MEMOIRS AND PROCEEDINGS

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NOTE.

The authors of the several papers contained in this volume are themselves accountable for all the statements and reasonings which they have offered. In these particulars the Society must not be considered as in any way responsible.

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MEMOIRS AND PROCEEDINGS

OF

THE MANCHESTER LITERARY AND PHILOSOPHICAL SOCIETY.

Ordinary Meeting, October 2nd, 1894.

HENRY WILDE, F.R.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

Reference was made to the loss by death, since the last meeting, of four honorary members of the Society—Professors HELMHOLTZ, MARIGNAC, KUNDT, and ROSCHER.

There was a brief discussion on the alleged discovery by Lord RAYLEIGH and Professor RAMSAY of a hitherto unknown gas in the atmosphere ; and on the experiments of M. MAXIM with his flying machine.

Mr. HENRY WILDE, F.R.S., read a paper on "A Magnetometer for showing the influence of temperature on the magnetization of iron and other magnetic substances," which was illustrated by successful experiments.

On a Magnetometer for showing the Influence of Temperature on the Magnetisation of Iron and other Magnetic Substances. By Henry Wilde, F.R.S.

(*Received October 2nd, 1894*).

It is not a little remarkable that, in this age of active experimental research, there should be any doubt as to the influence of temperature on the magnetic power of iron and other magnetic substances; yet, from the 17th century to the present time, the most discordant opinions have prevailed on this subject. Barlow, in the year 1822, found that the magnetic power of bars of iron which he experimented upon, as measured by the deflections of a compass needle, *increased* with the temperature up to a dull red heat, at which it was the strongest; but, at a bright red heat, all magnetic action of the iron suddenly disappeared.* Scoresby, Christie, and others, have also noted a similar increase in the magnetic power of iron with increase of temperature, when measured by the same means. Faraday, on the other hand, described experiments to show that the magnetic power of iron *diminished* with increase of temperature. He also found that iron at a bright red heat was not entirely insensible to the action of large magnetising forces.

More recently, Rowland† and Hopkinson,‡ by the employment of electro-dynamic methods and the needle indications of Barlow, have also found an increase in the magnetic power of iron with increase of temperature.

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* *Phil. Trans.*, 1822, p. 117.

† *Phil. Mag.*, 1874, Vol. LXVIII., p. 321.

‡ *Phil. Trans.*, A, 1889, Vol. CLXXX., p. 443.

These experimenters were, however, the first to recognise that the apparent increase of the magnetic power of iron, up to the dull red heat, only held good for small magnetising forces, and, further, they found with Faraday, that the power diminished for large magnetising forces with ascending temperatures. Rowland extended his observations to the magnetisation of nickel and cobalt, and found that the magnetic behaviour of these metals with increase of temperature was the same as he had observed in iron.

Experiments have also recently been made by Rücker on the effects of temperature on the natural magnet (*magnetite*), and he has found that the magnetic power of this mineral apparently increases with ascending temperature. A later pronouncement on this subject was made by the President of the Royal Society (Sir G. G. Stokes) in the year 1890, in the course of his anniversary address, in which he stated that, it was generally believed that the susceptibility or magnetisation of iron decreased with the temperature, but, on the contrary, it had been recently found that the susceptibility was enormously increased with ascending temperatures.* This generalisation was afterwards limited, through my representations, to the action of small magnetising forces.†

In my paper on "The Unsymmetrical Distribution of Terrestrial Magnetism,"‡ it was shown that by heating small surfaces of the thin sheet iron covering the ocean areas of the mapped globe, strong polarity was induced at the junction of the heated parts, just as when the magnetic continuity of the iron was interrupted by cutting through the same parts of the iron in an equatorial direction. Although this experiment appeared to me to demonstrate, conclusively, that the magnetic power of iron was reduced at

* *Nature*, Dec. 11th, 1890.
† *Proc. Roy. Soc.*, Dec. 1st, 1890.
‡ *Proc. Roy. Soc.*, Jany. 22nd, 1891.

comparatively low temperatures and with small magnetising forces, yet, from the contradictory results which had been obtained by other experimenters, directly opposite conclusions as to the magnetic intensities of the land and ocean areas respectively might, with some show of reason, be drawn from those which I had arrived at. The important bearing which the influence of temperature has upon the phenomena of terrestrial magnetism, induced me to undertake an investigation into the causes of the conflicting results hitherto obtained, with the hope, also, that I might be able to extend still further our knowledge of magnetic substances.

The results of my experiments, which are embodied in a paper read before the Royal Society,* confirm the general law of the diminution of the magnetisation of magnetic substances with increase of temperature for *small* as well as for *large* magnetising forces. I have also demonstrated in this paper that the apparent increase of the magnetic power of heated iron, magnetite, and nickel is so small as to be a negligible quantity in general magnetic phenomena and terrestrial magnetism, and is due to a surface resistance of these substances which disappears—(1) on the application of heat; (2) by the action of strong magnetising forces; (3) by diminishing the mass of the magnetic substance acted upon by the magnetising force.

I have further shown that the surface resistance of cobalt at normal temperatures is so great, as to require a tractive force equal to 373 lbs. per square inch, acting on a minute quantity of the metal, to overcome it.

The general results of my experiments have been confirmed by M. P. Curie, in two able papers in the *Comptes Rendus* of the French Academy for April and May of the present year. M. Curie also agrees with my conclusion

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* *Proc. Roy. Soc.*, June 11, 1891.

that the apparent increase of the magnetisation of iron, magnetite, and nickel is anomalous, and masks the principal phenomena of the decrease of magnetic power with ascending temperatures. M. Curie has extended his observations to the magnetic behaviour of gaseous oxygen, and has found with Professor Dewar, when experimenting with this element in a liquid state, a decrease of power with increase of temperature.

The general law of the diminution of the magnetisation of all known magnetic substances with increasing temperatures is now completely established.

In connexion with this brief summary of experiments on the influence of temperature on magnetic substances, I would direct attention to the close analogy, if not an actual relation, which subsists between the anomalous surface resistance of cold iron to magnetisation and its anomalous property of resisting chemical action. Schönbein and Faraday have shown that bright iron wire, slightly oxidised by heat, is quite insensible to the action of strong nitric acid.* Not only is there no reaction under these conditions, but the oxidised wire has the property of inducing voltaic passivity in a number of pieces of bright iron wire by simple contact with them when immersed in the acid. Further, a passive bright wire has the property of inducing the passive condition in other pieces of ordinary bright iron wire.

It is admitted on all hands that this anomalous voltaic condition of iron is a surface resistance, as it disappears (1) by abrasion; (2) by the action of dilute nitric acid; and (3) by the application of heat to the wire.

To affirm, therefore, as a general property of iron, that its magnetic power increases with the temperature, is as irrational as to maintain that iron throughout its substance is, like gold and platinum, insensible to the action of strong nitric acid.

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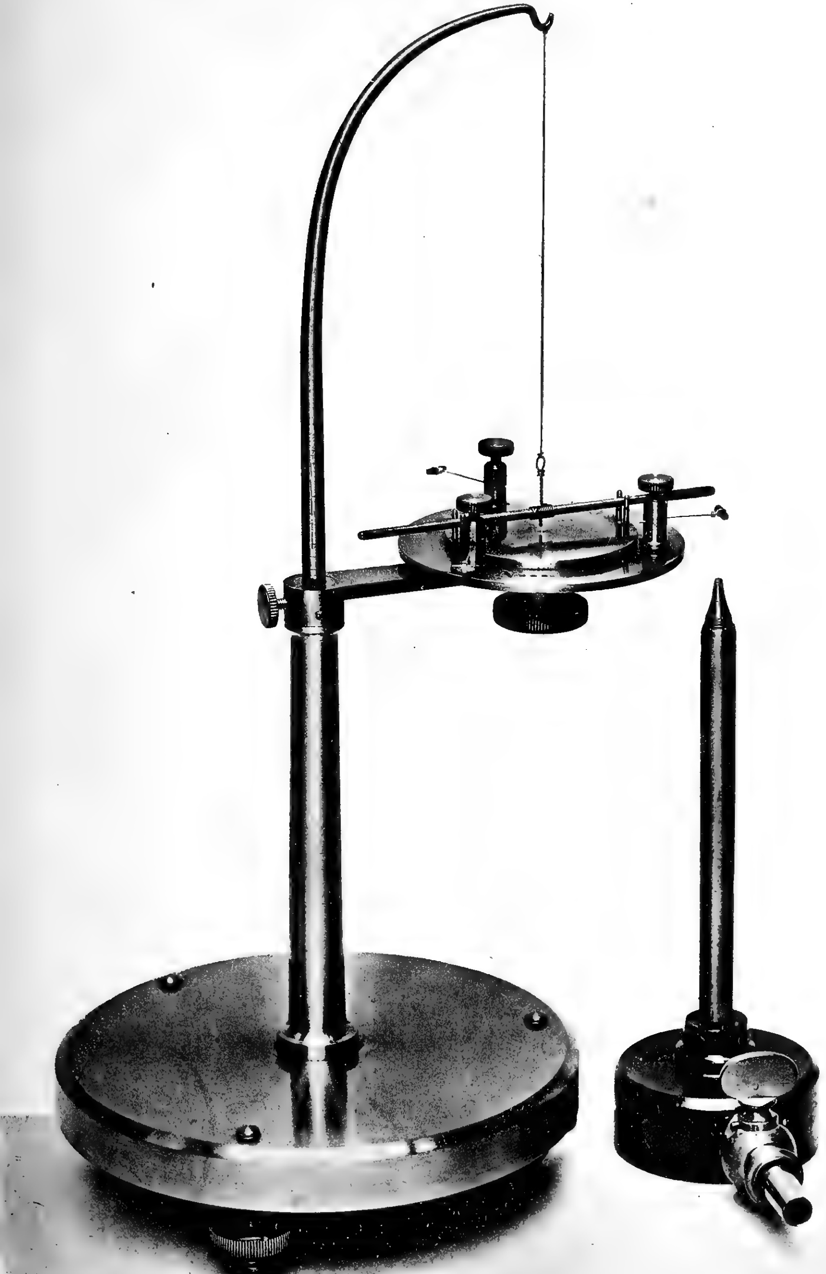
* *Phil. Mag.*, 1836, Vol. IX., pp. 53-65.

