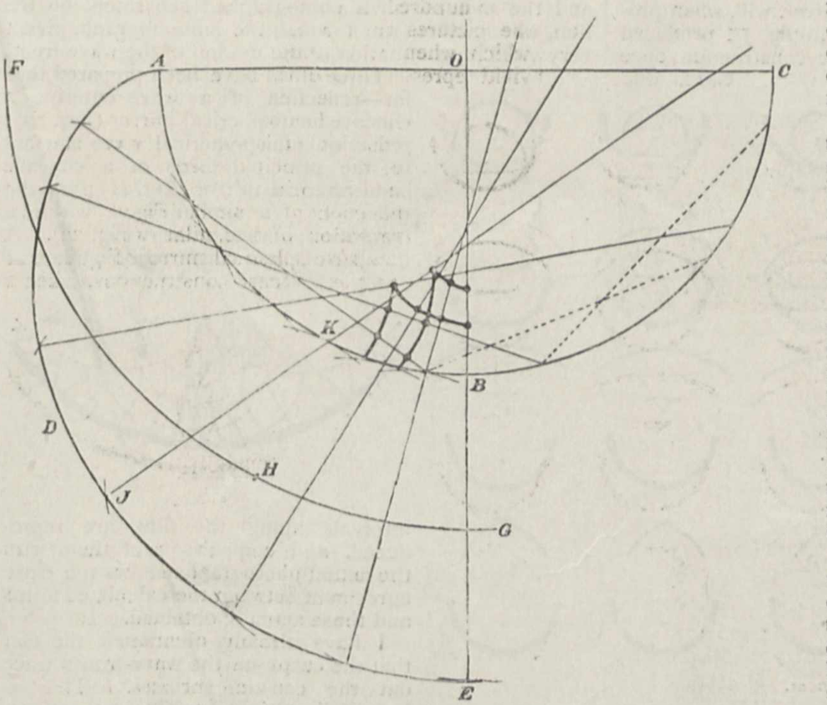

FIG. 19.

into a new wave-front is beautifully shown. In No. 3 the reflected wavelets have converged to the centre, but as each one is a complete hemicylinder, we see them radiating from the centre. This form can be constructed by describing semicircles around points on a circle of such radius that they all pass through the circle's centre. These semicircles represent secondary wavelets starting simultaneously from the various grating elements. In the last three pictures of the series the wave passes down, strikes the table, and is reflected up again, and it is interesting to see how the medium is broken up into meshes by the crossing and recrossing of the secondary waves.

Fig. 17 shows the form of the secondary wavelets formed by the reflection of a wave from a corrugated surface, and is interesting in connection with reflection gratings.

The formation of a musical note by the reflection of a single pulse from a flight of steps is shown photographed in Fig. 18. This phenomenon is often noticed on a still night when walking on a stone pavement alongside a picket-fence, the sound of each footstep being reflected from the pailings as a metallic squeak, which Young has pointed out to be analogous to the power of a diffraction grating to construct light of a definite wave-length.

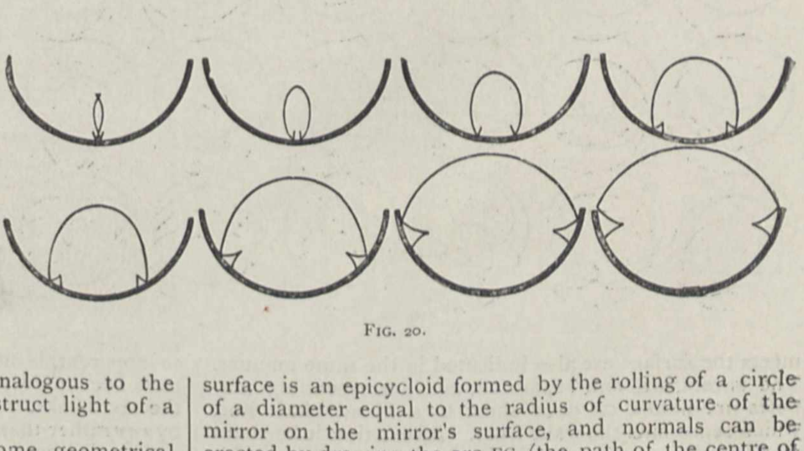

FIG. 20.

It occurred to me, while making some geometrical constructions to aid in unravelling some of the complicated forms reflected from surfaces of circular curvature, that a very vivid idea of how these curious wave-fronts are derived one from another could be obtained if a complete series could be prepared on the film of a cinematograph, and projected in motion on a screen.

Having been unable to so control the time-interval between the two sparks that a progressive series could be taken, I adopted the simpler method of making a large number of geometrical constructions, and then photographing them on a cinematograph film.

As a very large number of drawings (100 or so) must be made if the result is to be at all satisfactory, a method is desirable that will reduce the labour to a minimum. I may be permitted to give, as an instance, the method that I devised for building the series illustrating the reflection of a plane wave in a spherical mirror. The construction is shown in Fig. 19.

ABC is the mirror, AOC the plane wave. Around points on ABC as centres describe circles tangent to the wave. These circles will be enveloped by another surface, ADE, below the mirror (the orthogonal surface). If we erect normals on this surface, we have the reflected rays, and if we measure off equal distances on the normals, we have the reflected wave-front. By drawing the orthogonal surface we avoid the complication of having to measure off the distances around a corner. The orthogonal surface is an epicycloid formed by the rolling of a circle of a diameter equal to the radius of curvature of the mirror on the mirror's surface, and normals can be erected by drawing the arc FG (the path of the centre of the generating circle), and describing circles of diameter BE around various points on it. A line joining the point of intersection of one of these circles with the epicycloid, and the point of tangency with the mirror, will, when produced, give a reflected ray; for example, JK produced for circle described around H. The construction once prepared, the series of wave-front pictures can be very quickly made. Three or four sheets of paper are laid under the construction, and holes are punched through the pile by means of a pin, at equal distances along each ray (measured from the orthogonal surface).

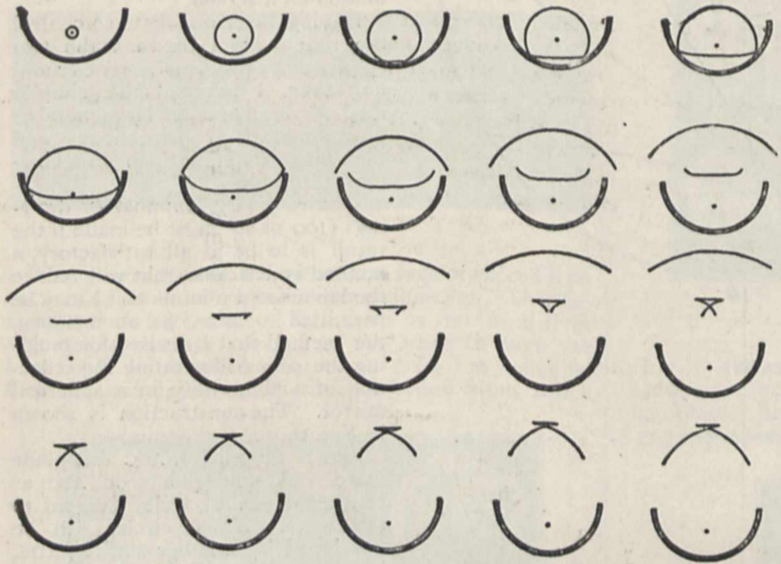

FIG. 21.

The centre of the mirror and the point where its axis meets the surface are also indicated in the same manner. The sheets are now separated, and corresponding pinholes are united on each sheet by a broad black line, which represents the wave-front. After a time it becomes necessary to consider double reflections, and to do this we are compelled to construct twice-reflected rays (indicated by dotted lines), and measure around a corner each time.

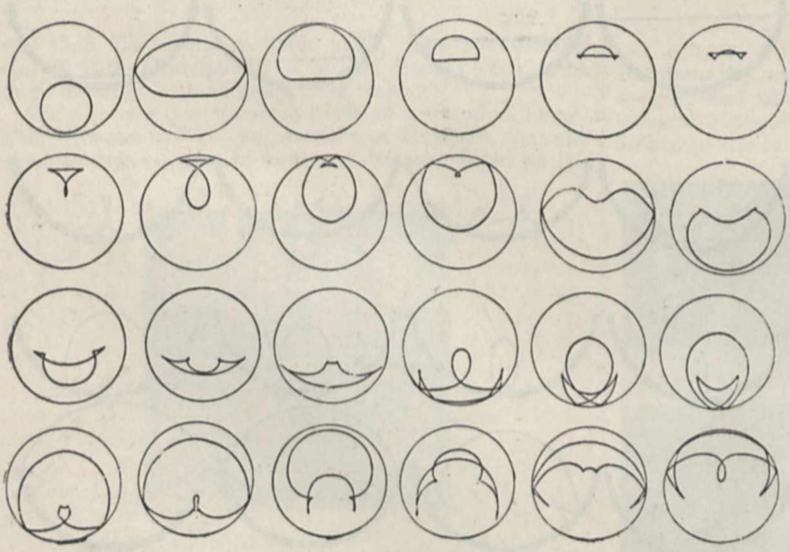

FIG. 22.

About a hundred pictures are prepared for each series, and the pictures then photographed separately on the film, which, when run through the animatograph, give a very vivid representation of the motion of the wave-front.

Three films have been prepared thus far—reflection of a wave entering a concave hemispherical mirror (Fig. 20); reflection of a spherical wave starting in the principal focus of a concave hemispherical mirror (Fig. 21); and the reflection of a similar wave within a *complete* spherical mirror (Fig. 22). A number of these constructions, taken at intervals along the film, are reproduced, and comparison of them with the actual photographs shows the close agreement between the calculated forms and those actually obtained.

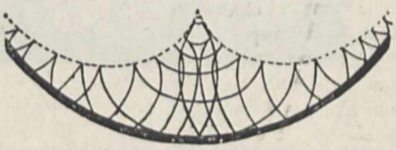

FIG. 23.

I have already mentioned the fact that the cusps on the wave-fronts trace out the caustic surfaces. This is beautifully shown in Figs. 23 and 24, where the successive fronts are seen superposed. The former is for the reflection of a plane wave in a spherical mirror, the latter for the reflection of a spherical wave starting at the focus of a similar mirror. The caustic curve is shown by a dotted line in Fig. 23, and is seen to be traced by the cusps on the wave-fronts. The construction shows that there is a concentration of energy at the cusp; consequently we may define the cusp as a moving focus, and the caustic as the surface traced by it. Though I hesitate in claiming that this relation, at once so apparent, is at all novel, I may say that, so far as I have been able to find, it is not brought out in any of the text-books, caustic surfaces being invariably treated by *ray* rather than by *wave-front* methods.

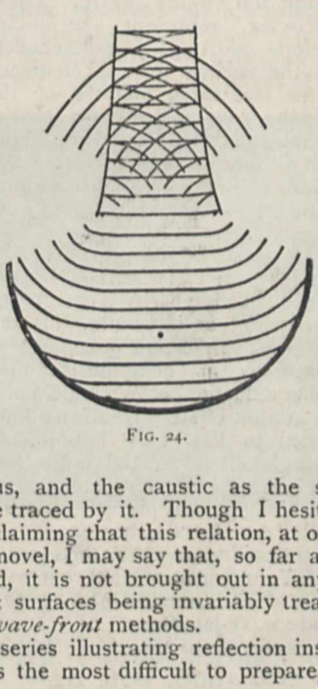

FIG. 24.

The cinematograph series illustrating reflection inside a complete sphere was the most difficult to prepare, as several reflections had to be considered. It has been completed for three reflections, and Mr. Max Mason, of Madison, to whom I am greatly indebted for his patient work in assisting me, is going on with the series. As will be seen, the wave has already become quite complicated, and it will be interesting to see what further changes result after three or four more reflections. I am also under obligations to Prof. A. B. Porter, of Chicago, who prepared the set of drawings illustrating the passage of a wave out from the principal focus of a hemispherical mirror.

R. W. WOOD.

NOTES.