For demonstrating the influence of temperature on magnetic substances, I have devised a magnetometer which is shown in the accompanying figure (*Plate* I.) two-thirds the actual size.

The instrument consists of a declination needle freely suspended from a double fibre of untwisted silk over a disk of brass. One end of the needle is thickly covered with spun silk to prevent the weakening of its magnetism by close proximity to the heated substance under examination. The excursions of the needle are limited in both directions by pins inserted a little distance apart on a diameter near the edge of the disk. The disk is pivotted on the end of an arm, to which it can be clamped firmly by means of a milled screw when the needle is drawn out of the magnetic meridian. Three binding screws are mounted at equal distances from each other round the circumference of a circular table, which has an independent movement round the disk. The magnetic substances are held in loops of platinum wire fixed by the binding screws to the table, and the properties of the specimens can be examined in succession.

The action of the instrument is as follows :—The needle is drawn out of the magnetic meridian from 15° to 20° by turning the disk on its axis. The magnetic substance is then brought round towards the needle until equilibrium is established between its magnetism and the horizontal component of the earth's magnetism. The magnetic substance is heated by a small gas flame from below; when the needle recedes from heated iron, magnetite, and nickel, and advances again when the source of heat is removed; thereby indicating a decrease of magnetic power for these substances. On the other hand, the needle advances towards cobalt when heated, and recedes when the metal is cooled, by reason of its enormous surface resistance, which only disappears, as I have said, under the action of powerful magnetising forces.



S.B. Bolas & Co Collotype.

Ordinary Meeting, October 16th, 1894.

HENRY WILDE, F.R.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

A discussion took place on the spreading of thistles and dandelions, and on the restriction of plants to certain localities, as *Cotoneaster* to Great Ormes Head, in which Mr. CHARLES BAILEY, Mr. NICHOLSON, and Dr. SCHUNCK took part.

A paper by Mr. THOMAS HICK, B.A., B.Sc., "On Kaloxylon and Liginodendron," communicated by Prof. F. E. Weiss, B.Sc., was read.

Ordinary Meeting, October 30th, 1894.

HENRY WILDE, F.R.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

A paper by Mr. BEVAN LEAN, B.A., D.Sc., on "The Affinities of Polybasic Acids," communicated by Prof. W. H. Perkin, jun., F.R.S., was read. A discussion followed, in which Mr. R. L. TAYLOR, Dr. RÉE, and Mr. FRANCIS JONES took part.

Mr. H. B. POLLARD, B.A., D.Sc., introduced by Mr. R. F. GWYTHER, M.A., exhibited some models of siluroid fish, drawing attention to their construction. The models had been made after the manner well known in Germany, (invented by Born), but they were electroplated and produced on a much larger scale. The morphological features revealed led to the formation of a new theory on labial structure and the origin of part of the skull of vertebrates, which the author termed the Cirrostome-theory. The labial and other structures round the mouth were homologous with the oral cirri of *Myxine* and *Amphioxus*.

General Meeting, November 13th, 1894.

HENRY WILDE, F.R.S., President, in the Chair.

Mr. MARK STIRRUP, F.G.S., and Mr. WILLIAM BURTON were elected ordinary members of the Society.

Ordinary Meeting, November 13th, 1894.

HENRY WILDE, F.R.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

A paper by Dr. W. C. WILLIAMSON, F.R.S., "On the Question of the growth and development of the Carboniferous Arborescent Lepidodendra, by a study of the Details of their Organization," was read.

Ordinary Meeting, November 27th, 1894.

HENRY WILDE, F.R.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

Dr. LANGDON exhibited a sample of antitoxin, the alleged cure for diphtheria.

Professor HORACE LAMB, M.A., F.R.S., made a communication on "The Stability of Steady Motion."

This had reference to the distinction between 'ordinary' and 'secular' stability, and to the criterion for the latter kind of stability formulated by Thomson and Tait. A simple illustration of the theory is furnished by the case of a particle in an ellipsoidal bowl rotating about a principal axis which is vertical. In the absence of friction there will be 'ordinary' stability, with the particle at the lowest point, when the rotation is sufficiently slow, and again when it is sufficiently rapid; there being an intermediate stage of instability, viz., when the period of the rotation lies *between* the periods of the two principal modes of small oscillation when the bowl is fixed. But if there be friction between the particle and the bowl, there will be 'secular' or practical instability so soon as the rotation is more rapid than the slower of the two oscillations aforesaid. In this case the particle, if disturbed, will work its way outwards, and finally settle down into some excentric position; the energy of the system, for the same angular momentum about the axis of rotation, being less than when the particle was at the lowest point. Instead of a particle in a bowl we might have a Blackburn's pendulum, with the upper string symmetrically attached to a horizontal bar which is made to rotate about a vertical axis through its centre. But, as an illustration of the theory of secular stability, this is not so good as the bowl, since the frictional forces will now depend on the absolute and not on the relative motion of the particle.

Mr. CHARLES BAILEY, F.L.S., made some remarks on the anatomy of the *Iris sibirica*, Linn., a plant which occurs in the northern hemisphere, from Alsace eastwards to Siberia, northwards to Scandinavia and the Baltic provinces, and southwards to Italy and Servia. The young roots are noticeable for their clearly-defined endoderm, made up of a single layer of thick-walled cells. The creeping rhizome is remarkable for its large rhombic crystals, which are contained within cells of corresponding size; these crystals are the equivalents of the smaller and much shorter crystals in the epiderm of the bulb of the onion, and of the raphides of many other plants. These long crystals are not confined to the rhizome, as they are met with in the leaf, stem, and ovary, one of the latter being figured in Dr. Dodel's series of seven large chromo-lithographs, exhibited at the meeting. In this *Iris*, as in other flat-leaved monocotyledons, the leaves are divided by several parallel longitudinal bundles, which form the ridges so plainly to be seen and felt in the leaves of the dried plant; it is these parallel ribs which give the mechanical assistance which enables the long narrow leaves to maintain their erect position when growing. Large air-spaces, bounded by distorted or collapsed cells, occur between the ribs. In most leaves the differentiation of the vessels progresses, ordinarily, from the median rib towards the lateral ribs successively; but in *Iris sibirica* the vessels of the median rib appear the last, as shown by a section through the rhizome at a point where a leaf-bud was being given off, the arrangement of the leaves in the bud being equitant. The epiderm of the leaf presents an unusual arrangement of its flat elongate cells, and of the air-pores intermixed with the epidermal cells; in most flowering plants the distribution of the air-pores to the epidermal cells is that the latter are greatly in excess of the former, as 10 to 1, 50 to 1, 200 to 1, and so on, but in this species of *Iris* almost every epidermal cell touches an air-pore, except in those portions which cover the ribs of the leaf. Further, each epidermal cell possesses a peculiar round body, as though it were a protuberance, or papilla, on the external cell wall. By means of a paper model of the flower, the mechanism by means of which cross-fertilization was effected by insects, was illustrated.

Ordinary Meeting, December 11th, 1894.

HENRY WILDE, F.R.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

A discussion took place on the alleged new cure for diphtheria, antitoxin, in the course of which Dr. HODGKINSON gave evidence from his experience of the apparent efficacy of treatment with sulphite of magnesia.

Mr. HENRY WILDE, F.R.S., read a paper on "The Multiple Proportions of the Atomic Weights of Elementary Substances in relation to the Unit of Hydrogen," in which, with special reference to Lord Salisbury's statement in his presidential address to the British Association at Oxford, that there is no foundation for the theory that the atomic weights of elementary substances are multiples of hydrogen, he maintained the contrary views expressed in his paper on the origin of elementary substances read before the Society in 1878, and gave further evidence in their support. Starting from the nebular hypothesis of the successive condensations of a primordial substance into planetary systems in definite proportions, Mr. Wilde maintains that elementary "species" have been formed from the further condensations of the nebular substances into a series of typical hydrogen molecules, that the series of so-called elements have been formed by the successive condensation of the molecule at the head of each series in multiple proportions, and that the atomic weights of each series are multiples of the typical molecule. He exhibited tables showing such multiple relations between the planetary distances from the sun in a geometric series, and similar relations between the atomic weights of the elements in an arithmetical series. It was admitted that the latest experimental determinations of the atomic weights of some of the elements enumerated did not agree perfectly with the theoretic weights as indicated in Mr. Wilde's tables, worked out from his hypothesis of multiple relations, but, taking four series, including twenty-four members, the author urged that the differences, when distributed over the series, only amounted to 0·0036, or less than half of 1 per cent of the actual determinations, and that chemists should rather endeavour by further investigations to explain these small anomalies than reject his law because of their existence. Dalton's law of definite combining proportions, first given to the world by the Society, might, he contended, have been rejected on similar grounds. In illustration of this point, Mr. Wilde referred to the anomalous specific heat of silicon, and to Regnault's statement that, in order that silicon might enter into conformity with the law of the specific heat of other elements, its atomic weight should be 35, which, though not in accordance with the accepted valency, is in accordance with the theoretic weight as indicated by Mr. Wilde's hypothesis of multiple relations. Mr. Wilde adversely criticised the periodic law of Newlands and Mendeléeff, and, comparing his tables with those drawn up by those chemists, maintained that the latter arrangements were arbitrary, and that when the seriatim order of the atomic weights is rightly adhered to, the idea of octaves, recurring properties, or periodic functions in terms of the vertical series of Newlands or the horizontal series of Mendeléeff has no real foundation in nature.

A discussion ensued, in which Dr. SCHUNCK, Professor H. B. DIXON, Dr. BOTTOMLEY, and Professor SCHUSTER took part.

[*Microscopical and Natural History Section.*]

Ordinary Meeting, 8th October, 1894.

Mr. JOHN BOYD, President of the Section, in the Chair.

Mr. NICHOLSON drew attention to recent correspondence in the press on the shamrock, and stated that the specimens of the plant he had seen in Ireland were of a darker green than those he had noticed in this country.

Mr. ROGERS described the plant as *Trifolium repens*, a clover frequently brought to the Manchester markets from Ireland, which, if planted, flowers late in the year.

Mr. ALLEN suggested that peaty soil, with nitrogenous or ammoniacal constituents, would account for the darker colour.

Mr. ROGERS exhibited a collection of shells from Counties Sligo and Clare (Ireland), consisting of numerous varieties of *Helix nemoralis* and *H. aspersa*, showing great variations of colouring.

[*Microscopical and Natural History Section.*]

Ordinary Meeting, November 5th, 1894.

JOHN BOYD, Esq., President of the Section, in the Chair.

Professor WEISS drew attention to the stem of the melon, in which he had noticed an abnormal growth this autumn—known as thyllosis—which tends in older plants to fill the whole of the cavity of the tracheæ and wide-pitted vessels. The protrusions inwards arise from parenchymatous cells in contact with the vessels, and in the instance of the melon these thyloses consisted of cells with spiral thickenings.

Mr. CHARLES BAILEY, F.L.S., stated that a similar growth occurred in the vine, as Professor van Heurck had sent him a slide in 1864, in which the large vessels of that plant were filled with thyloses, and the compression of growth had made them polyhedral in shape.

Mr. J. COSMO MELVILL, M.A., F.L.S., exhibited a shell, *Voluta aulica*, found near the Philippine Islands, and described as the most beautiful shell in the world.

Mr. THOMAS ROGERS exhibited some shells collected in Egypt, of archæological interest (*Nerita*, *Cypræa*, *Columbella*) of the period of the XXII. dynasty, about 900 years B.C., several being perforated for use as ornaments. They were found by Mr. Flinders Petrie; also specimens of *Nassa* out of Coptic tombs (Egypt), probable date 600 A.D.

Mr. CHARLES BAILEY exhibited a set of Swedish pond weeds, just issued by Dr. Gustav Tiselius, entitled "Potamogetones Suecici exsiccati, Fasc. I. Nos. 1–50; 1894." He pointed out that the southern portion of Sweden is studded with fresh-water lakes and streams, which form a suitable habitat for these plants. They occur in these situations in great variety. The water is stationary as well as flowing at varying rates of speed, deep and shallow. Variations occur mainly in the forms of the leaves, and are probably due to the local condition of the water in which the plants grow. Thus the same species will have broad leaves in one situation, and leaves of an entirely different form in another situation. On a much smaller scale, similar conditions occur in the meres and streams of Cheshire, and among the fens of the eastern counties of this country. Special attention was drawn to the series of *Potamogeton gramineus*, Linn. (=*P. heterophyllus* of British botanists), and to *P. nitens*, Web., one of the Scotch pond-weeds. The specimens were beautifully preserved, and the whole series is likely to prove of great value to students of the genus, as they are accompanied by critical notes upon the new forms which Dr. Tiselius has differentiated.

[*Microscopical and Natural History Section.*]

Ordinary Meeting, December 17th, 1894.

JOHN BOYD, Esq., President of the Section, in the Chair.

Mr. BROADBENT described further observations made by him on the Infusoria.

Mr. BOYD drew attention to a plague of fleas that had infected a refuse heap, on which a cucumber frame was placed, in a garden at Bowdon, after a long spell of fine dry weather this summer. Fleas are known to lay their eggs and to pass their larval and pupal stages in the bed of their host, and from the rapidity with which they breed under favourable conditions it would appear that for some generations at least they can dispense with a host; as, on enquiry from various gardeners, he found that it was not an uncommon thing for a dunghill to get densely populated with fleas in dry weather, but they disappear again when a wet spell comes.

From this Bowdon locality he had had a number of specimens sent him, and had no difficulty in determining that they were of two distinct species, the rat's and the cat's; and on mentioning these facts was informed that the heap was much frequented by both rats and cats, so it is evident from what hosts the fleas originally came. The cat's flea is well known, so the comparison was easily made, and Mr. Boyd had in his possession specimens of fleas taken from a rat's nest with which some of the fleas taken from the refuse heap tallied exactly. This flea of the rat is very long and slender, colour very dark, nearly black, legs short, antennæ erect, and has a pectinate fringe at the back of the head, but not at the anterior extremity of the head.

Mr. Boyd also mentioned that in the early summer he found that some sparrows had taken possession of a martin's nest, and were breeding in it; accordingly he took down the nest, which the martins afterwards rebuilt. He found this nest was infested by small fleas, of the species commonly found associated with fowls, pigeons, and other birds.

The opinion was expressed that although the fleas of other animals or of birds may cause some temporary inconvenience to man, they will not stay with him or trouble him long, as they do not breed on him, but only in the bed of their respective hosts, or in other suitable localities.

Mr. MARK STIRRUP read a paper on "Some arenaceous Foraminifera from deep-sea dredgings," and exhibited a large number of specimens under the microscope.

On the Affinities of Polybasic Acids. By Bevan Lean, D.Sc., B.A., Assistant Lecturer, and late Bishop Berkeley Fellow of Owens College. Communicated by W. H. Perkin, jun., F.R.S.

Received October 30th, 1894.

Introduction.

The author has described elsewhere[1] some tetracarboxylic acids which possess some very remarkable properties. They are derivatives of butane, of the general formula

$$\begin{matrix}HOOC\\HOOC\end{matrix}\!\!>CR-CH_2-CH_2-CR\!<\!\!\begin{matrix}COOH\\COOH\end{matrix},$$

in which R represents the alkyl group methyl, ethyl, cetyl or benzyl, and, although they contain four carboxyl groups, these acids do not in all cases behave as tetrabasic acids.

On determining their basicity by titration with standard solution of potassium hydrate, some of these acids show *di*-basicity: notably is this the case with dibenzylbutanetetracarboxylic acid, the result being the same whether phenol phthaleïn or litmus solution is used as the indicator. On the other hand, dimethyl-, diethyl-, and dicetyl- butanetetracarboxylic acids, on being titrated with potassium hydrate, give different results, according as phenol phthaleïn or litmus is employed as an indicator. They behave as tetrabasic acids when phenol phthaleïn is employed. If, however, one or two drops of litmus solution be added to

[1] "On Ethyl Butanetetracarboxylate and its Derivatives," a Thesis accepted for the degree of Doctor of Science of the University of London.

the solution of these acids in potassium hydrate, which, as shown by phenol phthaleïn, has been neutralised by hydrochloric acid, a distinctly blue coloration is produced. On adding more hydrochloric acid, the blue coloration changes gradually to a red tint, and the solution appears to become really neutral only when sufficient hydrochloric acid has been added to neutralise one half of the potassium hydrate, which was equivalent, as shewn by phenol phthaleïn, to the tetracarboxylic acid present.

In view of these results, obtained in determining the basicity of the acids, it appeared of interest to examine some of their salts. While the silver and calcium salts prepared in the usual way from dimethyl and diethylbutanetetracarboxylic acid are found to be tetrabasic, those prepared from dibenzylbutanetetracarboxylic acid are found to have the formulae $C_{22}H_{20}O_8Ag_2$, and $C_{22}H_{20}O_8Ca + 2\ H_2O$ respectively; so also the salts prepared from dicetylbutanetetracarboxylic acid are found to be dibasic.

On the different behaviour of Indicators.

By these observations is brought out, in the first place, the fact of the different behaviour of indicators towards one and the same acid. It has been shown that the tetrabasic potassium salts of dimethyl-, diethyl-, and dicetyl- butanetécarboxylic acids are neutral to phenol phthaleïn, but alkaline to litmus, and in titrating these acids with litmus the final colour-changes are very indefinite.

To illustrate further the different behaviour of indicators, reference may be made to a systematic investigation of the use of litmus, methyl-orange, and phenol-phthaleïn as indicators, which was carried out by Smith[1] in 1883. The following table, compiled from his results, shows the character of the final colour-changes with several organic acids:—

[1] Smith, *Chem. News*, 47-136. (1883).

	Oxalic.	Acetic.	Tartaric.	Citric.
Methyl-orange ...	low results	very low results	very low results	very low results
Litmus	sharp	indefinite	indefinite	indefinite
Phenol - phthaleïn	sharp	sharp	sharp	sharp

Engel[1], too, has shewn that when a solution of phosphoric acid is titrated it appears monobasic if methyl-orange is used as the indicator, but dibasic with phenol-phthaleïn, and tribasic with Poirier's soluble blue. He also showed that boric acid is neutral to methyl-orange, feebly acid to litmus or phenol-phthaleïn, and acid to soluble blue.

From these instances it appears that litmus is liable to give lower results than phenol-phthaleïn, and in the case of litmus, the final colour-change is usually very indefinite. It also is evident that any knowledge of the basicity of an acid obtained by titration is only relative to the nature of the indicator employed. And, further, when a polybasic acid has been only partially neutralised its acid character may be enfeebled altogether out of proportion to the amount of a base which has been added to it.

This raises the wider question of the basicity of a polybasic acid, and of its affinity as a function of the affinity of any one of the replaceable hydrogen atoms which it contains.

On the Affinities of Polybasic Acids.

It will be in place, at the outset, to point out the essential character of an acid. The evolution of an all-embracing yet sufficient *definition of an acid* has been a gradual one, and it is of no small interest to trace the views of Paracelsus, Boyle, Stahl, and Becker, the oxygen-acid theory of Lavoisier, and Berzelius, and the hydrogen-acid views of

[1] *Comptes Rendus*, 102, 262 (1886).

Davy, Dulong, and Liebig. It may be remarked, too, that after the work of Kolbe and Frankland, Kekulé stated that the basicity of an organic acid was determined solely by the number of carboxyls which it contained—a conclusion which can only be maintained by defining an organic acid as a substance containing carboxyl. The following definition of an acid states as clearly as may be the modern conception of an acid ; it is due to Ramsay :—

> "An acid is a compound of hydrogen, which when mixed with or dissolved in water, is capable of exchanging the whole or a portion of the hydrogen which it contains for a metal, with simultaneous formation of water, by the action on the aqueous solution of the acid, of a metallic oxide or hydroxide."

Substances which come under this definition are found to contain hydrogen in intimate combination with one or more of the following : fluorine, chlorine, bromine, iodine, oxygen, sulphur, selenium, tellurium, or certain groups of elements of which carbon is one. Amongst organic compounds there are many besides carboxyl derivatives which can exchange hydrogen for a metal by the action of an oxide or hydroxide. The chief of these are certain acid ethereal salts, the mercaptans, many nitro-derivatives of the alkyl radicals, and phenols. From a consideration of these compounds Ramsay has drawn the following deductions :

(*a*) A powerfully electro-negative element such as chlorine bromine, or iodine, confers acid properties on its compound with hydrogen.