MANY friends and admirers of the late Sir William Flower will be glad to know that a committee has been formed, with Lord Avebury as chairman, to secure the erection of a memorial to him. It is proposed that the memorial shall consist of a bust and a commemorative brass tablet to be placed in the Whale Room of the Natural History Museum—one of the departments in which he was most interested, and to which he devoted special care and attention. There should be a ready response to the invitation for subscriptions to carry out this scheme, for Sir William Flower's services to science are appreciated by every one interested in the extension of natural knowledge. The Natural History Museum ought not, indeed, to be without a memorial of the man who took such an active part in its development. Subscriptions (which must not exceed two guineas) should be paid to Dr. P. L. Sclater, treasurer of the Flower Memorial Fund, 3, Hanover Square, W.

IN the House of Commons on Tuesday, Mr. Goschen gave some particulars with regard to the Committee to inquire into the boilers of her Majesty's ships. The Committee will consist of seven members, and the president will be Vice-Admiral Sir Compton Domvile. The other members of the Committee already chosen are Mr. List, superintending engineer of the Castle Company; Mr. Bain, superintending engineer of the Cunard Line; Mr. Milton, chief engineer surveyor of Lloyd's Registry of Shipping; Prof. Kennedy, formerly professor of engineering at University College; and, sixthly, an engineer of the Royal Navy holding the rank of an inspector of machinery. The seventh member of the Committee has not yet been selected. The instructions to the Committee are:—To ascertain practically and experimentally the relative advantages and disadvantages of the Belleville boiler for naval purposes as compared with the cylindrical boiler. To investigate the causes of the defects which have occurred in these boilers and in the machinery of ships fitted with them, and to report how far they are preventable either by modifications of details or by difference of treatment, or how far they are inherent in the system. Also to report generally on the suitability of the propelling and auxiliary machinery fitted in recent war vessels, and to offer any suggestions for improvement, stating at the same time the effect as regards weight and space of any alterations proposed. To report on the advantages and disadvantages of the Niclausse and Babcock and Wilcox boilers compared with the Belleville, as far as the means at the disposal of the Committee permit, and also to report whether any other description of boiler has sufficient advantages over the Belleville or the other two types mentioned, as a boiler for large cruisers and battleships, to make it advisable to fit it in any of her Majesty's ships for trial. For the purpose of making direct experiments between ships fitted with Belleville and cylindrical boilers respectively, the *Hyacinth*, fitted with Belleville boilers, will be placed at the disposal of the Committee. A cruiser of similar type fitted with cylindrical boilers will also be placed at the disposal of the Committee when required for the purpose of comparison. Mr. Goschen added that it is particularly desired that any conclusions the Committee may arrive at should be supported by experimental proof as far as possible, and that they should propose any further experiments which may be considered necessary for this purpose.

WE learn from the *Electrician* that a prize of 1000 francs (40*l.*) is being offered by the Association des Industriels de France contre les Accidents du Travail, 3, Rue de Lutèce, Paris, for the most efficacious insulating gloves for electrical workmen. They should be strong enough to resist not only the electric pressure, but also accidental perforations by copper wires, &c., and must, in addition, be easy to wear by hands of any size and allow the workmen's fingers sufficient freedom to execute their work. The competition is international, and competitors must send two pairs of gloves, accompanied by an explanatory note, to the president of the Association before December 31, 1900. The Association reserves to itself the right to publish descriptions of samples submitted to it, and inventors should therefore take the precaution of protecting their inventions previously.

A GLANCE through the addresses delivered at the meeting of the British Medical Association held at Ipswich last week, and published in the *British Medical Journal*, shows that leading members of the medical profession recognise the close relationship between medicine and other sciences. The president, Dr. W. A. Elliston, in an address in which he traced the developments of the science of British medicine and the evolution of the modern physician, remarked: "I am not unmindful of the up-to-date requirements of general culture—of an accurate knowledge of anatomy, chemistry, physiology, biology, bacteriology, pathology, physics, optics, mechanics, electricity and photography, which are all essential to the well-educated physician; they are daily called into requisition in order to diagnose and to direct the eye and hand in the treatment of disease." Similar acknowledgment of the dependence of medicine upon other sciences was made by Dr. Pye-Smith in his address abridged in another part of the present number. Mr. Frederick Treves, however, in his address on the progress of surgery during the last hundred years, ended his remarks with a sketch of the surgeon's place in the future, and expressed the hope that surgery might remain a handicraft, and that before all things the surgeon would strive to render his own hands self-sufficing, and not trust too much to diagnoses made for him in the laboratory. Short addresses were delivered by some of the presidents of the thirteen sections of the Association. In the section of pathology, Dr. E. E. Klein spoke upon bacteriology in relation to pathology, giving as illustrations of his theme the bacteriological work bearing upon inflammation, necrosis and cell secretions. Dr. Howard Marsh, in his address to the section of surgery, remarked: "Long a mere matter of routine, the treatment of fractures has lately felt the influence of modern advance in other departments of surgery. The Röntgen process secures an accuracy of diagnosis which formerly was often impossible." Dr. W. G. Smith made some suggestive remarks upon the teaching of pharmacology, pointing out some of the relationships between physiological action and chemical constitution. This fascinating subject has occupied the attention of several physiological chemists, and it offers numerous interesting problems for investigation.

WE learn from the *Athenaeum* that the 83rd Annual Meeting of the Swiss Natural Science Society will be held at Thüsis, Canton Grisons, from September 2-4. Three other Swiss scientific societies—the geological, the zoological, and the botanical—will hold their annual meetings at the same time and place. Intending guests are asked to communicate with the president, Dr. Lorenz, at Coire, as soon as possible. Prof. Forel, of Morges, will lecture at the general meeting of the

Society on changes in glaciers; Prof. Zschokke, of Basle, on the fauna of mountain streams; and Prof. Schardt on the tectonic conditions on the northern slopes of the Swiss Alps.

A LENGTHY treatise on that mysterious form of atmospheric discharge known as "globe lightning" appears in the current number of the *Annalen der Physik*. It is by Prof. Max Toepler, the inventor of the Toepler machine and the discoverer of the stratified brush discharge. After comparing all the published records of the phenomenon, he comes to the conclusion that the globe is a form of continuous atmospheric discharge analogous to the "brush arc discharge" of the laboratory. A lightning flash leaves behind it a track of heated and possibly ionised air, along which a slow continuous discharge passes for some time after the flash has passed. When this continuous discharge is strong enough, any part of the track which has an exceptionally high resistance may be made to glow, and the glow may continue for several seconds or even half a minute. The track may be blown aside by the wind or driven by electrostatic forces, and then the globe will be seen to wander as is usually described. It often finishes with another lightning flash, and the thunderclap following that is described as an "explosion" of the ball. Considering the size and duration of the globe, Prof. Toepler estimates its current strength at something between 2 and 20 amperes. Considering that a lightning flash often carries 10,000 amperes, the destruction wrought by globular lightning should be inconsiderable.

THE uses of monochromatic light in optical experiments are so numerous that considerable interest attaches to the paper, on the means of producing such light, by MM. Charles Fabry and A. Pérot in the *Journal de Physique* for July. After pointing out the disadvantages of sodium light on account of the proximity of the D lines, the authors divide the methods of producing a beam of monochromatic light into two, viz.: (1) simplification of a beam of white light, and (2) use of light emitted by a gas. Under the latter method are included (*a*) flames; (*b*) gases or vapours rendered luminous by electricity; (*c*) induction sparks; and (*d*) the electric arc. In connection with (*b*), it is found that the quality of the rays depends on the nature of the current exciting them, and the authors consider the use of (1) a coil with secondary condenser, (2) alternating currents, (3) continuous currents; of these methods the last is the best, though the second is better than the first. While the results of these investigations cannot be briefly summarised, we notice that the authors have shown the possibility of improving the action of Michelson's tubes, of using a modification of the mercury arc of Arons as a source of monochromatic light of great intensity, of using the rays of a certain number of metals for interference observations where the difference of path is considerable, and, by measuring the wave-lengths, of adding a number of new fixed points on the spectrum. The paper concludes with a table of wave-lengths determined by MM. Pérot and Fabry, and compared with the determinations of Michelson.

STORMY and boisterous weather has occurred over the greater part of the British Islands during the past week, and exceptionally heavy rains have been experienced in many districts. On August 3 a storm of unusual severity for the time of year swept across England, and a heavy gale blew over the southern portion of the kingdom, occasioning considerable damage on our coasts, as well as to the fruit and corn in the inland districts. A similar disturbance struck our west coasts on August 6, and although it followed very much the same path as the storm of Friday it was more erratic, both in its track and rate. The storm was heavy again in many parts of England, and further damage to the crops has been occasioned. The temperature has fallen considerably during the last few days, and the weather has been cold for the time of year over the whole country, the mid-day readings in many places being below sixty degrees.

THE new Daily Weather Report, the issue of which was announced in NATURE of July 26 (p. 300), is now on sale every day at the Meteorological Office and several railway bookstalls in London. The attempt thus made to create an intelligent interest in meteorological records and forecasts is one to be encouraged, but we are afraid that the method adopted is not very attractive. The weather charts are admirable, and in connection with the statement of the general situation and the forecasts they are most instructive. Too much prominence could not be given to these two pages of the Report, which ought to find a place in the hall of every educational institution in the country. But the tabular matter included in the Report is of too detailed a character to be of public interest, and the Meteorological Council might usefully consider whether it would not be sufficient to publish such statistical information once a week or once a month instead of every day.

THE high kite flight at Blue Hill Meteorological Observatory, of which mention was made a few weeks ago (p. 252), was, Mr. Lawrence Rotch informs us, exceeded on July 19. A line of six kites reached an altitude of 15,900 feet, or three miles and sixty feet, above the sea, which exceeds the highest point ever reached in America by a balloon used for scientific purposes. Prof. Hazen, of the U.S. Weather Bureau, obtained observations in a balloon at a height of 15,400 feet in an ascent from St. Louis in June 1887. This is the highest ascent in America from which observations have been published. Four and three-quarter miles of steel piano-wire were used at Blue Hill as a flying line. The instruments attached to the kites showed freezing temperature at the highest point and a north-west wind with a velocity of twenty-six miles an hour. The air was found to be exceedingly dry.

THE *Proceedings* of the Geologists' Association for May contains an interesting paper, entitled "The Natural History of Phosphatic Deposits," being an address delivered in February last by the retiring President of the Association, Mr. J. J. H. Teall, F.R.S. The phosphates of igneous rocks and mineral veins are first discussed, and it is pointed out that apatite, the most abundant phosphatic mineral, is the principal source from which the phosphorus of the sedimentary rocks and of organic bodies is derived. Attention is drawn to the points of analogy in the vein-occurrence of apatite and tin-stone. Having shortly described the conditions and causes which bring about the formation of modern phosphatic deposits, the author passes in review the principal occurrences of phosphates in the successive geological formations, and concludes by stating that "from the earliest time down to the present day, the physical and chemical conditions under which phosphatic deposits have been formed have remained essentially the same." A useful bibliography of the subject is appended.

IN the *Bulletin de la Classe des Sciences* of the Brussels Academy (1900, No. 4), M. Louis Dollo, curator of the Brussels Museum, describes the new fish, *Racovitza glacialis*, discovered in the Belgian Antarctic Expedition. This is the third new fish discovered by the party, and only one specimen was found, and that a small one, somewhat mutilated at the caudal extremity, the length of the body, exclusive of the tail, being 82 millimetres. It was found on May 28, 1898, in lat. 71° 23′ S., long. 87° 32′ W., depth 435 metres, and is a member of the family Trachinidæ, distinguished from the genera Bathydraco, Bembrops, Chænichthys, Cryodraco and Gerlachea by well-marked characteristics, which M. Dollo describes. It is, however, most nearly allied to Bathydraco and Gerlachea, and its existence within the Antarctic Circle furnishes a fresh proof of the frequency of the Trachinidæ in the neighbourhood of this circle.