(*b*) In compounds of elements exhibiting less markedly electro-negative properties than the halogens, the presence of an electro-negative element is necessary for the development of acid character. In illustration of this the following series of compounds may be noted :—

methane—methyl alcohol—prussic acid.
anthracene—anthraquinone—alizarine.

The study of the *basicity of acids* has done much to enlarge our knowledge of acids. From the dualistic stand-point of Berzelius a neutral salt was regarded as the compound of an acid with a basic oxide, and this combining proportion was considered the rule.

The conception of the basicity of acids was introduced by Graham's famous research upon the phosphoric acids in 1833. He showed that the three phosphoric acids contained one atom of phosphoric acid, PO_5, in union with different amounts of "basic water," which were replaceable by metallic oxides, and he showed that the different properties of these acids depended upon the different amounts of "basic water" they contained.

In 1838, after a study of the organic acids—malonic, citric, aconitic, comenic, tartaric, and others — Liebig advanced a Theory of Polybasic acids, and laid down as the criterion of polybasicity the capability of forming salts with different metallic oxides, and he was the first to distinguish between mono-, di-, and tri-basic acids. The theory of polybasic acids was further developed by Laurent and Gerhardt, and later by Wurtz and Kekulé.

As a result of their labours the basicity of an acid has been regarded as determined by the number of stages in which the hydrogen can be replaced; in other words, by the number of salts it can form with a specified monovalent metal.

More recently the researches of Thomsen have shown that the basicity of an acid may also be determined by an examination of its *Heat of neutralisation*, and that the results so obtained agree with the conclusions drawn from the study of the salts of an acid.

The principle of the thermal method may be stated thus:—the thermal value of the reaction of a monobasic acid with a monacidic base in dilute aqueous solution is independent of the ratio between the number of molecules of acid and base, provided not less than one of base is mixed with one of acid; whereas in the case of a polybasic acid, the thermal value varies according as one, two, three, etc., molecules of a monacidic base react with one of the acid.

Attention should particularly be directed to the fact that the relative energy of combination of the first, second, and third equivalents of a base with an acid are not necessarily the same—in fact they are in general different. The following instances may be quoted from Thomsen's work:

	Heat produced on neutralisation.			
	Sulphuric.	Oxalic.	Succinic.	Phosphoric.
1st NaOH...	14,750	13,850	12,400	14,850
2nd NaOH...	16,650	14,450	11,750	12,250
3rd NaOH...				6,950

We have in these numbers the first illustration of that which it is especially desired to bring out in this paper, namely, that the affinity of a polybasic acid is a complex function, and is not measured by a simple multiple of the affinity of one of the acid groups contained within the molecule.

Although the above numbers sufficiently indicate the basicity of the acids, it is now recognised that the heats of neutralisation of the aqueous solutions of the acids do not represent exactly the quantities of heat liberated by the combinations of the acid with the base. Secondary actions often occur, such as the dissociation of the salts and formation of hydrates, so that the thermal effect observed is only a resultant one. To avoid these sources of error Bertholet[1] showed several years ago that it is sufficient to refer all the compounds to the solid state. Some determinations which Massol[2] made in this direction in 1891 are particularly

[1] *Ann. Chim. Phys*; 5. IV. 122 and 130.

[2] *Comptes Rendus*; 112, 1062.

worthy of attention. He measured the heats of neutralisation of the first and second molecules of a base with the molecules of dibasic acids of the oxalic acid series, with formation of solid salts. He obtained the following results :—

	Oxalic.	Malonic.	Succinic.	Sulphuric.
1st KOH ...	34,280	27,870	25,260	47,800
2nd KOH ...	24,690	20,700	21,150	33,600

The particular point of importance in these observations is that in every case the second molecule of the base liberated *less* heat than the first, while in measurements of the heat of neutralisation in aqueous solution the reverse was frequently observed by Thomsen. Massol pointed out that while the heat of neutralisation of formic acid with potassium hydrate and formation of a solid salt is 25,800 units, that of oxalic acid, which may be regarded as a carboxyl derivative of formic acid, has more than twice as great a heat of neutralisation, as though the two carboxyls effect a mutual strengthening of one another. It is seen from the above table that when one of these carboxyls is neutralised, the acid salt of oxalic acid acts like formic acid, and has almost the same heat of neutralisation.

The results, then, at which he arrived, Massol attributed to a reciprocal action between the acid groups—an action which is less in degree in malonic and succinic acids, in which the carboxyl groups are further apart from one another.

Berthelot, in a note to Massol's paper, pointed out that the greater heat liberated by the first molecule of base is a necessary consequence of the fact[1] that a dibasic acid combines with its own normal salt to form an acid salt in the solid state with disengagement of heat.

[1] *Ann. Chim. Phys.*, 5. IV. 130.

Turning now to the researches of Ostwald and his collaborateurs on the *Electrolytic conductivity of carboxylic acids* other facts are found, which have significance in the present connection. In 1884, Arrhenius advanced the theory that the electrolytic conductivity of acids is proportional to the velocities of their reactions or 'affinities' as measured by several methods. This proportionality was fully verified by W. Ostwald in 1884-5, and hence, as electrolytic conductivity can be measured with very great accuracy, a most important method is at hand by means of which to obtain a further insight into the functions of acids. Ostwald especially studied the influence of dilution upon the electrolytic conductivity of aqueous solutions of acids. He found that all the strong monobasic acids, such as hydrochloric or hydrobromic acids, have nearly the same conductivity, and that this increases 10-12 per cent. on dilution. Kohlraush proved that the conductivities of strong acids reach a maximum at great dilutions and then remain constant, a fact which he attributed to the complete dissociation of an acid R_1H into the ions $\overline{R_1}$ and $\overset{+}{H}$. With weak monobasic acids, however, Ostwald showed that values are obtained, which still increase with the utmost dilution; nevertheless he has shown how to calculate from determinations at finite dilutions what he has termed the dissociation or affinity constant of the acid.

It has been shown above that the researches of Thomsen and Massol upon the heats of neutralisation of acids bring out the fact of the strengthening influence which one carboxyl exerts upon another. Further evidence of this effect is afforded by a consideration of the affinity constants of acids. The following table has been drawn up to show the relation between the affinity constants of the monobasic acids of the acetic series and the dibasic acids of the oxalic series.

Monobasic Acids.[1]		Dibasic Acids.[2]	
Formic Acid	... ·0214	Oxalic Acid	... 10·
Acetic ,,	... ·0018	Malonic ,,	... ·171[3]
Propionic ,,	... ·00134	Succinic ,,	... ·00665
Butyric ,,	... ·00149	Glutaric ,,	... ·00475
Valeric ,,	... ·00161	Adipic ,,	... ·00371
Hexylic ,,	... ·00145	Pimelic ,,	... ·00357

It is seen at once that while in both series the affinities of the acids decrease as the homologous series are ascended, in every case the affinity of a monobasic acid is more than doubled by the introduction of a second carboxyl group, indicating that the two carboxyl groups have a mutual strengthening influence upon one another. It appears also that this influence decreases in extent as the distance between the two groups is increased.

The influence which other groups than the carboxyl group may effect upon the affinity of an acid can be illustrated among the dibasic acids of the oxalic acid series. The following tables of affinity-constants have been compiled from papers by Bethmann[4], Walden[5], and Walker[6] :—

Malonic Acid 0·171.			
Methyl-malonic ...	·086	Dimethylmalonic ...	·076
Ethyl- ...	·127	Diethyl- ...	·74
Propyl- ...	·113	Dipropyl- ...	
Benzyl- ...	·151	Dibenzyl- ...	4·1

[1] Ostwald : *Zeit. für phys. Ch.* ; 3.174 (1889).
[2] Ostwald : *ibid* 3.271 (1889).
[3] Bethmann : *ibid* 5.402 (1890).
[4] *Zeit. f. phys. Ch.* 5. 403 (1890).
[5] *Ibid*, 8, 433 (1892).
[6] *J. C. S.* 61, 696 (1892).

Succinic Acid ·00665.				
			Anti.	Para.
Methyl-...	·0086	Dimethyl- ...	·0122	·0204
Ethyl-	·0085	Diethyl-	·0245	·0343
Propyl-...	·0089	Methylbenzyl-...		·0219
Benzyl-...	·0091	Ethylbenzyl- ...		·0261

Glutaric Acid ·00475.				
			Anti.	Para.
Methyl-...	·0052	Dimethyl- ...	·0053	·0055
Ethyl-		Diethyl-	·0055	·0055
Propyl-...		Methylpropyl...		·0059
Benzyl-...		Methylbenzyl...		

Pimelic Acid. ·00357[1].		
	Dimethyl-	·00339
	Diethyl-	·00345
	Dipropyl-	·0032
	Dibenzyl-	·0048

Whilst there are some irregularities which require explanation, the figures in the above tables bring out clearly the fact that an increase in the conductivity of a dibasic acid is effected by the introduction of alkyl-groups, and the heavier the group, the greater is its influence. The benzyl group, on account of its mass, and probably still more by reason of its acid character, appears to have an especial influence.

[1] The dialkyl pimelic acids have not been separated into two modifications.

In view of the relations which have already been brought out, it is of great interest to compare the constants of tetracarboxylic acids with those of the corresponding dicarboxylic acids. The only cases which have apparently been investigated hitherto are the dimethyl and diethyl derivatives of pentanetetracarboxylic acid ; in each case as Walker[1] has pointed out, the affinity of the acid is enormously increased by the close proximity of the two carboxylic groups at either end of the molecular chain.

	Pimelic Acid.	Pentanetetracarboxylic Acid.	Ratio.
Dimethyl ...	·00339	0·37	1 : 109
Diethyl ...	·00345	2·1	1 : 608

The new dialkyl-derivatives of adipic acid and of butane-tetracarboxylic acid, which the author has described elsewhere, are now in the hands of Dr. J. Walker, and the determination of their affinity constants will be awaited with interest.