A SUGGESTIVE paper on the driving energy of physico-chemical reaction and its temperature-coefficient is contributed to the *Proceedings* of the American Academy of Arts and Sciences, xxxv. 23, by Prof. Theodore William Richards, in which the author, starting with the close similarity between the equations of Clausius and van 't Hoff, $d\ln P/dT = \lambda/RT^2$ and $d\ln K/dT = U/RT^2$, points out the advantages, previously recognised by Arrhenius, of regarding *pressure* to be the fundamental quantity which determines the progress of chemical reactions, as this aspect affords a more direct method of analysis than the study of volume, concentration or entropy. An expression called the "reaction metatherm" is evolved, which represents in terms of pressure the temperature-coefficient of the equilibrium ratio of ideal physico-chemical reaction. The equation obtained is the mathematical expression of the theorem of Maupertuis or Le Chatelier, and when analysed it shows that the part played by each substance in a reaction may be considered as the logarithm of the product of its "physico-chemical potential" and its actually present pressure. The reaction metatherm may be simplified into a reaction-isobar and a reaction-isochor, according as the pressure or volume is kept constant during the reaction. While, however, the reaction-isobar offers the most convenient basis for calculations to which it is applicable, results under constant volume are more conveniently calculated if the reacting substances are expressed in terms of concentration according to the equation of van 't Hoff.

THE iconography and anthropology of the Irano-Indians is the subject of a recent study by M. Ujfalvy in the current volume of *l'Anthropologie*. He concludes that the ancient Persians had a narrow-faced, dolichocephalic, somewhat flattened head resembling that of the ancient Hindus. They were all fair or reddish, and closely resembled the Macedonians of Alexander. It is impossible to say whether this was the primitive Persian type; at all events, it was their well-characterised type six centuries before our era. Two centuries later the type began to be slightly modified. This took place in the interval between the decline of the dynasty of the Achemenides (328 B.C.) and the rise of that of the Sassanides (240 A.D.). This alteration was probably due to the Semites of Elam and Syria, and to the Turanians of Babylon. The former influence did not affect the dolichocephaly, but it slightly increased the height of the head, and modified the nose considerably. The latter influence shortened the head, and but slightly modified the face. The Sassanide warriors exhibited the new complex type. At the close of the Sassanide period the Arabs reinforced the Semitic characters. M. Ujfalvy accepts and reinforces Houssay's dictum that, in a mixture of Aryans with Mongols or Mongoloids, the latter lose their facial characters, flattening of the nose, prominence of the cheek-bones, absence or sparseness of the beard; but, in exchange, they impose the shape of their skull on the former.

MESSRS. SWIFT AND SON have just patented a very handy little electric lamp for microscopic purposes. The lamp—a 16 candle-power one—is enclosed in a metal cylinder, the inner surface of which is painted white. The light makes its exit through a circular aperture in the side of the cylinder near its free end; the end is closed by a plate set at an angle of 45° and painted white, so as to reflect the light through the circular aperture. The light thus does not pass direct from the incandescent carbon filament to the mirror of the microscope, but is reflected from the white walls of the cylinder. In this way a very even illumination is obtained, which is more uniform than that obtained from the average ground glass lamp. While, however, the light given by this lamp is admirably suited for the ordinary powers such as are attached to the average student's microscope, it is, in our opinion, neither powerful enough nor white enough for high-power work, this being a defect common to all electric microscope lamps. Where in addition a lamp is required for dissection purposes, as is so often the case, the direct light of the ordinary type of electric lamp will be found more suitable. This lamp is very compact and steady, and its movements, especially those about its horizontal axis, are particularly easy and steady.

THE Botanical Museum of Florence has recently received a donation of considerable interest in connection with the history of botany in Italy, viz. the collections made by Micheli, by Bruno Tozzi, and by G. Targioni-Tozzetti in the 18th century, including the type-specimens of species named by these and other eminent botanists. The donation includes also Micheli's and Targioni-Tozzetti's collections of sea-weeds.

IN No. 4 of vol. xxi. of *Notes from the Leyden Museum*, Dr. J. Büttikofer, the director of the Zoological Garden at Rotterdam, records the birds collected by the Dutch expedition to Central Borneo. Testimony is borne to the thoroughness of the work of the English naturalists, the late Messrs. Everett and Whitehead, and Mr. Charles Hose, by the fact that the author has not been able to add a single new species to the avian mountain fauna of the island. Dr. Büttikofer comes to the conclusion that both the mammalian and the avian faunas of Borneo are remarkably homogeneous, especially so far as the lowlands and the mountain bases up to an elevation of about 1000 metres are concerned. In vol. ii. No. 1 of the same serial, Mr. M. C. Piepers defends his theory of the evolution of colour in Lepidoptera, as explained at the recent Zoological Congress at Cambridge, against the criticisms of Miss Newbiggin and Dr. von Linden.

IN *Nature Notes* for August the Selborne Society refers to the urgent need of a crusade against pigeon-shooting.

THE MS. of the second volume of the late Dr. Stark's "Birds of South Africa" has been found amongst the papers of the deceased naturalist, who was killed at Ladysmith during the siege. It has been revised for the press by Mr. W. L. Sclater, director of the South African Museum, Cape Town, and will be shortly published by Mr. R. H. Porter. It will form part of Mr. Sclater's series of volumes on the fauna of South Africa.

THE report of the Zoological Garden of Calcutta for the year 1898–99, which has recently been received in this country, gives a favourable impression of the present condition and prospects of this establishment, drawn up by Lieut.-Colonel P. A. Buckland, the honorary secretary and treasurer. The superintendent of the Calcutta Garden, Babu R. B. Sanyal, who represented that Institution at the International Congress of Zoology at Cambridge in August 1898, contributes to this report an interesting account of his experiences at the Cambridge meeting, and of his observations on many of the zoological gardens of Europe, which he took the opportunity of visiting on the same occasion.

THE additions to the Zoological Society's Gardens during the past week include a Macaque Monkey (*Macacus cynomolgus*) from India, presented by Mr. T. Forsyth Forrest; a Diana Monkey (*Cercopithecus diana*) from West Africa, presented by Mr. W. Cleaver; two Greater Vasa Parrots (*Coracopsis vasa*) from Madagascar, presented by Mr. G. Barfoot; a Silky Cowbird (*Molothrus bonariensis*) from South America, presented by Mr. F. Willes; seven Algerian Skinks (*Eumeces algeriensis*), a Spiny-tailed Mastigure (*Uromastix acanthinurus*) from North Africa, presented by Mr. G. H. Fernan; a Common Viper (*Viper berus*), British, presented by Mr. Alfred Cooper; a Green Lizard (*Lacerta viridis*), a Dohl's Snake (*Zamenis dahli*), European; two Snakes (*Coluber prasinus*) from Upper Burmah, deposited; two Ring-necked Pheasants (*Phasianus torquatus*), two Gold Pheasants (*Thaumalea picta*) from China, a Pheasant (*Phasianus colchicus*), five Barn Owls (*Strix flammea*), British, purchased; a Japanese Deer (*Cervus sika*), born in the Gardens.

OUR ASTRONOMICAL COLUMN.

COMET BORRELLY-BROOKS (1900 *b*).—Several observations of this comet are announced. The comet is at present easily seen with a small telescope, but is becoming fainter.

Ephemeris for 12*h. Berlin Mean Time.*

1900.	R.A. h. m. s.	Decl. ° ′	Br.
Aug. 9	3 11 45	+61 11·9	0·91
10	15 14	63 37·6	87
11	19 12	65 56·8	83
12	23 41	68 9·4	79
13	28 47	70 15·6	75
14	34 46	72 15·3	71
15	41 48	74 8·6	67
16	3 50 8	+75 55·7	0·63

During the week the comet passes rapidly northwards from α Persei, across into Camelopardus, and then near the boundary of this constellation and Cassiopeia. Its path is at present so nearly linear that it may be found by sweeping along the direction formed by the stars π, κ and α Persei.

EPHEMERIS OF COMET 1894 IV. (SWIFT).—Mr. F. H. Seares sends the following search ephemeris for the assistance of interested observers:—

Ephemeris for 12*h. Berlin Mean Time.*

1900.	R.A. h. m. s.	Decl. ° ′
Aug. 8	15 57 20	−24 32·8
12	15 59 31	36·0
16	16 2 10	40·2
20	16 5 17	45·4
24	16 8 50	51·4
28	16 12 50	−24 58·1

VARIABLE STARS IN CLUSTERS.—*Harvard College Observatory Circular* (No. 52) contains the results of the measures of a set of photographs of the star cluster Messier 3 (N.G.C., 5272). This object is so low in the sky at Arequipa, and the stars so faint, that satisfactory photographs of it could not be obtained with the 13-inch Boyden refractor with exposures less than 90m. The rate of increase of the light of many of these stars is extremely rapid, and in order to determine such change with the greatest precision, it is necessary to have photographs taken with short exposures. Accordingly, at Prof. E. C. Pickering's request, Prof. J. E. Keeler has taken a series of excellent pictures of the cluster with the 3-foot Crossley reflector of the Lick Observatory. The first of these had an exposure of 60m., while twenty-four others were obtained with exposures of 10m. each. Prof. Bailey has examined these photographs very carefully, devoting attention specially to three of the variable stars. It has previously been stated (*Circular* No. 33) that the proportion of variable stars is greater in this cluster than in any other object of the same class.

The periods of the three variables were found to be: No. 11, 12h. 12m. 25s.; No. 96, 12h. 0m. 15s.; No. 119, 12h. 24m. 31s. The variations were recorded for intervals of 5m., and are given in a table. From this it appears that the total increase of light takes place in the case of No. 11, within 70m.; No. 96, within 60m.; and No. 119, within 80m. The greatest rapidity of increase of light occurs in the star No. 96, which increases during 5m. at the rate of at least 2·5 magnitudes per hour, and during 30m. at the rate of more than 2·0 magnitudes per hour. This rate of change appears to be the most rapid of any known variable. The Algol variable U Cephei, which perhaps undergoes the most rapid change of any variable *not* found in clusters, changes at the rate of about 1·5 magnitudes per hour during about 30m. of its period. In all these stars the rate of change is relatively slow near the beginning and end of the period of increase. In No. 96 the increase is about *ten* times as rapid as the decrease. Generally speaking, the lengths of period and form of light curves of these three stars are similar to those of the variables in the clusters Messier 5 and ω Centauri (*Astrophysical Journal*, vol. x. p. 255).

RECENT INVESTIGATIONS ON RUST OF WHEAT.

RUST, or mildew, is familiar to the agriculturist as a disease destructive to wheat and other cereals, and to the botanist as the subject of important researches relating to fungi. It was known in times of antiquity, as shown by numerous references indicating its destructiveness. Virgil says, "Soon, too, the corn gat sorrow's increase, that an evil blight ate up the stalks" ("Georgics," i. 150-1). In Britain, it is stated that "mildew of wheat-plants has been known for over 300 years, according to the records" ("Report on Mildew on Wheat Plants, 1892," Board of Agriculture, 1893, p. 25). Shakespeare ascribes it to "the foul fiend Flibbergibbet" (*King Lear*, Act iii. Scene 4). The works on husbandry of Hartlib (1655) and Jethro Tull (1731) refer to it. The connection of rust of cereals with a specific fungus is generally ascribed to Fontana (1767), and Persoon, after further investigation, in 1797 named the fungus *Puccinia graminis*. An account of rust, with illustrations of the *Puccinia*, by Sir J. Banks in 1805, is apparently the first important paper on the rust and its fungus in Britain. Since then the epidemic has been the subject of many papers, and of, at least, three organised inquiries. The historical side of the subject is conveniently summarised by Worthington G. Smith ("Diseases of Crops," London, 1884, Chapter xxv.), by C. B. Plowright ("British Uredineæ and Ustilagineæ," London, 1889, p. 46), and in the Board of Agriculture report ("Report on Mildew on Wheat Plants, 1892," Board of Agriculture, 1893, p. 25).

Rust of wheat occurs throughout Britain, especially in the wheat-growing districts, and forms of it are found on oat, barley, rye, and almost all grasses The losses from the form on wheat, reported to the Board of Agriculture in 1892, vary from nine to sixteen bushels per acre of crop. Rust-epidemics have been the subject of special attention in Europe, more particularly in Sweden, Germany, France and Austria. A rust conference was formed in 1890 for Australasia, and still continues to meet. In the United States of America, the Department of Agriculture sanctions the statement that "the damage to wheat and oats from rust in this country probably exceeds that caused by any other fungous or insect pest, and in some localities is greater than that caused by all other enemies combined" (Carleton, M. A., "Cereal Rusts of the United States," U.S. Department of Agriculture, *Bulletin* 16, 1899). In India and Japan, substantial losses are ascribed to this disease.

The remedy for this epidemic is a difficult problem, and the aim of recent research has been, in the first place, to obtain a true conception of the fungus causing it. The facts leading up to recent investigations may be briefly reviewed. It is an old and deep-rooted belief amongst growers of wheat that the rust of their crops is influenced by the neighbourhood of barberry bushes. Evidence of this is seen in certain old enactments enforcing destruction of the barberry; for instance, that passed by a parliament at Rouen in 1660, and others included in the Province Law of Massachusetts (America) between 1738 and 1761. Sir Joseph Banks, in his paper (1805), holds the same opinion.

In 1841 Prof. J. S. Henslow (*Journal* of the Royal Agricultural Society, vol. ii. 1841) suggested that the yellow summer rust of wheat, and the black mildew which comes later, are stages in the life of one and the same fungus. Passing over many papers discussing these relationships, we come to one by De Bary published in 1865 ("Untersuchungen üb. Uredineæ." *Monatsber. d. Berlin Akad.*, 1865). From his experiments De Bary concludes, that the yellow summer rust (*Uredo linearis*, Persoon) on *Gramineae*, the black autumn rust (*Puccinia graminis*, Persoon) also on *Gramineae*, and the rust on barberry (*Aecidium berberidis*, Persoon) with its associated "spermogonia" stage, are phases in the life-history of the same fungus, for which the name *Puccinia graminis* is retained. In other words, that three (or four) recognised species of fungi are one and the same. At the same time a new phenomenon in the life of fungi was revealed, namely, that there existed parasitic fungi which required two host-plants in order to develop the forms of reproduction included in their life-cycle; this De Bary named metœcism or (as better known in Britain) heterœcism. The life-history of *Puccinia graminis*, as defined by De Bary, is given in all our text-books. Uredospores (see Fig. 1) are produced on wheat and other *Gramineae* throughout the summer, and infect the same group of host-plants; the teleutospores of the *Puccinia* stage hibernate and in the following spring germinate, producing secondary spores (also known as sporidia), which infect barberry foliage and give rise there to the *Aecidium* stage with its aecidiospores; aecidiospores do not infect barberry again, but on *Gramineae* produce the uredospore stage, thus completing the cycle. Accompanying the aecidium-cups there occurs constantly a form of reproduction, the spermogonia, which gives off spermatia or spore-bodies whose function neither De Bary, nor any one since, has been able to determine.

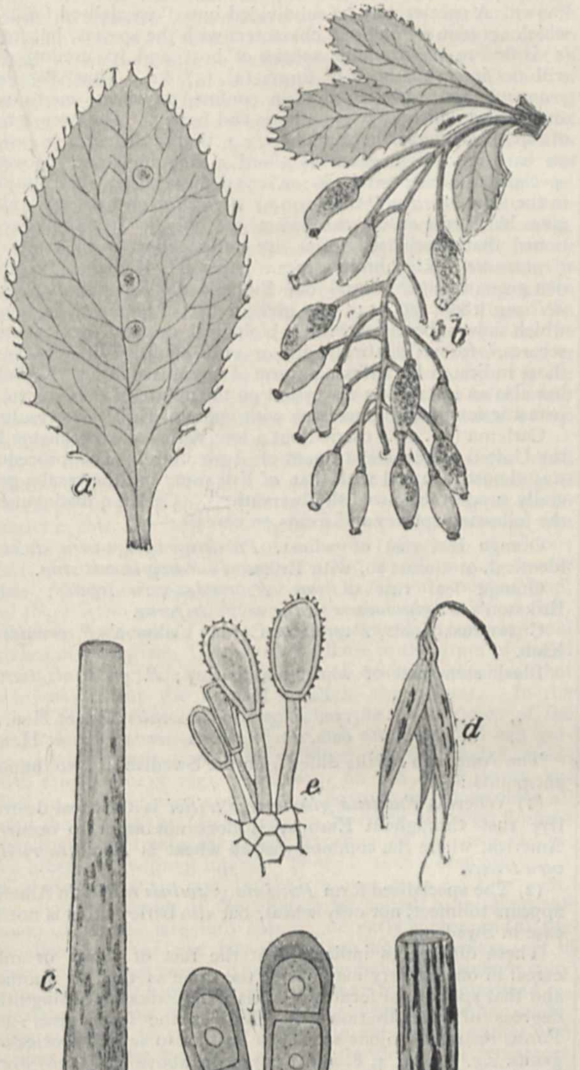

FIG. 1.—Black rust of oats (*Puccinia graminis*, spec. form *Avenae*). *a*, leaf, and *b*, cluster of fruits of barberry with *Aecidium berberidis* (nat. size); *c*, leaf, and *d*, a spikelet of oat with *Uredo* stage (nat. size); *e*, uredospores (× 500); *f*, sheath of oat with *Puccinia* stage (nat. size); *g*, teleutospores (× 500). (J. Eriksson.)

These results had an important and direct bearing on rust-epidemics of cereals, and they gave an impetus to further research on the biology of the whole group of rust-fungi or *Uredineae*, and, in fact, of all other parasitic fungi. In 1889, twenty-five years after De Bary's first results, both Plowright (*loc. cit.*, p. 56) and Rostrup published a list of fifty heterœcious rust-fungi. Recently, Dietel (Engler's "Pflanzenfamilien") gave about a hundred cases, including species outside the *Uredineae*. Works like Plowright's "British Uredineæ" are the evidence of this impulse, and a perusal of current botanical periodicals shows that the subject is by no means exhausted.

Ten years ago, three species of rusts occurring on crops of cereals were recognised:

(1) *Puccinia graminis*, with its *Aecidium* stage on barberry and mahonia; its uredospore and teleutospore stages on wheat, barley, oats, rye, and about a hundred species of grasses (see Fig. 1).

(2) *Puccinia rubigo-vera*, with *Aecidium* on many species of *Boragineae*; uredospores and teleutospores on wheat, rye, and a number of grasses (see Fig. 2). A variety, *simplex*, was distinguished on barley.

(3) *Puccinia coronata*, with *Aecidium* on species of buckthorn (*Rhamnus*); uredospores and teleutospores on oats and several grasses.

The four important European cereal-crops were thus known to have each two forms of rust-fungi, distinguished in their external characters, and with distinct *Aecidium* host-plants. Yet it was by no means certain that epidemics of rust were fully traced out. Fortunately the economic importance of rust-epidemics was enough to enforce attention from State departments, notably in Sweden, United States of America, Australasia, and in various parts of Europe and other countries. In Britain, while good work has been and is still done on rust-fungi, there has, in recent times, been no specially organised research relating to cereal rusts, probably because recent developments on the subject have rendered a research too extensive for the resources of any but workers specially retained and remunerated. The investigations on rusts of cereals reviewed here are mainly the outcome of State-aided research.

In Sweden, the Government in 1890 offered ten thousand kröner (about 560*l.*) to the Royal Swedish Academy of Agriculture for an investigation on rust of wheat, &c., intended, at first, to extend over three years, but which has been continued up till now. The grant was placed under the control of Jakob Eriksson, now professor of vegetable physiology at the experimental station of Albano, near Stockholm. The experiments were started in 1890; the first important results of Eriksson and his co-worker, E. Henning, appeared in 1894 (*Zeitsch. f. Pflanzenkrankheiten*, iv. 1894, pp. 66, &c.), and as a bulky volume in 1896 ("Die Getreiderost," Stockholm, 1896; 463 pp. and 14 plates). Other contributions, and re-statements of former work, have been made by Eriksson in almost every existing botanical periodical. The present summary is based chiefly on the latest re-statement (*Revue gén. d. Sciences*, ii. January 15, 1900, pp. 30–39), with aid from other papers.[1]

In Eriksson's experiments test-plants of cereals were grown from seed, or young plants from the open were transferred into pots. The soil used was generally sterilised. After inoculation with rust the plants were watered with distilled water, placed under large glass bell-jars moistened with distilled water, and left undisturbed for twenty-four hours in glass-houses specially constructed for the experiments. After this, observations were made at frequent intervals. The main lines of investigation were: (1) to define the species which cause rusts of cereals and grasses, and to trace their life-history; (2) the propagation of the rusts; (3) germination and vitality of the various forms of spores.

According to Eriksson's results, the three species and one variety of rusts attacking cereals and grasses as recognised in 1890 really represent twelve species and many subdivisions. His list is as follows, but the less important host-plants amongst the grasses are omitted:—

Species 1. *Puccinia graminis*. Pers. (Black Rust), with *Aecidium berberidis*. Specialised form (1) *Secalis*, on *Secale cereale* (Rye), *Hordeum vulgare* (Barley), *H. jubatum*, *Triticum repens*, *T. caninum*, &c., *Elymus arenarius*, and *Bromus secalinus*. (2) *Avenae*, on *Avena sativa* (Oat), *A. elatior*, &c., *Dactylis*

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[1] J. Eriksson: *Ber. d. deutsch. botan. Gess.*, 1894, p. 292; 1897, p. 183. *Jahrbuch f. wiss. Botanik*, xxix. 1896. *Botan. Centralblatt*, lxxii. 1897, pp. 321–5 and 354–62. *Centralblatt f. Bakter. u. Parasitenkunde*, Abt. ii. 1897, pp. 291–308.

glomerata, *Alopecurus pratensis*, &c. (see Fig. 1). (3) *Tritici*, on *Triticum vulgare* (Wheat). (4) *Airae*, on *Aira caespitosa*. (5) *Agrostis*, on *Agrostis stolonifera*, &c. (6) *Poae*, on *Poa compressa* and *P. caesia*.

2. *Pucc. Phlei-pratensis*, Er. et Hen., *Aecidium* unknown. On *Phleum pratense* and *Festuca elatior*.

3. *Pucc. glumarum* (Schm.), Er et Hen. (Yellow Rust), *Aecidium* unknown. Sp. form (1) *Tritici*, on Wheat (see Fig. 2). (2) *Secalis*, on Rye. (3) *Hordei*, on Barley. (4) *Elymi*, on *Elymus arenarius*. (5) *Agropyri*, on *Triticum repens*.

4. *Pucc. dispera*, Er. (Brown Rust of Rye), with *Aecidium Anchusae*. On Rye.

5. *Pucc. triticina*, Er. (Brown Rust of Wheat), *Aecidium* unknown. On Wheats—*Triticum vulgare*, *compactum*, *spelta*, and *dicoccum*.

6. *Pucc. bromina*, Er., *Aecidium* unknown. On many species of *Bromus*.

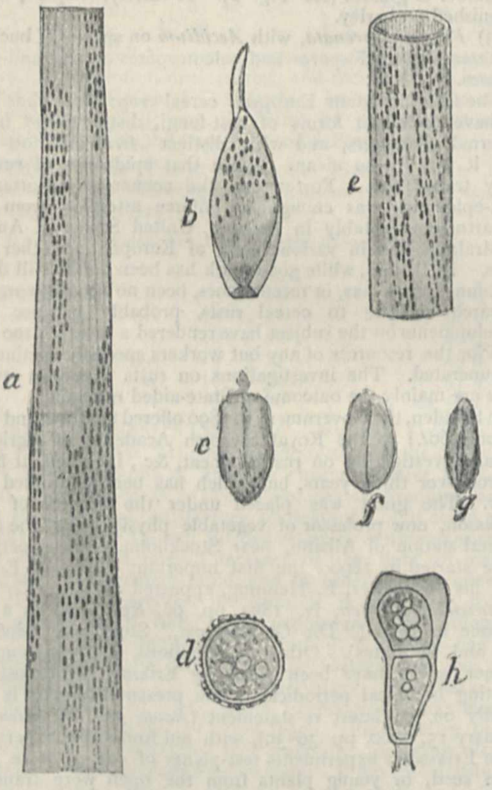

FIG. 2.—Yellow rust of wheat (*Puccinia glumarum*, spec. form *Tritici*), *a*, leaf (nat. size), *b*, outer glume (× 2), and *c*, a grain (× 2), bearing the *Uredo* stage; *d*, uredospore (× 375); *e*, sheath bearing *Puccinia* stage (× 2); *f*, a healthy grain, and *g*, a rusted grain (both × 2); *h*, teleutospore (× 500). (J. Eriksson)

7. *Pucc. agropyrina*, Er., *Aecidium* unknown. On *Triticum repens*.