In view of the various evidences which have been adduced of the strengthening influence of one group upon another, the facts referred to in the Introduction appear somewhat less anomalous. In the tetracarboxylic acids referred to of the general formula

$$\begin{matrix} HOOC \\ HOOC \end{matrix} \!> CR - CH_2 - CH_2 - CR <\! \begin{matrix} COOH \\ COOH \end{matrix},$$

there is that juxtaposition of acid groups which we have seen so enormously increases the affinity of the acid, and in accordance with this they have a well-marked acid character. So soon, however, as the dibasic salt

[1] Walker, *loc. cit.*

$$\begin{matrix} KOOC \\ HOOC \end{matrix} > CR - CH_2 - CH_2 - CR < \begin{matrix} COOK \\ COOH \end{matrix}$$

is formed, the strengthening influence of one carboxyl upon another no longer exists, and as a matter of experience such a salt has little or no acid character. When R represents the alkyl groups, methyl or ethyl, the dibasic salts, have a slight acid action and yield tetrabasic salts, whereas when R denotes the heavier groups, benzyl or cetyl, it was not found possible to prepare tetrabasic salts in the usual way.

The facts which have been brought forward show that the chemical activity of a polybasic acid is a complex function of the affinities of the several groups which it contains, and that the action of one or more groups cannot be "neutralised" without affecting the affinities of the rest. The chemical character of a group, in fact, depends not alone upon itself, but also upon the nature of those in the society of which it is found.

On the light thrown upon the question of the Growth and Development of the Carboniferous Arborescent Lepidodendra by a study of the details of their Organisation. By W. C. Williamson, LL.D. and F.R.S., Emeritus Professor of Botany in the Owens College, Manchester.

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Prior to the year 1832, when Witham published his account of his newly discovered specimen of *Lepidodendron Harcourtii*, nothing was known respecting the internal organisation of the magnificent *Lycopodiaceous* Plants found so abundantly in the strata of Carboniferous age. The discovery of that specimen marked an epoch in the history of Palæobotany. Sections of this important fragment came into the possession of Adolphe Brongniart, then our supreme authority in Palæo-botanical subjects, and that distinguished man described them with the greatest care in the last published part of his "Histoire des Végétaux Fossiles." So far his work was admirably done, but unfortunately he was led by it to adopt an erroneous hypothesis, to which he clung to the end of his life. The influence of his distinguished name caused this hypothesis to be adopted by most of the then living Palæobotanists, and it has been handed down to an entire generation of their successors. In 1845, Corda obtained a second and somewhat similar specimen; but our real progress in connection with these studies dates from about 1855, when Mr. Binney discovered, in some of the lowest of the Lancashire coal-seams, a vast number of Calcareous nodules, containing remains of Carboniferous plants, in most of which the internal organisation was as well preserved as in Witham's specimen. Still later similar deposits were found in various parts of the contiguous district of Halifax. At that time Binney fully accepted Brongniart's erroneous conclusions. About that period my own attention became directed to the same class of objects, and as my researches progressed I discovered what the error was into which Brongniart had fallen.

In living *Cryptogamic* plants such as *Equisetums*, *Ferns*, and *Lycopods*, no trace of a secondary Exogenous Zone, the product of a Cambium layer, was then known to exist. Brongniart interpreted his fossils by what he believed to be characteristic of all the living ones ; hence he adopted the hypothesis that if any of these Carboniferous fossil plants possessed a secondary or exogenous xylem structure they could not possibly belong to the *Cryptogamic* family. Since his day we have found that this mode of growth exists in the living *Isoetes* or Quill-worts. I soon discovered that all the extinct *Equisetiform Calamites* possessed this structure, and as time went by I obtained the clearest evidence that nearly all the Carboniferous *Lycopods*, the *Lepidodendra*, the *Sigillariæ* and the *Stigmariæ* were similarly organised. It required a long conflict to convince the disciples of the Brongniartian school of the correctness of these conclusions ; but after a contest of nearly twenty years' duration my views were almost universally recognised as correct. But other and not unimportant questions remained, on which wide differences of opinion existed. In the earlier stages of my investigations, and when my specimens were comparatively few, I arrived at certain conclusions respecting the mode of growth of the Carboniferous *Lycopods*, which were not accepted by some of my botanical friends, especially by Graf Solms-Laubach. Time rolled by without our coming to any general agreement. At length, the specimens in my cabinets having enormously increased in number, I determined to subject them to an elaborate investigation in order to observe carefully what the facts were bearing upon the disputed points, and six of the summer months of 1894 were perseveringly devoted to this enquiry. Some preparatory observations on the general structure of these plants will help students to understand what these points are. In the youngest *Lepidodendroid* twigs the conspicuous central tissue is a small vascular bundle known as the Primary Xylem strand. It extends, under varied modifications of form and size, from near the apex of the youngest twig to the base of the oldest stem. In its downward course it gives off a large number of small vascular bundles, known as leaf-traces, each one of which passes outwards to a leaf, supplying it with its vascular tissues. In many cases we discover a few cells in the centre of its component tracheids, which, on passing downwards towards the lower members of the tree, enlarge into a more or less conspicuous medulla. In a few cases the smaller shoots exhibit no traces of these cells, which are only discoverable in branches of somewhat larger size; but in all, the larger the twig, the larger also is the central cellular tissue in varying degrees and in different types. This is a true medulla, which generally exhibits its maximum diameter only at the base of the oldest stems. Externally to this Primary Xylem system, and in the closest contact with it, a second vascular zone, known as the *Secondary Xylem*, is developed, much like the wood of ordinary trees, from a cambium layer investing its periphery. This second tissue system is composed of vertically prolonged, radiating, vascular laminæ, which are separated by intervening medullary rays. This Secondary zone and the Primary Xylem enclosed within it form what is known by the name of the *stele;* and, as in these Carboniferous *Lycopods* we have but one such concentric combination of tissues, these stems are said to be *monostelic.*

All the yet more external zones of tissue constitute the Cortex, supporting the leaves on its outer surface. In its youngest state this tissue consists almost wholly either of rounded cells (parenchyma), or of vertically elongated ones with pointed ends (prosenchyma). At a more advanced stage of growth, the commencement of which varies in different types, a thin *meristemic* zone makes its appearance in the outermost parenchyma of the Cortex; an irregular ring of its rounded cells, seen in transverse sections, undergo divisions: the more internal of these new cells are developed into *prosenchymatous* ones, thus causing the formation of a layer of "*periderm*" which continues to grow by similarly produced additions to its exterior so long as the plant continues to live. It is this layer that constitutes the great bulk of the gigantic stems, some of which have a circumference of ten or twelve feet, and at the bases of which this periderm attains its greatest thickness. The outermost of the cells produced by the above meristemic action again undergo a succession of similar metamorphosis, so that whilst the periderm enlarges, there always remains a thin layer of parenchyma between the periphery of that periderm and the bases of the leaves. These leaves vary much in the different types, being sometimes elongated and narrow, and in other forms they are very short and broad; the bases of these leaves, which are small and nearly square in their young state, becoming very much enlarged and protuberant as growth advances. Eventually the true leaf falls off, leaving its base, known as the leaf cushion, behind it, but on the point from which the leaf was detached we find it has left the *leaf-scar*, a quadrangular area of varied shapes and sizes upon which we discover three well-marked points. These leaf bases are more often than otherwise arranged upon the aged stem in *diagonal* lines, though in others these lines are conspicuously vertical; but even in these latter the diagonal disposition is easily traced. In the majority of the specimens of these barks collected from horizontal beds of soft shale, the normally prominent leaf-cushions have been so mechanically compressed that all traces of their prominence have disappeared. The branching of these plants is universally dichotomous. Such is an outline of the fundamental characteristics of these Carboniferous *Lycopods*; thus far intelligent palæobotanists, like my old friend Graf. zu Solms and others, are substantially in agreement with me. But we now have to deal with facts respecting the explanations of which we were not in agreement. These differences related to problems connected with the growth of these plants, and especially affecting the organisation and development of the tissues constituting the Primary Xylem or central part of the stele. In his "Fossil Botany," Professor Solms stated, on p. 230 of the English Edition, the points on which he differed from my conclusions on the debated question, and there are other friends who agreed with his opinions. When preparing for publication Part III. of my series of memoirs "On the Organisation of the Fossil Plants of the Coal Measures," I arrived at the conclusion that the young twig was merely an infantile representative of the matured stem; that young and small twigs only differed from matured stems and branches so far as the age and growth of the latter altered their development and organisation; and in Plate I., Figs. 2, 3, 4, and 5, I represented transverse sections of the Primary Xylem of the stele, as it appeared in branches of various dimensions, and which I regarded as representing what we should have found if we could have made such a series of sections of the same living branch at various parts of its length. But my friendly opponents denied the possibility that Figs. 8 and 11 of the series referred to above, ever were, or could have been, in the condition represented by Figs. 3 and 4, but that each of this series must have belonged to "branches of different orders." In like manner they disbelieved that Fig. 20 of Plate XLIII. ever was in the condition of Fig. 19, only altered by age and growth. Until now no tabulated collection of the facts by which this controversy must be decided has been made by anyone; and I further doubt if any cabinets exist, save my own, large enough to supply such facts. But I have long been utilising the contents of those cabinets in bringing together the facts, the full knowledge of which is necessary for the settlement of the question.