8. *Pucc. holcina*, Er., *Aecidium* unknown. On *Holcus lanatus*, and *H. mollis*.

9. *Pucc. Triseti*, Er., *Aecidium* unknown. On *Trisetum flavescens*.

10. *Pucc. simplex* (Kleb.), Er. et Hen., *Aecidium* unknown. On Barley.

11. *Pucc. coronifera*, Kleb., with *Aecidium Catharticae*. Sp. form (1) *Avenae*, on Oat. (2) *Alopecuri*, on *Alopecurus pratensis*, &c. (3) *Festucae*, on *Festuca elatior*. (4) *Lolii*, on *Lolium perenne*. (5) *Glyceriae*, on *Glyceria aquatica*. (6) *Holci*, on *Holcus lanatus* and *H. mollis*.

12. *Pucc. coronata* (Corda), Kleb. (Crown Rust), with *Aecidium Frangulae*. Sp. form (1) *Calamagrostis*, on *Calamagrostis arundinacea*, &c. (2) *Phalaridis*, on *Phalaris arundinacea*. (3) *Agrostis*, on *Agrostis stolonifera*, &c. (4) *Agropyri*, on *Triticum repens*. (5) *Holci*, on *Holcus lanatus* and *H. mollis*.

Comparing these species with those known in 1890, *Puccinia graminis* is now divided into Eriksson's 1 and 2; *Puccinia rubigo-vera* into species 3 to 9: the variety *simplex* is now the species 10; and *Puccinia coronata* is divided into 11 and 12.

The species are distinguished by characters of uredospore and teleutospore, and by the host-plants of the *Aecidium*, where known. A species may be subdivided into "specialised forms," which agree in all external characters with the species, but form (1) is tied to one or more species of host, and its uredospores will not infect the hosts of forms (2), (3), &c. Thus *Puccinia graminis* has a specialised form confined to wheat, one to oat, and a third which attacks both rye and barley. The occurrence of the *Aecidium* on the same host, *e.g.* that of *Puccinia graminis* on barberry, might seem to afford a stepping-stone between specialised forms; yet Eriksson says definitely that, for example, in the form *Avenae* "the form of *Aecidium* on barberry which gives black rust on oat can infect oat only." It may be mentioned that specialised forms are not peculiar to the rusts of *Gramineae*. Klebahn in a recent paper (H. Klebahn, "Ueber den gegenwärtigen Stand der Biologie der Rostpilze," *Botan. Zeitung*, 1898, pp. 145-58) gives a list of heterœcious fungi, which show subdivision into "biological species" or "species sorores," forms identical with or only slightly different from those indicated by Eriksson's term of specialised forms. Klebahn has also an interesting discussion on the nature of these forms of parasitic fungi, and joins issue with many of Eriksson's results.

Carleton (*loc. cit.*) carried out a long series of experiments for the United States Department of Agriculture. The procedure was almost identical with that of Eriksson, and the results generally support the Swedish observations. Carleton distinguishes the following species and forms on cereals:—

Orange leaf rust of wheat, *Puccinia rubigo-vera tritici*; identical, or almost so, with Eriksson's *Puccinia triticina*.

Orange leaf rust of rye, *P. rubigo-vera secalis*; either Eriksson's *P. glumarum secalis* or *P. dispersa*.

Crown rust of oats, *P. coronata*, Corda; Eriksson's *P. coronifera*, Kleb.

Black stem rust of wheat and barley; *P. graminis tritici*, Er. et Hen.
,, ,, ,, rye, *P. graminis secalis*, Er. et Hen.
,, ,, ,, oats, *P. graminis avenae*, Er. et Hen.

The American results differ from the Swedish in two important points:—

(1) Whereas *Puccinia glumarum tritici* is the most destructive rust throughout Europe, it does not seem to occur in America, where the common rust on wheat is *Puccinia rubigo-vera tritici*.

(2) The specialised form *Puccinia graminis tritici* in America appears to infect, not only wheat, but also barley; this is not the case in Sweden.

These differences indicate that the rust of wheat or other cereal in one country may not be the same as that in another; and that specialised forms are variable. Eriksson distinguishes degrees of specialisation and classifies the forms thus: (1*a*) Forms restricted to one species of host, or to several species of a genus, *e.g.* species 4, 8, and 1 (5) in the above list. (1*b*) Forms occurring on hosts belonging to different genera, *e.g.* species 1 (1) and 1 (2) in list.

(2) Forms, which, under certain conditions of environment, are less fixed in regard to their hosts; thus, until recently, Eriksson included species 4, 5, 6, 7 as forms of one species, *Puccinia dispersa*, and it is still doubtful whether they are distinct enough in their external characters to be regarded as species

Further experiments are necessary to clear up many points regarding the distribution of species of rust. Yet the practical bearing of the results is evident. For example, wheat cannot now be regarded as subject to infection from any cereal or grass showing rust, but only from those which are host-plants of the species or specialised forms peculiar to wheat; thus a comparison from the above lists shows that no rust from oats has been found to infect wheat. The theoretical bearing of biological species or forms in relation to the classification and phylogeny of fungi is also of the deepest interest.

The propagation of the rusts of cereals has, in the hands of recent investigators, assumed new aspects. The life-cycle of *Puccinia graminis* as defined by De Bary, and already given above, is the one generally described in text-books. Many observers, however, have doubted whether this, the perfect life-history, is always followed entirely. Strong objections of this kind are given by Worthington G. Smith (*loc. cit.*), although at the time (1884) these were raised, the imperfect knowledge regarding the species of rust-fungi somewhat weakens the arguments at the present time. Yet Eriksson, Carleton, and other recent workers show even greater opposition. We are told that rust is a serious epidemic amongst wheat in Australia where there are no native barberries; in India an undoubted black rust (*Puccinia graminis*) occurs on wheat where there are no barberries nearer than 300 miles off in the Himalayas. More conclusive is Eriksson's observation of aecidium-cups on a barberry, yet the rust could only be traced on rye, barley, and couch-grass to a distance from 10 to 25 metres; or, again, tufts of *Festuca elatior* were found with uredospores of *Puccinia coronifera*, while across a road there was a hedge of *Rhamnus* almost free from the aecidial stage, yet easily infected by means of teleutospores from the grass transferred to it by hand. These observations appear to show, firstly, that the aecidial stage is not necessary in the life-history of rust of cereals; secondly, that the range of infection by aecidiospores, or the reverse, is not great. What then remains is one of the following possibilities: (1) The mycelium can hibernate and resume activity in the following spring; (2) the fungus is carried over to a new season by the seed-grain, either through adherent spores, or in some form internally; (3) the uredospores can hibernate; (4) the teleutospores can infect other *Gramineae*. In reviewing these we can only give a few of the leading points relating to cereals.

It is unlikely that the mycelium hibernates in the dead remains of grasses, because it must then be capable of living as a saprophyte for a short time in spring when it awakens to activity; this has not yet been proved. If, however, one examines the undergrowth of an area of grass in winter, green shoots are generally present; the mycelium may winter here. Yet grain-crops are never sown except on ploughed land, and there is no good evidence to show that epidemics of rust, extending over whole acres, are propagated altogether from patches of wild grass. Uredospores adhere to the grain of rusted cereals, and there is a fair amount of evidence to show that these may assist the fungus through the winter. In the United States, Carleton believes that the uredospores of the orange leaf rust of wheat and rye are produced and can germinate late in the autumn, and so infect the sprouted autumn-sown crop for next year. Eriksson, on the other hand, has failed to discover that any one of the rusts of wheat lives all round the year in the *Uredo* stage in Sweden, although Sorauer states that in Germany the *Uredo* mycelium of *Puccinia rubigo-vera* hibernates without injury. There is thus a possibility that the uredospore stage may transmit a rust from year to year. This is more probable if the climate be suited to prolong the growth of grasses late into autumn or early winter, and if the specialised form of rust has more than one host-plant; if it occurs only on one cereal, it seems improbable that enough stray plants are present after harvest to account for a widespread reappearance of rust in the succeeding year. Whether uredospores adhering to straw or grain can survive the winter and germinate has not yet been made quite clear. In laboratory experiments it has been observed that uredospores frequently exhibit deferred germination. After being soaked in water, only a small percentage may produce germ-tubes. Eriksson and others have observed that if the dormant spores are cooled in ice, a further proportion are induced to germinate. Klebahn states that the greater number of all forms of spore germinate if placed on a suitable host-plant; he believes that the proportion which do not germinate at once, do so gradually later on, and sees in this an adaptation for preservation of the race.

The teleutospores of the rusts of cereals have, as a rule, proved incapable of infecting cereals or grases, the aecidium stage must intervene. There is, however, the objection that observations can only be made under more or less artificial conditions in laboratory or green-house, and may not fulfil all the conditions of infection out-of-doors. Plowright recorded an instance of infection of cereals from the teleutospores of *Puccinia graminis* (*Gardeners' Chronicle*, August 19, 1882), but gives no special prominence to it in his "British Uredineæ" (1889). Indirectly certain facts lead one to suppose that teleutospores may have the power to reproduce other stages in the life-history than the aecidium. A rust-fungus of the group *Leptopuccinia* (e.g. *Puccinia malvacearum* on mallow and hollyhock) produces only teleutospores; these give rise to sporidia, which re-infect the mallow, and form the mycelium from which a new crop of teleutospores arises. Many forms of rust-fungi have only teleutospores and uredospores on the same host: for instance, in Eriksson's list many of the forms have no *Aecidium*; either the hosts of this stage remain to be discovered, or the teleutospore production is fruitless, or the teleutospores are capable of bringing about infection of the cereal or grass host. Species like *Puccinia suaveolens* on thistles have all the forms of spore on one host-plant except aecidiospores, which are unknown; here the teleutospores must, after hibernation, bring about re-infection of the host. The existence of rust-fungi producing all the forms of spore on one host, shows that two hosts are not necessary for the development of the aecidium stage, and suggests that heterœcism may be a later development in the history of the group. It is also noteworthy that the teleutospore is produced by all rust-fungi, with very few exceptions. It is therefore not improbable that the teleutospores of heterœcious rust-fungi may still, through their sporidia, retain the power of infecting the host on which they are produced; in other words, that heterœcism may be facultative.

In investigating the germinative power of teleutospores, Eriksson finds the general opinion, that teleutospores must hibernate, to be true only to a certain degree. As a rule, they do not germinate unless they have passed the winter exposed to all the changes of weather out-of-doors. Spores collected in autumn and kept indoors soon lose the power of germination; hence his conclusion that rusted straw housed in barns will not be in a condition to propagate the disease next spring. In the case of spores left out-of-doors, the germinative power decreases rapidly during the year after their formation, and in October they no longer germinate. There is one exception, teleutospores of *Puccinia graminis tritici* have a feeble power of germination after two winters. On the other hand, Eriksson finds that certain teleutospores (e.g. *Puccinia dispersa* and *P. glumarum tritici*) can germinate in the year of their formation; in the case of the former species, aecidia were produced on *Anchusa* in a short time; in the latter form the host of the aecidia is unknown. Plowright states that a bundle of rusted wheat straw laid near plants of *Anchusa* in August 1885 produced aecidia in September.

Eriksson, after all his experiments, professes to be at a loss to account for epidemics of rust on cereals year after year by external contagion alone, and he adopts the view that *infection is due to an internal germ*. He thus introduces an agent for the propagation of parasitic fungi which has hitherto been received very sceptically by the plant-pathologist. His conclusion is the result both of experiment and examination with the microscope. In the experiments, varieties of cereals were used which are known to be specially liable to rust. Vigorous shoots were taken out-of-doors in spring, and enclosed in long glass tubes with the open ends closed with cotton wool. Seeds were also germinated in sterilised soil and kept in culture boxes, with precautions against entrance of spores by stuffing the ventilators with cotton wool. At first the results were negative, but after (in some way) improving the methods, the test-plants showed rust, especially those shoots taken from out-of-doors. Examination with the microscope failed to reveal any mycelium or other traces of the fungus until a few days before appearance of the rust externally. At this time, however, with the aid of staining reagents, certain protoplasmic bodies were observed in the green cells near the margin of a rust-patch. These plastids occur solitary or in masses in a cell; they are oblong or slightly curved, simple or somewhat branched, and recall the form of bacteroids found in root-tubercles of the *Leguminosae*. In a short time the branch-processes pierce the cell-wall of the host, and develop outside the cell into an intercellular mycelium, part of the original plastid remaining inside the cell as the first haustorium or sucker. Soon after this a rust-pustule appears on the exterior of the host. The plastid is regarded as having passed a period mingled with the cytoplasm of the host "in a kind of symbiosis," till in response to external conditions—nutrition, moisture, heat and light—the "mycoplasm" becomes separated from the cytoplasm, and assumes the form of a plastid. The mycoplasm has its origin from the rust-fungus in the parent host-plant, it becomes located in the embryo of the grain, develops apace with the young plant, and so bridges the period between one crop and the next. The following general facts are said to support this mycoplasm theory: (1) The appearance of rust on plants carefully isolated from contagion; (2) the disease in a field appears regularly four to five weeks after sowing the grain of certain varieties of wheat and barley known to be very liable to yellow rust; (3) this rust is always more prevalent in sunny parts of the field.

A hypothesis so revolutionary is not likely to be adopted by a cautious fungologist without further evidence. At present, as far as we know, no figures illustrating the development of the mycelium have been published, nor can we obtain details of the staining methods adopted. Klebahn (*loc. cit.*) has entered his protest to the theory, chiefly, however, in general terms. In regard to the prevalence of rust in sunny parts of a field, he points out that Eriksson's own results confirm the fact that dormant spores are induced to germinate by alternate cooling and heating, drought and moisture; just the conditions to be expected in early summer in sunny parts rather than in shaded parts of a field. Klebahn also supports the view that spores of rusts are capable of wider distribution than Eriksson's results show; for instance, they have been found in analyses of air. We may recall, in support of this, Robert Hartig's observation in the Tyrol, when, after showers of rain, a yellow dust, coating objects in the neighbourhood, was found to consist almost entirely of the yellow spores of a rust-fungus, *Chrysomyxa* ("Diseases of Plants," Tubeuf and Smith, London, 1897, p. 54). If it be the case, as Eriksson says, that certain rusts of cereals appear regularly in four or five weeks, it seems quite as likely to indicate external infection of young plants at a certain stage in their existence, as to support the theory of an internal germ. The Swedish experiments in isolating test-plants from contagion have been repeated in America by Bolley.[1] Young plants of cereals growing amongst others in a field were enclosed in rust-proof cases; they grew to maturity without showing any rust, although plants left unenclosed were much attacked. The results are quite negative.

Recent investigations have been directed towards advancing our knowledge regarding the varieties of cereals suited to resist the various forms of rust. Carleton,[2] whose work was aimed in this direction, summarises our general knowledge thus: "as yet there is but little certainty concerning rust resistance, which varies continually under different conditions. Heretofore, in testing varieties for rust resistance, little attention has been paid to the species of rust concerned." For our own part, we feel that our ability in combating the diseases of plants would be greatly strengthened by searching investigations towards attaining disease-proof varieties. A certain amount has been done, much more must yet be done. The results hold good for only small areas of the earth, and there must be thorough and systematic research in many countries before any definite conclusion be arrived at. From a practical point of view the combating of rusts of cereals, and diseases of plants generally, seems likely to be solved sooner in this way than by investigations on the complex conditions of life amongst the rust-fungi. One cannot but feel that the long recent researches have added to what we knew only minor details of practical importance, although they have opened new vistas of the deepest interest to the fungologist; the outstanding lesson is the close dependence of the fungi on their environment, and the complexity thereby introduced into the study of diseases of plants.

WILLIAM G. SMITH.

MEDICINE AS A SCIENCE AND MEDICINE AS AN ART.[3]

IT has sometimes been disputed whether medicine should be regarded as a science or an art, but there is no doubt that the original meaning of the term medicine, in English and in other languages, is the Art of Healing. Medicine is so defined by Aristotle, and it has all the characters of an art. It depends upon experience and skill; it deals with individual cases; and the perfection it aims at is practical, not speculative: the knowledge how to do, not the knowledge how things happen.

Nevertheless, as practical navigation is founded on astronomy, meteorology and physics; as the art of agriculture rests on botany, geology and vegetable physiology, so the art of medicine depends on the science of pathology, the practice of physic on the principles of physic.

On the one hand, then, we must never forget that we practice an art; we must never allow theories, or even what appears to be logical deduction, or explanations, however ingenious, or statistics, however apparently conclusive, or authority, however venerable, to take the place of the one touchstone of practical medicine, observation and experience. We must never treat the disease without considering the patient, for the art of healing is the art of healing individually; nor need we wonder if profound learning and the best scientific training sometimes fail to make a successful practitioner. For beside adequate knowledge to save us from gross blunders, and a strenuous endeavour to do your best for each individual patient, however uninteresting the case or however irksome and unrewarded our toil—beside these first requisites for our art, there is ample room for those personal qualities which ensure success in every department of life; for power of observation and insight, for the personal influence by which a strong character will secure obedience and inspire hope, for the judgment which divines what kind of remedies are suited to each patient, what kind and of what strength, and for the sympathy which puts one in the patient's place, and not only meets, but anticipates his wants.

On the other hand, however, if medical science without art is inefficient, medical art without science is not only unprogressive, but almost inevitably becomes quackery. As soon as we treat our patients by rule of thumb, by tradition, by dogmas, or by metaphysical axioms, we do injury to ourselves as well as to them. The bone-setter who is ignorant of anatomy; the wise woman, who cures by charm, are not more irrational or less successful than was the physician of the seventeenth century who, in obedience to the doctrine of signatures, advised an infusion of roses for hæmorrhage, and saffron for jaundice, and lung-wort for consumption; or the astrologer who prescribed salts of silver, of iron, copper, lead, or mercury in accordance with the horoscope of the patient and the planet under which he was born.[1] Not less mischievous, and in the true sense of the word unscientific, were the systems of medicine known as the Iatromechanical and the Iatrochemical, which in their turn had their vogue. The Brunonian system, explaining all diseases as due to laxity of fibre, was no better; for indiscriminate use of "corroborants," or as they would now be called "tonics," is irrational. There is no such thing as a tonic or strengthening medicine, the only source of strength is oxidisable food, and bitter medicines only give strength indirectly by improving appetite. The last of the systems of medicine founded on a dogma is homœopathy, of which the theoretical absurdity is somewhat concealed by the more obvious nonsense of infinitesimal doses. It, like the other systems which preceded it, is not a rival to rational medicine; they are not mistaken answers to a legitimate question, but attempted solutions of a problem which does not exist, attempted answers to a riddle which has none.

Apart from these exploded systems of treatment, our profession has often suffered from lack of the scientific, inquiring, sceptical spirit, and has often been led too easily by authority, by tradition, and by fashion. The reckless abuse of venesection in the last century and the former half of this led to almost complete disuse of a valuable means of treatment; the misuse of mercury in the treatment of syphilis led to the denial of its unquestionable efficacy; have we not seen the value of stimulants with fever lead to their indiscriminate use in almost every ailment? Has not the immense value of careful and thorough nursing led to its absurd exaltation to an independent place, as if good nursing was anything more than an intelligent carrying out of the physician's directions? Has not the remarkable powers of electrical stimuli led to a blind, unscientific and mischievous employment of this remedy, as if it had some mystic power apart from its demonstrable physiological effects? May we not say the same of hydropathy, of massage and of hypnotism? It is significant that the irrational exaltation of any of these particular modes of treatment into a panacea, while it begins in want of scientific intelligence invariably ends in imposture and deceit. Our only safeguard against the spirit of quackery and the deserved loss of public confidence in the

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[1] *Centralblatt f. Bakt. u. Parasitenkunde*, Abt. II., vol. iv., 1898, pp. 855-9, 889-96, 913-9 (6 figs.). Also *Proc.* Amer. Ass. Adv. Science, 1898, p. 408 (the limits of this paper prevent a longer reference to this research).

[2] *Loc. cit.*, p. 69.

[3] Abstract of the Address in Medicine delivered before the British Medical Association at Ipswich, on August 1, by Dr. P. H. Pye-Smith, F.R.S.

[1]

☉	☽	♂	☿	♃	♀	♄
Sol	Luna	Mars	Mecurius	Jupiter	Venus	Saturnus
Au	Ag	Fe	Hg	Sn	Cu	Pb
Sunday	Mon-day	Mardi	Mercredi	Thors-day	Vendredi	Saturday

These relations of metals to the planets, and also to the days of the week, are commemorated in the phrases:—*lunar* caustic, *martial* disposition, *mercurial* temperament, ℞ before a prescription, *Cuprum a Cypro* (*divapoteus Cypri*) and *saturnim* gout.

profession which it brings with it, is continued recurrence to the scientific basis on which the practice of medicine rests. Our art is most satisfactory and efficient when most closely resting on science. The surgeon is continually guided by anatomy and mechanics in dealing with injuries and deformities. The physician is often able to apply his knowledge of chemistry and natural history to the direct and satisfactory treatment of disease. In general, medical science justifies its claim to the title by the same conclusive argument as astronomy or chemistry—by its predictions coming true. In particular, the detection and treatment of plumbism, the diagnosis and cure of scabies and ringworm, the treatment of poisons by chemical antidotes, and of specific diseases by attenuated inoculations are all instances of strictly scientific medicine. Nor can I refrain from citing the most recent and one of the most remarkable advances of our science in the discovery of the origin of malaria. This heavy tax upon national as well as individual vigour and happiness has been known and treated from the dawn of medicine; but although by a happy accident its efficient treatment was discovered, it is only lately that, by the combined labours of scientific physicians—Frenchmen, Italians, and our own countrymen—the origin of the disease has been discovered, the mode of its transmission traced, the diagnosis of its several forms established, and its prevention brought within reasonable hope.

We know that treatment of symptoms without a diagnosis is always unsatisfactory, and frequently worse; but we know also that diagnosis must rest upon accurate knowledge of morbid anatomy, and of the natural history of the disease. Scientific medicine based on observation and experiment is always practical as well; but empirical medicine, whether based upon fanciful speculation or working by blind rule of thumb, is the most unpractical thing that can be.