But before proceeding to lay before the Society the various measurements and other results of my investigations, I would call attention to what takes place sooner or later, when each hitherto undivided stem dichotomises, producing, at a higher level, two younger and smaller branches. It is to the ascending series of these dichotomies that the *Lepidodendra* owe their characteristic structure and modes of development. The normal form of a transverse section of an ordinary branch is cylindrical, as is also that of several of the tissue systems that occupy its interior. The first internal change that takes place affects the central vascular cylinder of Primary Xylem, and its contained cellular medulla. These can only be well seen on making transverse sections of the branch. This cylinder becomes split vertically for a very short distance, dividing it into two crescentic diverging halves. As soon as this process has fairly occurred, the external form of the branch begins to alter. The two leafy surfaces parallel to a plane through the two diverging crescents become flattened, and transverse sections of the branch, at this point, gradually assume an oval in place of a circular form. The higher the point at which such sections are formed within the dichotomising area, the greater becomes the difference between the longer and shorter axes of the dividing cortex. Still no separation of the branch into two smaller ones is yet visible externally, but such a separation speedily manifests itself. Before this latter stage is reached the two transverse sections of the divided Primary Xylem cylinder now appear as two crescents, the two horns of each of which approach one another; at this point the cells of the two *medullæ* are in direct continuity with those of the inner cortex. Several of my sections demonstrate that, for a very short space, this crescentic condition is a permanent one, and approximates to what Du Bary speaks of as "the Foliar gap" in Ferns (*Comparative Anatomy of Phanerogams and Ferns*, English Translation, p. 283). But at a slightly higher point the horns of each of these two crescents rapidly converge, and become united into two circular cylinders differing in no respects, save size, and number of internal parts, from that of the parent stem. Sachs designates each portion of a stem or branch immediately below a dichotomy, the *basis of bifurcation.* Yet higher there occurs sooner or later a second dichotomy at the summit of each of the two smaller branches produced by the first one. What takes place in this is a mere repetition of what had occurred lower down, and each of the four resultant younger branches has, as before, though diminished in diameter, exactly the same type of organisation as the two "bases of bifurcation" from which they sprang. We thus see that, however numerous the dichotomies, they are all produced in exactly the same way; and from the base of the parent branch up to the smallest terminal twig of the full-grown tree, no structural changes are introduced, save certain secondary ones produced by growth processes, which begin to manifest themselves at the base of that trunk.

It will be readily understood that at each of this ascending series of divisions the number of the cells and vessels of the bark, Primary Xylem strand, and medulla contained within each "basis of bifurcation" are reduced to one-half in each of the younger branches, and that a similar diminution occurs in the leaves with which the cortex is clothed. It must be remembered that such dichotomies can only occur when the twigs about to be divided are terminal ones, provided with a growing point.

But, besides these equal dichotomies, there exists in these plants a series ot unequal ones of a different character, and leading to different results. These present themselves in two secondary forms. In one, instead of the cylinder of Primary Xylem being divided into two practically equal halves, a very small segment of the circle is cut out of it, and passes outwards as a branch, carrying with it a small portion of the medulla. As it does so this unsymmetrical segment gradually changes its form, becoming a solid tracheal strand without any trace of a medulla; but occasionally we find that a similar bundle retains a cylindrical medulla in its interior. This latter condition is rare; but in most cases, on reaching the axis of the strobilus it is intended to support, a central medulla is developed. The solid type just described seems to be confined to strands destined to supply organs of fructification. In the second form of this unequal dichotomy, instead of the segmentation reaching the medulla, a limited number of tracheids is detached from the periphery of the Primary Xylem strand, the segmentation not reaching the medulla. Strands thus produced also go to reproductive organs.

My renewed researches have been made among numerous types, from which I have selected the following, because they supply me with a large range of specimens of various dimensions and, as I believe, of different ages, calculated to throw light upon some of the debated questions:—

Lepidodendron Selaginoides.
L. brevifolium.
L. Wunschianum.
L. Harcourtii.
L. fuliginosum.
L. mundum.
L. parvulum.

But it may be well to explain how I have obtained some of the statistics recorded in the following pages. My measurements are chiefly made in millimetres. So far as regards the mean diameters of the medullæ, the Primary and Secondary Xylem cylinders, and the thickness of the walls of these cylinders, reliance may be placed upon their strict accuracy. More difficulty was experienced in counting, with approximate accuracy, the number of the tracheids visible in transverse sections of those cylinders. The difficulties arose from the fact that, in young growths especially, the *peripheral* tracheids are so small and their cell walls so thin that they were sometimes almost undistinguishable from the cells of the surrounding cortex. But I am certain that I have made a sufficiently close approximation to their true numbers to shew the enormous differences between what we find in the younger twigs and the larger and older growths. In cases where those tracheids were numbered by hundreds, and even by thousands, a different method had to be employed. I measured with the utmost care the circumference of the section of the cylinder, and the mean thickness of the cylinder wall. I then counted the number of the tracheids enclosed in each of six squares of the twentieth of an inch in diameter, and I placed these data in the hands of my friend Professor Hudson, of King's College, who kindly superintended the calculations based upon them, and placed in my hands the results recorded in the following pages.

The further question has arisen, how far has the ordinary growth of a branch exercised any influence upon, or borne any relation to, the varying dimensions of the Primary Xylem cylinder of the stele, and upon the number of its component tracheids? I think my measurements will be found to give some decided answers to these questions. By what *modus operandi* these results have been brought about was hitherto an open problem. Unlike what occurs amongst the living *Lycopods*, amongst the Carboniferous *Lepidodendra* we find, as we descend from the uppermost and youngest shoots, that there is a regular progressive enlargement of the branches below each succeeding dichotomy ; and, what has an important bearing upon my present methods and ultimate conclusions, these enlargements are accompanied by a similar though less conspicuous enlargement of the cylinder of Primary Xylem, and also in the number of its component tracheids.

In measuring the relative sizes of these branches I confine myself to the periphery of the Prosenchymatous or Periderm Zone of the cortex. I do so because the leaves are an uncertain boundary as well as being so frequently absent, which is rarely the case with the tissue referred to. In some of my larger sections even this peripheral outline has broken away. Nevertheless, I have still measured what remains of the cortex, since its large dimensions shew how much the branch from which it is taken must have advanced in age.

The Type of Lepidodendron Selaginoides.

In this type a peculiarity exists which prevents my measuring the Primary Xylem of the stele beyond recording the diameter of its periphery. The latter margin is sharply defined, but its internal one is not so. Unlike all the other types the tracheids, which are numerous and densely aggregated at the periphery, become fewer in number and less densely packed as we approach the centre of this tissue system, where the tracheids are frequently interspersed amongst the cells of a peculiar form of barred parenchyma occupying the position of the medullary cells of all the other *Lepidodendra.* This renders the counting of these tracheids almost an impossibility and the measurement of the quasi-medulla an absolute one.

The Table I. shews that in ten sections of this plant the diameter of the cortex advances from nine and a half millimetres to ninety-two in C.N. 1922D. That in the same series the diameter of the Primary Xylem cylinder increases from 1·5 mm. in C.N. 337 to 6 mm. in C.N. 1922D ; and that whilst in 337, 335, and 337A, no trace of a secondary xylem has yet made its appearance, we find a thin crescent of this tissue-strand in C.N. 339, it has steadily increased to 14·5 in C.N. 1922D. We thus see that throughout these fourteen sections the increase in the diameter of the branch as a whole has been accompanied by a corresponding enlargement of the succession of tissue systems that occupy the interior of the branch.

Here also we have in C.N. 340 and 340A two examples of equal dichotomies, and one, 1922D of an unequal Dichotomy, but of the type in which, though one of the two resultant branches is very much smaller than the others, there is no difference in the details of their organisations. This dichotomy occurs in the largest section of the Selaginoides type that I have yet discovered.

Type of Lepidodendron brevifolium.

This Burntisland plant is primarily important because of the extraordinary profusion and exquisite preservation of the youngest twigs in various stages of their development, of which some portions of the stratum in which they are imbedded are almost entirely composed. Another feature consists in the remarkable number of equal dichotomies which exist amongst these young twigs. In the first eleven sections recorded in Table II. the very distinct cylinders of *Primary* Xylem are composed of varying and increasing numbers of tracheids, from 40 in C.N. 480 to 80 in C.N. 468 and 478. Beyond this stage of growth we commence with C.N. 466 with a *Primary* Xylem cylinder enlarged from ·24 mm. in 480 to ·4, and containing 105 tracheids. From this stage we advance to 345 tracheids in C.N. 482; to 400 in C.N. 470; to 3,049 in C.N. 489, in which the Primary Xylem has reached a mean diameter of 13·5 mm., and 3,720 in C.N., 502, and with a Primary Xylem cylinder with a diameter of 155 mm. In the latter case the cylinder of *Secondary* Xylem has attained to a diameter of 35 mm., whilst the medulla has advanced from a scarcely recognisable feature in the youngest twigs to 11 mm. in C.N. 489, and 10mm. in 502. In this type we also have the two forms of equal and unequal dichotomy. In each of C.N. 484 and 486 the two divisions of the Primary Xylem cylinder have recovered their circular form, but in C.N. 503 we have the condition represented in *Memoir* III., Fig. 20. In this specimen both the two separated crescents remain unclosed, shewing that the section has been made at a point low down in the dichotomising branch. It now appears certain that at this point the tracheal crescents never became closed to form perfect cylinders. Between their disunited horns the cells of the cortex and those of the medulla met and blended in a continuous tissue. But in the specimen 503 a further remarkable circumstance has occurred. Each crescent of the Primary Xylem has become invested by a crescent of Secondary Xylem, which has a maximum thickness of 5mm. On reaching the horns of each of the Primary Xylem crescents, this secondary tissue has grown closely round the points of the primary one and pushed its way into the interiors of their contained medullæ. (See *Memoir* III., Fig. 20.)

In my Section C.N. 502 we have a good example of *Unequal* dichotomy. A small segment of Tracheids is being detached from the extreme periphery of the Primary Xylem cylinder, but appears to have been shut in by the thick investing secondary one. We thus see that in *L. brevifolium* both the equal and the unequal dichotomies occur. The former in branches of all ages, from my youngest to my oldest. The unequal one also occurs in one of my most advanced forms.

Type of Lepidodendron Wunschianum.

THE ARRAN PLANT.

This type (Table III.) is one of the most valuable that we possess, because it is the only one in which we can trace the development of the tissues from the youngest twigs, down to stems six feet in circumference, embedded in volcanic ash, obviously not far from, if not actually on, the spot where they had originally grown ; the investing rock was full of fragments of their twigs and branches. In the British Natural History Museum in Cromwell Road are some fragments of the same plant derived from the quarries of Cragleith, near Edinburgh.

The youngest twigs (C.N. 428 to 432) are thickly clothed with very short leaves and have a Primary Xylem composed of a solid bundle of tracheids, devoid of all traces of a medulla. Counting the tracheids in this characteristic bundle, the sole representative of the stele in these young growths, I found them to be about 204. This primary bundle has a diameter of little in number more than ·7 of a millimeter. We next advance to the twig (C.N. 433), which is of much larger dimensions, cortex and leaves having increased much in size, and the central Primary Xylem, still devoid of a medulla, has now a diameter of a trifle under 4 mm., but of which, though I found it difficult to count the number of the tracheids, there are certainly more than 700.