Preventive Medicine and Aetiology.—That important and constantly-growing branch of medicine, which deals with the prevention rather than the cure of disease, depends no less upon science, for tracking the dependence of one event upon another is the essence of inductive science. All efficient measures for the preservation of health, whether by individuals or communities, rest upon exact knowledge of the natural course of diseases. In fact, disease may be defined as the reaction of the human organism under conditions which make for its destruction. We must never forget that no irritant will cause inflammation in a lifeless skin; that no bacteria can produce fever without a nervous system to play upon; that no meal, however Gargantuan, and no potations, however deep, can produce their wonted effect without a stomach to react. The infection of small-pox, of diphtheria, or of tubercle exerts a very different influence upon vaccinated or unvaccinated subjects, upon one who has received and one who has not received the prophylactic serum, upon an organism which is predisposed to or refractory against the invasion of the enemy. How closely natural science is related to preventive medicine is shown by the history of Jenner, who was a naturalist, and of Pasteur, who was a chemist. How dependent we are upon science is well illustrated by the history of myxœdema. The cretinoid condition in adults which was discovered by the clinical acumen of Sir William Gull, unintentionally produced by the surgical skill of Prof. Kocher, and reproduced in animals by Mr. Horsley, is now cured by the eminently scientific method due to Dr. Murray, of Newcastle, and to Dr. Hector Mackenzie, of St. Thomas's Hospital. Such examples of accurate tracing of causation by observation and experiment admonish us to give up the perfunctory explanations which so often do duty for investigation. If we ascribe every inflammation to cold, and every vague complaint to gout; if we acquiesce in the popular ascription of disease to over-work, mental strain, and the nervous tension of modern life, we shall make no progress in true ætiology. I see many patients suffering from idleness—few, or none, from hard work. "Nerve-prostration" from "worry" and "brain-tension" often proves a decent synonym for the effects of gambling and drink. Modern life is easier, safer, and smoother than it was a hundred years ago. Our young men and maidens are healthier, stronger, better grown, less hysterical and sounder in mind and body than their great-grandparents. I venture to think that the duty of a physician is not to flatter the self-love of neurotic patients, but to inspire fortitude, and to prescribe regular and steady work as the best cure for a thousand nervous ailments.

As another point in scientific ætiology, allow me to warn against the temptation to assume that because many diseases are now proved to depend upon the presence of bacteria this must be true of all. Science does not anticipate, but waits for proof. We have complete scientific evidence, according to the criteria so well formulated by Koch, of the absolute and constant cause of anthrax, of relapsing fever, of tubercle, and several other diseases in both men and animals; but we must not forget the preliminary difficulty of identifying the specific bacillus—as in the case of enteric fever and diphtheria—nor the difficulty of finding one of the lower animals which is susceptible to the disease, as again in the case of typhoid fever and of cholera; nor the difficulty of the same anatomical and clinical conditions being produced by different organisms, as in the case of pneumonia and ulcerative endocarditis. Moreover, while in some diseases, which are undoubtedly infective and specific, no constant pathogenic microbe has yet been determined—as in typhus, measles, small-pox, and syphilis—we have, on the other hand, in the case of leprosy and of lupus, examples of disease unquestionably specific and bacterial in origin, but very unlike other infective maladies in their clinical course and natural history. At present it is surely undesirable to speak of "the undiscovered microbe of rheumatism." Science has to do with proved facts alone, and our language should never outrun our knowledge.

Experiments in Scientific Medicine.—There is one aspect of scientific medicine so important that it must not be omitted—the necessity of experiments for the progress of pathology, and, through it, for the prevention and cure of disease. It requires no argument to convince any one who is the least acquainted with the principles of inductive science that experiment is no less necessary than observation. In physics and in chemistry this is obvious and universally acted on. The same method is indispensable for the progress of animal and vegetable physiology, and to such practical applications of science as engineering, agriculture and medicine. Nor can experiments be restricted to rare occasional and solemn occasions; they must be carried on in large numbers, by many different experimenters, and under every variety of condition. Any attempt to abolish, to check or to limit this experimental work is, in the degree that it is successful, fatal to progress. Happily it can never be successful, for the impulse to increase knowledge of the works of creation is too deeply implanted in men. Investigation must and will go on by the only path which it can follow. The method which was preached by Bacon and followed out by his great contemporary, William Harvey, which was continued by Lower, Hooke and Mayow in the early days of the Royal Society, by Aselli, Malpighi and Haller, by Hunter, Hewson and Hales, by Edward Jenner, by Sir Charles Bell, by Johannes Müller, by Claude Bernard, by Ludwig, and by the many eminent physiologists and pathologists in Germany, in France and throughout the civilised world, this method of investigation is absolutely necessary for the progress of our science and the improvement of our art. As its objects and methods are better understood, it will secure the enlightened patronage of all who desire the diffusion of human knowledge and the further spread of human happiness. Fortunately this very progress of science has brought with it the removal of the one grave drawback, as every right-thinking man must have felt it, to the benefits of these experiments upon living animals. Inflicting pain upon the humblest of God's creatures is repugnant to our feelings, though no one, unless maintaining a thesis, would contend that it is wrong to exact the most painful efforts, or even the death from exhaustion of a horse in order to carry help to a human being. But the discovery of ether, chloroform, and other anæsthetics, and the improved methods that we owe to the genius of Lister, have not only relieved the surgeon of the most repulsive part of his duties, but have relieved the experimenter also. Except in the investigation of the action of new remedies or in the inoculation of infective diseases, both of which inflict discomfort of a limited degree and duration rather than anything that can be described as pain, the experiments of the laboratory, whether physiological, pathological or therapeutical, are conducted without inflicting pain. The opposition to them has not succeeded, and is sure to diminish. However mistaken our opponents, we are glad to find there is even exaggerated jealousy to avoid anything approaching to cruelty. This legitimate object our more candid critics may be assured is already amply provided for.

MR. BALFOUR ON SCIENTIFIC PROGRESS.[1]

APART altogether from individual likes and dislikes, is there any characteristic note which distinguishes this century from any that have gone before it?

On this point I range myself with those who find the characteristic note in the growth of science. In the last 100 years the world has seen great wars, great national and social upheavals, great religious movements, great economic changes. Literature and art have had their triumphs, and have permanently enriched the intellectual inheritance of our race. Yet, large as is the space which subjects like these legitimately fill in our thoughts, much as they will occupy the future historian, it is not among these that I seek for the most important and the most fundamental differences which separate the present from preceding ages. Rather is this to be found in the cumulative products of scientific research, to which no other period offers a precedent or a parallel. No single discovery, it may be, can be compared in its results to that of Copernicus; no single discoverer can be compared in genius to Newton; but, in their total effects, the advances made by the nineteenth century are not to be matched. Not only is the surprising increase of knowledge new, but the use to which it has been put is new also. The growth of industrial invention is not a fact we are permitted to forget. We do, however, sometimes forget how much of it is due to a close connection between theoretical knowledge and its utilitarian application which, in its degree, is altogether unexampled in the history of mankind. I suppose that, at this moment, if we were allowed a vision of the embryonic forces which are predestined most potently to affect the future of mankind, we should have to look for them, not in the Legislature, nor in the Press, nor on the platform, nor in the schemes of practical statesmen, nor the dreams of political theorists, but in the laboratories of scientific students whose names are but little in the mouths of men, who cannot themselves forecast the results of their own labours, and whose theories could scarce be understood by those whom they will chiefly benefit.

I do not propose to attempt any sketch of our gains from this most fruitful union between science and invention. I may, however, permit myself one parenthetic remark on an aspect of it which is likely more and more to thrust itself unpleasantly upon our attention. Marvellous as is the variety and ingenuity of modern industrial methods, they almost all depend in the last resort upon our supply of useful power; and our supply of useful power is principally provided for us by methods which, so far as I can see, have altered not at all in principle, and strangely little in detail, since the days of Watt. Coal, as we all know, is the chief reservoir of energy from which the world at present draws, and from which we in this country must always draw; but our main contrivance for utilising it is the steam engine, and, by its essential nature, the steam engine is extravagantly wasteful. So that, when we are told, as if it was something to be proud of, that this is the age of steam, we may admit the fact, but can hardly share the satisfaction. Our coalfields, as we know too well, are limited. We certainly cannot increase them. The boldest legislator would hesitate to limit their employment for purposes of domestic industry. So the only possible alternative is to economise our method of consuming them. And for this there would, indeed, seem to be a sufficiency of room. Let a second Watt arise. Let him bring into general use some mode of extracting energy from fuel which shall only waste eighty per cent. of it, and lo! your coalfields, as sources of power, are doubled at once. The hope seems a modest one, but it is not yet fulfilled; and therefore it is that we must qualify the satisfaction with which at the end of the century we contemplate the unbroken course of its industrial triumphs. We have, in truth, been little better than brilliant spendthrifts. Every new invention seems to throw a new strain upon the vast, but not illimitable, resources of nature. Lord Kelvin is disquieted about our supply of oxygen; Sir William Crookes about our supply of nitrates. The problem of our coal supply is always with us. Sooner or later the stored-up resources of the world will be exhausted. Humanity, having used or squandered its capital, will thenceforward have to depend upon such current income as can be derived from that diurnal heat of the sun and the rotation of the earth till, in the sequence of the ages, these also begin to fail. With such remote speculations we are not now concerned. It is enough for us to take note how rapidly the prodigious progress of recent discovery has increased the drain upon the natural wealth of old manufacturing countries, and especially of Great Britain, and, at the same time, frankly to recognise that it is only by new inventions that the collateral evils of old inventions can be mitigated; that to go back is impossible; that our only hope lies in a further advance.

After all, however, it is not necessarily the material and obvious results of scientific discoveries which are of the deepest interest. They have effected changes more subtle and perhaps less obvious which are at least as worthy of our consideration and are at least as unique in the history of the civilised world. No century has seen so great a change in our intellectual apprehension of the world in which we live. Our whole point of view has changed. The mental framework in which we arrange the separate facts in the world of men and things is quite a new framework. The spectacle of the universe presents itself now in a wholly changed perspective. We not only see more, but we see differently. The discoveries in physics and in chemistry, which have borne their share in thus re-creating for us the evolution of the past, are in process of giving us quite new ideas as to the inner nature of that material whole of which the world's traversing space is but an insignificant part. Differences of quality once thought ultimate are constantly being resolved into differences of motion or configuration. What were once regarded as things are now known to be movement. Phenomena apparently so wide apart as light, radiant heat and electricity, are, as it is unnecessary to remind you, now recognised as substantially identical. From the arrangement of atoms in the molecule, not less than their intrinsic nature, flow the characteristic attributes of the compound. The atom itself has been pulverised, and speculation is forced to admit as a possibility that even the chemical elements themselves may be no more than varieties of a single substance. Plausible attempts have been made to reduce the physical universe, with its infinite variety, its glory of colour and of form, its significance and its sublimity, to one homogeneous medium in which there are no distinctions to be discovered but distinction of movement or of stress. And although no such hypothesis can, I suppose, be yet accepted, the gropings of physicists after this, or some other not less audacious unification, must finally, I think, be crowned with success. The change of view which I have endeavoured to indicate is purely scientific, but its consequences cannot be confined to science. How will they manifest themselves in other regions of human activity, in literature, in art, religion? The subject is one rather for the lecturer on the twentieth century than for the lecturer on the nineteenth. I, at least, cannot endeavour to grapple with it.

SOCIETIES AND ACADEMIES.

LONDON.

Royal Society, June 14.—"The Electrical Effects of Light upon Green Leaves." By Augustus D. Waller, M.D., F.R.S.

In the preliminary communication recently made to the Royal Society, the author shows how, from the study of the electrical effects of light upon the retina, he was led to ask whether the chemical changes aroused by the action of light upon green leaves are also accompanied by electrical effects demonstrable in the same way as the eye currents. The question is tested in the following way:—A young leaf freshly gathered is laid upon a glass plate and connected with a galvanometer by means of two unpolarisable clay electrodes A and B. The half of the leaf connected with A is shaded by a piece of black paper. An inverted glass jar forms a moist chamber to leaf and electrodes, which are then enclosed in a box provided with a shuttered aperture through which light can be directed. A water trough in the path of the light serves to cut out heat more or less. Under favourable conditions there is obtained with such an arrangement a true electrical response to light, consisting in the establishment of a potential difference between illuminated and non-illuminated half of a leaf, amounting to 0·02 volt.

The deflection of the galvanometer spot during illumination is such as to indicate current in the leaf from excited to protected part. The deflection begins and ends sharply with the beginning and end of illumination; it is provoked slightly by diffuse

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[1] Address delivered by Mr. Balfour, M.P., at the opening of the Cambridge Summer Meeting on August 2. Abridged from the *Times*.

daylight, more by an electric arc-light, most by bright sunlight. It is abolished by boiling the leaf, and by the action of an anæsthetic, carbon dioxide.