We next reach a branch of still larger dimensions (C.N. 434). Its Primary Xylem has now a diameter of 5·5 mm., composed of about 729 tracheids, but which in addition encloses a medulla, having a diameter of nearly 2·5 mm. This section is represented in *Memoir* X., Fig. 3, and on a further enlarged representation of it is the primary cylinder given in Fig. 4. In all the sections described thus far the Primary Xylem gives off numerous leaf-traces, as shown in the enlarged figures of *Memoir* X., Figs. 2 and 4.

In section C.N. 456A, only the inner portion of the black mass of outer bark exists, the more external zone of prosenchymatous periderm having disappeared. Yet we find that what remains of the cortex has a circumference of fully twenty-one centimetres. The diameter of the Primary Xylem has reached 9·7 mm. and the component tracheids have now reached 2,225 in number. In C.N. 452 this corresponding cylinder has enlarged to 22mm. and the tracheids increased to 6,900. The Secondary Xylem reached a diameter of 69mm. But a still more conspicuous example of what appears to have been a primary stem (C.N. 350) has advanced yet further. What remains of the cortex is still 23 centimetres in diameter. Its Primary Xylem cylinder is 36·5 mm. in diameter and its component tracheids about 19,220 in number. In addition this is the smallest stem-section in which we find a trace of a secondary xylem. It is a very thin ring investing the primary cylinder, having only a thickness of 4 mm. on one side and but 1 mm. on the opposite one of the ring. These conditions demonstrate that in this type of *Lepidodendron* the upper branches attained to very large dimensions before the secondary growth of xylem began to be developed.

The magnitude of the central medulla is remarkable, being fully 24 mm. in diameter. The next section, C.N.

452, also requires a few words of explanation. As already mentioned, at Laggan Bay the bases of thirteen large stems stood erect and closely aggregated. Further investigation shewed that twelve of these were merely cylinders of outer cortex, all their more internal tissues having disappeared and been replaced by volcanic ash, with which the trees had been destroyed and buried. The decay of the softer portions of the bark had loosened all the harder vascular structures compassing their several steles, and allowed them to float out when the area became submerged. But the exceptional stem had met with different treatment. In the first instance it also had lost all its vegetable contents, which had evidently floated out upon the neighbouring waters. Directed by some fortunate current, a quantity of the floating *débris* had been washed back into and filled the vacant cavity of the thirteenth stem. Further examination of this *débris* shewed that it consisted of fragments of bark and of *Stigmariæ* rootlets, including a fragment of a vascular axis of a *Stigmaria*; but what was still more important, we found in it the entire and fully developed steles of no less than five of the remaining trees which had been tumbled into this single one. A perfect section of this entire stem, with all its contents, is now in my collection, and the basal portion of the same stem, equally rich in similarly precious remains, is in the Museum of the Owens College, Manchester, to which I presented it.

My cabinets contain several fine sections of the steles thus obtained, most of which had attained to about the same measure of growth and maturity. One of the finest of these, of which my C.N. 452 is a section, is represented by the Figs 6 and 6A of my *Memoir* X. The diameter of its Primary Xylem cylinder is 22 mm., enclosing a large medulla, and containing about 6,900 tracheids. Its cylinder of Secondary Xylem has a diameter of 69 mm.

In my sections of this type I have examples alike of equal and unequal dichotomies. Of the equal ones I have two sections from the same branch, in the lower of which (C.N. 456) the inner or non-peridermal portion of the cortex has a diameter of 71·5 mm.; the Primary Xylem cylinder is divided into two crescents which have not yet separated far apart. In a second section made a little higher up in the same branch, and with a slightly increased diameter of the cortex, the two crescents are nearly an inch apart, and an inward extension of the inner cortex already separates them.

In the British Museum at Cromwell Road is a much larger section than C.N. 455, which is divided into two virtually equal parts, each one of which will be as large as the entire cortex of 455. This section is already divided by a thin rudimentary cortical septum into two incipient branches. The Primary Xylem in each of these divisions has recovered its cylindrical form. We have here a very large branch of the type of Wunschianum undergoing an equal dichotomy.

But we have examples of unequal dichotomy in the same type. In my *Memoir* XIX. I have entered largely into the subject of Halonial branches in relation to the strobili which they supported or were destined to bear; and even in earlier *Memoirs* I demonstrated that the tracheidal bundles, given off like huge leaf-traces from the Primary Xylem, to the Halonial fruit-bearing tubercles, never possessed a medulla. I have a very young example of one of these fruit-bearing bundles divided into a consecutive series of eight transverse sections. (C.N. 458 to 465). This branch, like the young twig 428—432, has a solid tracheal stele, but with the dimensions of C.N. 433. This Halonial form is described and figured in my *Memoir* XII., the most characteristic of my eight sections (C.N. 465) being represented in Fig. 21. The separation of small segments from the periphery of the central stele is shown, each of such segments going to one of the peripheral Halonial tubercles.

The remarkable range of the characteristic features of the *Lepipodendroid* stems and branches, from the youngest twigs to the arborescent stems, without any changes in their typical organisation save such as are due to growth, makes this type an extremely significant and valuable one.

Type of Lepidodendron Harcourtii.

This is the type of which Brongniart received a section, and through an erroneous inference which he drew from it led to so many years of conflict and misinterpretation. No specimen of it has yet been found shewing a trace of Secondary Xylem. It appears probable that in this respect the type resembled *L. Wunschianum*, viz., that the exogenous, or secondary xylem, only made its appearance at an advanced stage of growth, and that we have as yet obtained no specimen sufficiently advanced to have entered upon that stage. In other respects the type bears prominently upon the questions constituting the main subject of this *Memoir*.

The two smallest stems I possess of this type are seen in C.N. 1596A. In this slide are two very small and young sections severally marked A and B. In the former, marked A, the Primary Xylem cylinder has a diameter of 2·6 mm. and contains 681 tracheids. Now, as in the case of most, if not all, of these young Primary Xylems we find here two types of tracheids. That occupying the greater part of the area of the transverse section of the organ consists of large and conspicuous ones, and contrasts with the medulla; but there is a peripheral series of small, and often of extremely minute, ones. It is these latter which constitute the "Corona" of Professor Bertrand, and from which the leaf-traces are given off. Now in 1596A, section A, we find 492 of the larger ones and but 189 of the smaller ones. The effect of this upon the forms of the Corona is shown in my *Memoir* XIX., Figure 6. What M. Bertrand designates the "points," a characteristic feature of the "Corona" of these young twigs, are small and few in number. In the section B, in the same slide, we have a similar condition. The section of the primary cylinder has a diameter of 2·7 mm., whilst of the larger tracheids we have 308 and of the smallest one 252. Thus in A we have a total of 681 and in B 560. But in the larger section, C.N. 1593, the section of the Primary Xylem cylinder, which has a diameter 6·5 mm., contains 2910 tracheids, of which 1110 are large and 1800 are small and peripheral; the latter now preponderating over the larger ones. In C.N. 380, which is from my largest stem of this type, the diameter of the Primary Xylem cylinder is 12 mm., but I can only count 2082 large tracheids. In the periphery, where the smaller ones ought to be in considerable numbers, none are preserved. The numerous positions which they ought to have occupied are clearly marked by a defined brown tint, but the walls of the tracheids have entirely gone. That these coloured areas mark points from which the tracheids have disappeared, is demonstrated by another specimen, from which most of the corona and its characteristic "points" have vanished, their position being only represented by the brown stains referred to; but in a small portion of the circle these stains are covered by the perfectly preserved small tracheids. In C.N. 381 all these tracheids are exquisitely seen. The diameter of the primary xylem is 9·5 mm.; of the large tracheids there are 1572, and of the small peripheral ones there are 2917. Whence has the enormous increase in the older branches been derived. The differences in the composition of the corona in the younger and older branches is well shown in my *Memoir* XIX. by the two figures 5 and 6. A comparison of the above details will be seen at a glance in Table IV.

Dichotomies—I have hitherto met with no example of an equal dichotomy of the type of *L. Harcourtii*, but this has doubtless arisen from the small number of specimens that we have hitherto obtained of this rare type. On the other hand, unequal dichotomies are frequent. Thus, in the two fine young sections of the same branch, 380a and 390b, lateral branches are being given off from opposite sides of the central branch; but in both cases the secondary branches of the primary xylem are of the solid type, invariably found when such bundles are destined to supply Halonidal tubercles and similar fruit-bearing organs. In N. 1596a, section B, we discover the origin of such bundles, as represented in *Memoir* XIX., Fig. 1, where we have the segment b′ becoming detached from the Primary Xylem cylinder b. We also have an excellent illustration of the course of a similar bundle going to the abortive branch B, in Fig. 29 of the same *Memoir*. (*See* C.N. 1596D.)

Type of Lepidodendron fuliginosum.

Very young examples of this type are more rare than those of more advanced growth, but this may be partly due to the fact that such examples are not easily identified as belonging to the type. It is only in such as are of more advanced growth that the characteristic features of the type assume their distinctive aspects; but we certainly have such an example in C.N. 379*. (Table V.) A segment has been separated from the cylinder of Primary Xylem, which cylinder has a diameter of about 3·5 mm. Measuring the defective portion of the cylinder I calculate that its tracheids have not exceeded 800. Its medulla had a diameter of 2 mm. In 379—⊙ the branch was a larger one. Its primary cylinder had a diameter of 4·5. I was unable to estimate its component tracheids, but its medulla had enlarged to 2·5, all which enlarged features suggest a further increase in the number of the primary tracheids. In C.N. 1922A, the diameter of the primary cylinder is

6 mm., that of the medulla 4·2, and the number of the primary tracheids 1292. In C.N. 1649, the branch has increased in size. The primary cylinder has a diameter of 7·2 mm., its tracheids are 2350, and its medulla is enlarged to 5·2 mm. In C.N. 1592, the diameter of the primary cylinder is again 7·2 mm.; its tracheids are 2·24; and its medulla 5·7. We have another somewhat parallel example in C.N. 1648, where the entire section has a mean diameter of 60 mm., that of the Primary Xylem cylinder being 7 mm. Its tracheids are 1847 in number and its medulla has a mean diameter of 5 mm. The number of the tracheids composing that cylinder increased successively to 1292, to 1847, to 2241, and to 2350, and following these progressive advances in the tracheal mass, there was a corresponding enlargement of the central medulla beginning at 2 mm. to 2·5—4·2, 5—5·2—5·2 and 5·7.