The first experiments, made at the end of March, were upon iris leaves taken from plants about 6 inches high, and the response to light was then between 0·001 and 0·002 volt in value. Experiments upon similar leaves were resumed early in May, when it appeared that the external condition by which the state of the leaf is most obviously governed is *temperature*. On warm days the response ranged from 0·005 to 0·02 volt; on cold days it did not rise above 0·005, and was sometimes nil. Some tests upon leaves in a warmed box gave satisfactory results, which may be thus summed up:—The normal response at 15°–20° C. is diminished or abolished at low temperature (10°), augmented at high temperature (30°), diminished at higher temperature (50°), and abolished by boiling.

As the month of May advanced, the iris leaves, even in the warm box, became more and more inert, and by the 23rd inst., when the plants were mostly full grown and in flower, no satisfactory leaf could be found. Leaves of iris appear to give more marked response at or about mid-day, than at or about 6 p.m. Tested by Sach's method the leaves gave no evidence of starch activity during insolation.

On the failure of the iris leaves to react, other leaves were sought for which should give evident differences of reaction in correlation with evident differences of state. Leaves of tropæolum and of mathiola gave a response to light contrary in the main to the ordinary iris response, viz. "positive" during illumination, and subsequently "negative."[1] In these two cases leaves empty of starch acted better than leaves laden with starch. Leaves of begonia gave a variety of responses strongly suggestive of the simultaneous action of two opposed forces effecting a resultant deflection in a + or − direction. Leaves of ordinary garden shrubs and trees, &c., *e.g.* lilac, pear, almond, mulberry, vine, ivy, gave no distinct response; this is possibly due to a lower average metabolism in such leaves as compared with the activity of leaves of small young plants in which leaf-functions are presumably concentrated within a smaller area. The petals of flowers gave no distinct response, which indicates that chloroplasts are essential to the reaction.

The effect of carbon dioxide upon the iris leaf was abolition of response during and after passage of the gas, with subsequent augmentation. Upon mathiola and tropæolum, augmentation of response followed on applying air containing 1 to 3 per 100 of carbon dioxide, and prompt abolition resulted from a full stream run through the leaf-chamber. On the air supply being kept clear of carbon dioxide there was gradual abolition of response, followed by gradual recovery on the re-admission of a small amount of carbon dioxide.

"Fatigue" effects may be produced if the successive illuminations (of 5 minutes duration) are repeated at short intervals (10 minutes). At intervals of 1 hour, successive illuminations of 5 minutes produce approximately equal effects. With the leaf of mathiola, periods of illumination of 2 minutes at intervals of 15 minutes were used without provoking any obvious sign of fatigue.

June 21.—"Note on Inquiries as to the Escape of Gases from Atmospheres." By G. Johnstone Stoney, M.A., Hon. D.Sc., F.R.S.

Three investigations have been published which profess to supply information about the escape of gases from atmospheres. Two of them, those of Messrs. Cook[2] and Bryan,[3] while differing in other respects, agree in reasoning forwards by the help of the kinetic theory of gas from the supposed causes; the third[4] pursues a method regarded as trustworthy by the present writer, and reasons backwards by the help of the same theory from the observed effects.

Where, as in the present instance, the *a priori* and *a posteriori* methods have led to inconsistent numerical results, it is incumbent upon us to search for the mistake or mistakes which must somewhere have been made. If these can be found and corrected, an important advantage is gained; and the present is an attempt to trace some of them by inquiring whether there are conditions or agencies in nature which facilitate the escape of gaseous molecules from the earth, and which are omitted, or which have not been sufficiently taken into account, in Mr. Cook's and Prof. Bryan's investigations.

Let ΔV be a volume containing at a given epoch a large number n of molecules of the atmosphere, and let Δt be a duration commencing at that instant. Also, let n' be the number of encounters which each of these molecules on the average meets with in the times Δt. Then will

$$N = nn'$$

be the total number of their free paths in that time; and the actual number of these free paths, in which the initial speed after an encounter lies at the time t between v and $v + dv$, must be precisely

$$dN = N(\pi + \delta)dv, \qquad (1)$$

where π is the probability function (that employed by Mr. Cook, or that employed by Prof. Bryan, or some other), and δ (the deviation function) represents whatever is the real divergence of the actual number from that computed by the formula used by them, viz.:

$$dN = N\pi dv; \qquad (2)$$

in other words, computed on the supposition that δ/π is of negligible amount.

Now π is one fully-determined function in Mr. Cook's investigation, and another fully-determined function in Prof. Bryan's; but little is known of what δ is in either case, except that it is in both an excessively complex function of N, v, t, with several other variables, some of which it is difficult even to indicate; and that by its amount for any given value of t and at any given position in the atmosphere it must supply in equation (1) the actual effect, at that time and place, of all natural agencies which had not been taken into account in calculating the expression π.

If due care has been taken in framing the probability law π, it will in many cases be legitimate to assume that δ/π is sufficiently small to warrant our using equation (2) when computing the approximate distribution among the free paths of those speeds which assign *large* values to π, while at the same time it may need proof and may not be a legitimate assumption in reference to those values of v which make π *small*. Now it is in this latter case that the assumption has to be made by Mr. Cook and Prof. Bryan.

The conditions under which the assumption is likely not to be true are the following:—

A. Where the events, the law of whose distribution purports to be represented by the π function, are of such a kind that a vast number of the events need to be passed under review in order to secure an approximate conformity to *any* fixed law. Now experiment shows that in ordinary air trillions of the free paths, probably many trillions, must be grouped together in order to make manifest any law in the distribution of the speeds. In all such cases we are not entitled to ignore the δ function, except in estimating the frequency of such speeds as can be shown to assign a sufficient preponderance to the π function. Accordingly it is not legitimate to ignore the δ function when treating of the frequency of speeds which make π excessively small, such as are the speeds which carry molecules away from the earth.

B. But a more important omission occurs where the function π has been arrived at without taking into account agencies in nature which affect the distribution of speeds. Where this has been done the δ function must include the whole effect of these agencies, and this again forbids our relying upon equation (2) in computing the frequency of any speed which makes the value of π small.

B 1. Thus in Mr. Cook's computation no notice is taken of the anisotropic character of the outer strata of the earth's atmosphere, which facilitates the escape of molecules. In Prof. Bryan's this is partly taken into account by treating the molecules as moving in a constant field of force. This may possibly be sufficient, though it ignores the reactions which are also necessarily present. To include them it would be necessary to extend the partition of energy beyond the molecules of the atmosphere to all the other molecules of the earth which attract them.

B 2. Then, again, both computations ignore the incessant turbulence of the atmosphere which, in its lower strata, produces all the phenomena of weather, and in its upper regions phenomena which are swifter and on a larger scale. This turmoil, with all its dynamical, thermal and electrical effects, is

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[1] "Negative" as the term is employed in physiological literature, *i.e.* negative pole of positive element ("zincative").

[2] *Astrophysical Journal* for January 1900.

[3] *Roy. Soc. Proc.*, April 5, 1900, p. 335.

[4] *Scientific Transactions of the Royal Dublin Society*, vol. vi. Part 13; or *Astrophysical Journal* for January 1898. And for further evidence that helium is escaping from the earth, see NATURE of May 24, 1900, p. 78.

due, like most other events upon the earth, to the shiftings about of energy which intervene between the advent of energy and from the sun and its radiation from the earth into space; and to take it into account in an investigation based on the laws of the partition of energy, it would be necessary to extend that partition beyond the earth to the sun and to the intervening æther.

B 3. So, again, the great absorption of solar radiation which takes place in the outer layers of the earth's atmosphere will have to be taken into account, and as it has not been included under function π, it still further augments the part which the δ function takes in equation (1) and renders equation (2) an insufficient one for the purposes of the investigation.

B 4. The commotion going on in the atmosphere consists in part of electrical phenomena. Some of these—thunderstorms, auroras, the electrical condition of fogs, &c.—can be observed from the stations which men occupy at the bottom of the atmosphere, and are of such a kind that they must be accompanied by a charged condition of that stratum of the atmosphere the density of which renders it a better conductor than the atmosphere above it and below. This stratum, then, and the strata above it receive charges of electricity which, according to the varying condition of the strata further down, will sometimes be disguised electricity and at other times undisguised. This electrified condition of the upper regions, co-operating with ascending currents, which necessarily increase in speed as they advance, will presumably give rise to prominences upon the earth's atmosphere, upon which the density of the electrification will be intensified and from which in consequence gaseous molecules find it easier to escape than from other situations. In this and other ways electricity may help the escape.

Now of these agencies, all of which affect the rate at which gas can escape from the earth, none is included in the investigation which Mr. Cook has made of that phenomenon; and only the first (B 1) is dealt with by Prof. Bryan. Moreover, it is probable that these are not the only ways in which nature can intervene, and which have been overlooked. The supposition then that either of the probability laws made use of by those investigators can be applied to our actually existing atmosphere, without a large correcting function δ, would appear to be a mistake; and, if so, the inferences from those laws when so applied are not part of a real interpretation of nature. It need not therefore occasion any surprise that, in the case of helium, the facts of nature seem to negative those inferences. (See NATURE of May 24, 1900; the second column of p. 78.)

EDINBURGH.

Royal Society, July 16.—Lord Kelvin, President, in the chair.—Lord Kelvin read a paper on the motion in an infinite elastic solid by the motion, through the space occupied by it, of a body acting on it only by attraction and repulsion. The ideal atom considered in this paper was a region of space in which the ether was changed in density by the action of forces upon it. In the particular case chosen for development the atom was taken as spherical with spherical distributions of density within it, and every element of matter was supposed to act on every element of the ether according to the Newtonian law. The further assumption was made that the average density of the ether within the atom was the same as if the atom were not present. The atom and the ether were then supposed to be in relative motion, and the total kinetic energy of the ether within the atom was calculated, as also the effective inertia of the ether in the space occupied by the matter. On the assumption that the density of the ether at the centre of the atom was 101 times greater than the undisturbed density, it was found that a refractivity was obtained a little smaller than that of oxygen. By assuming that the average density was in excess or defect of the undisturbed density of the ether, we could extend the method so as to include electrical actions.—In a second paper, on the number of molecules in a cubic centimetre of gas, Lord Kelvin pointed out that in the preceding paper he had been obliged to take the number as 4×10^{20} instead of Maxwell's number, 19×10^{18}.—In a paper on the hyperbolic quaternion, Dr. Alex. Macfarlane showed how by the introduction of "real" instead of "imaginary" vectors, quaternion theorems of spherical geometry could be generalised so as to be applicable to hyperbolic geometry.—Sir John Murray and Dr. Philippi communicated a preliminary note on the deep-sea deposits collected during the *Valdivia* expedition of 1898–9. Leaving Hamburg and passing round by the north of Scotland, the *Valdivia* proceeded southwards by the west coast of Africa to the Cape, thence to the Antarctic seas, returning by way of the Indian Ocean and the Suez Canal. Generally speaking, the nature of the deposits agreed with what was already known, but fuller information was gained in many instances. For example, off the mouth of the Congo samples of coprolitic mud had been obtained, largely made up of little oval pellets of mud which had passed through the intestines of echinoderms. These had consolidated and were apparently in the process of being transformed into glauconitic and phosphatic concretions. The study of the formation and distribution of glauconite was geologically of great importance, and a detailed examination of the *Valdivia* collections would probably throw much light on the subject.—Prof. J. C. Beattie communicated a second part of his researches into the leakage of electricity from charged bodies at moderate temperatures. In most of the experiments described, zinc strips resting on insulated iron plates were sprinkled with various salts and then heated to about 350° C., the whole being enclosed in an iron box which was connected to the case of the electrometer. Among the substances used were common salt, alone or with iodine or bromine, and similar combinations with the chlorides of lithium, lead, potassium, &c. Generally a steady negative charge was produced by the heating, but not always. The difference of potential so obtained depended on the nature of the insulated metals, but not on their distance apart. When high voltages were used, the positive charge leaked away, while the negative charge was retained. An explanation was offered founded on Enright's and on Townsend's experiments.—A communication was also presented by Dr. Thomas Muir on the theory of skew determinants and pfaffians in the historical order of its development up to 1857.—In a brief review of the session, the President referred to the great losses the Society had sustained through the deaths of the Duke of Argyll and Sir Douglas Maclagan.

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