Dichotomies—Equal.

Of this condition I have only obtained one example of the *fuliginosum* type, but this is the largest specimen of the type that my cabinet contains. The section has the usual oval form, its longer diameter being 130 mm., and its shorter one 60 mm. Its two primary cylinders have dimensions corresponding to those of the branch as a whole. One of them is crushed, but the other is perfect. The mean diameter of the latter one above is 8·7 mm. and contains 2195 tracheids. The two cylinders combined must have consisted of more than four thousand tracheids, and the one medulla of this one cylinder alone has enlarged to 6 mm.

Dichotomies—Unequal.

Of these we have several very interesting examples. In 379—⊙ we have detached a strongly marked and complete semicircular segment and carrying along with it a peripheral investment of the innermost cortex of the parent branch, perforated by ten well-defined leaf-traces. This section alone threw no light upon the future history of the detached branch. But fortunately another specimen, C.N. 1654, supplies the information needed, in a series of eleven sections (C.N. 1654 to 1664) made at various transverse levels of the same branch. In *Memoir* XVI., Fig. 1, the segment b′ is shown becoming detached from the primary cylinder b. In Fig. 3 we have the separated segment, carrying along with it a little of the central medulla of the primary cylinder, whilst at Fig. 2, b, b, we have the condition of the gap in that cylinder left by the detachment of Fig. 2. The more important changes undergone by the segment are seen in Figs. 4, 5, and 6, the last of which exhibits an oval bundle, composed wholly of 140 large and small tracheids; a fac-simile of all others originated by the same process of segmentation.

The above examples correspond in their teachings with the types previously described. C.N. 1653 demonstrates that their ordinary equal dichotomies are identical with the rest of the *Lepidodendroid* family, and the same observation applies to the unequal dichotomies. One more condition requiring attention exists in this fuliginosum type. I was long unable to discover any secondary xylem in their branches. At length, however, I obtained the section C.N. 387 (See *Memoir* XI. Fig. 11, hh′) and other similar examples, C.N. 1592 bis and 1592 A, have since come into my possession. The cells of the innermost cortex of this type are arranged in radial lines, and amongst these lines we find parallel ones of true tracheids, rudimentary representatives of the secondary xylem zone. In the longitudinal section these tracheids pursue a very irregular, undulating course, and they are very unequally distributed in the cortical ring in which they occur. I have seen no trace of this Secondary Xylem in young branches. As usual, it obviously indicates a more advanced stage of growth.

Type of Lepidodendron Mundum.

My sections of this small and somewhat rare type vary somewhat in the numerical relation of the several tissues. Nevertheless they virtually tell the same story as the preceding ones have done. Thus, commencing with my smallest twig, with a cortical diameter of 1 mm., we have a primary xylem consisting of but 26 tracheids. In C.N. 405b, where the cortex has enlarged to 2·5 mm., the tracheids have increased to 83. In 415a the cortex has enlarged to 4·7 mm.; the tracheids now number *at least* 123, and in 413, where the cortex has a mean diameter of 7·5 mm. and the Primary Xylem cylinder has reached its largest dimensions of 1·5 mm., the tracheids exhibit a corresponding increase to 190 in number. We thus discover that, as we descend from the smallest, *i.e.*, the uppermost, twigs to the larger and lower branches, we have the same enlargement of the primary stele as a whole and in the number of its component tracheids that we have seen in the types previously considered. The equal dichotomy of 416a, also shews that in *Mundum* we have exactly the same dichotomy as characterises the arborescent form. Like conditions are seen in C.N. 412, in the combined cylinders of which we have at least 154 tracheids. Of unequal dichotomies I have as yet seen no trace in *L. Mundum.* (Table VI.)

Type of Lepidodendron parvulum.

So far as I can judge from the limited number of specimens of this type which I possess, it is the smallest of the *Lepidodendra* yet discovered. I have included them here because, though the smallest, they present precisely the same form of equal dichotomy as we find in the largest of the arborescent groups. The diameter of my sections, C.N. 12, 420, and 421, including their leaf-cushions, does not exceed 4 mm. But besides these I have five transverse sections, C.N. 422 to 426, cut successively from the same branch. In the lowest of this series, we find the commencement of an equal dichotomy, whilst in the uppermost one this dichotomy is far advanced towards its completion. Three of the above sections are represented in *Memoir* XVI., Plate 8, Figs. 23, 24 and 25, including the dichotomy seen in the latter section.

Thus far I have done little more than lay before palæobotanical students a series of carefully observed facts, the greater number of which have not hitherto been published, and even those which have already been recorded in my various *Memoirs* are now laid before my readers in a collective and arranged form for the first time. We have next to consider what bearing these facts have upon the controversy which has led to the publication of this *Memoir*. When my earlier *Memoirs* were published, I was under the impression that the branches of *Lepidodendroid* trees grew like ordinary living exogens ; and that what were originally young twigs became enlarged as they grew older, under the influence of additional agencies associated with advancing years. All the *facts* of organization, so far as they went, were accurately stated even in my *Memoir* XVI. (1889), Meanwhile the sections in my collection continued to increase rapidly, throwing additional light upon the true history of these objects. Some of these novelties were described and illustrated in *Memoir* XIX. (1892), but even then I was much more occupied with questions of morphology and histology than of development. Yet, later, my close association with my distinguished friend and colleague Dr. D. Scott, brought developmental questions to the front. I was still under my old impressions respecting the modes of growth of these *Lepidodendroid* trees.

My prolonged investigation made it increasingly evident that the largest number of the leaves, leaf-traces, and tracheids were accumulated at the base of the central stem of the *Lepidodendon;* but the question now arose, how did they get there? My first idea was that they could not have existed there in such numbers when the tree was a young and small sporophyte; in which case they must have multiplied as the various parts of the plant grew larger. But against this explanation came the difficulty of understanding how additional leaves and leaf-traces could be intercallated amongst those already arranged in a system of geometrically disposed spirals. The longer I pondered this question the less I was able to suggest any solution of it. Utterly baffled, I then turned to Solms-Laubach's hypothesis, to see if it reduced the number of the difficulties to be overcome.

As I have already observed, my dissentient friends agree with me so far as the more conspicuous facts stated above are concerned, and the existence of which is clearly demonstrated in each of my six tables. They say that the increase in descending order of the tracheids and leaves never could have been developed by any known process of growth in the same branch. In p. 229 of his *Fossil Botany*, (English Translation), Solms-Laubach puts very fairly and clearly what my views were, but he then proceeds to give his reasons for rejecting them. He says, "It is to be remem-"bered that we must not simply compare the terminal "ramifications of the head of a tree with the still young and "growing ends of the main shoot or of its subordinate "branches. The central strand in the main shoot and in "the branches may and will have had a very different "diameter at the beginning of the growth in thickness, from "that of the later generations of branches, the last of which "may have had no growth of the kind." With these views my colleague, Dr. Scott, entirely agreed, an additional reason for submitting their hypotheses to a careful investigation. But whilst I arrived at the conclusion that their views inclosed fewer difficulties than my own had done, many serious ones remained. They involved the admission that in their earliest state these young plants were of sufficient magnitude to contain in their interiors a primary trachæal xylem large enough to contain 6900 individual tracheids, enclosing within their cylinder a medulla of considerable dimensions. How any embryonic growth could attain to such a size is difficult to understand. Of course this question involves the larger one of the primary origin of the young *Lepidodendroid* plants.

The only reproductive organs found upon these Carboniferous *Lycopods* are either homosporous or heterosporous strobili. This fact at once suggests that, like their living representatives, these plants were primarily sporophytes developed upon a prothallus. The spores produced within the sporangia of these strobili exist in a fossil state in such extraordinary profusion, and continued to be so during such a prolonged epoch, as to make it impossible to suppose that they were produced in vain. In addition to the vast numbers of them still retained within the sporangia of the fossil strobili, we find that they were shed and preserved in the vegetable soil, subsequently converted into coal, in the greatest profusion. A considerable number of the thick coal-seams of Europe, America, and Australia are largely composed of them ; and to suppose that such a provision should be made for the reproduction of the species, and yet be entirely in vain, exceeds all credibility. There seems to be no reason for doubting that the functions of these spores were identical with those of their living representatives, and that those functions were similarly performed.

Assuming, therefore, that the earliest state of a *Lepidodendron* was that of a minute sporophyte, other questions arise. One of these has reference to the existence of a primary root. Were the remarkable organs now known as Stigmariæ the first to fulfil the functions of roots to these young *Lepidodendra*, or were they furnished with some temporary organ to be permanently replaced by the Stigmariæ at a later period? They must from the beginning have possessed some such organ capable of extracting nutriment from the soil. Some living *Lycopods* possess a tap-root and others do not. Fankhauser found one in the sporophyte of *Lycopodium annotinum*.* Treub found no such primary root in the sporophyte of *Lycopodium cernuum*, but he observed that subsequently a root was developed laterally from the embryonic tubercle.† Hence the question of a primary tap-root is not an unimportant one. But whatever else was the case, the fact that my cabinet contains a true Stigmaria not more than 6 inches in diameter shews that their set of four dichotomising ones were capable of being developed from the base of a very young plant.

It is difficult to realize a sporophyte developed from a prothallus of sufficiently large size to contain a primary xylem strand, consisting of several thousands of tracheids such as we find at the base of the arborescent stem of the type of *Lepidodendron Wunschianum*. Then as the development of this primary strand seems to have been dependent upon the coalescence of an adequate supply of leaf-traces, demanding a corresponding number of leaves, it is difficult to realize a sporophyte, the cortical surface of which was large enough to carry the requisite number of leaves to furnish these leaf-traces. This difficulty raises the question of what changes the sporophyte underwent to enable it to bear the innumerable leaves that Solms-Laubach's hypothesis demands. All perfect examples of the four united primary roots indicate the exact diameter of the base of the *Lepidodendroid* stem. Now we may be quite certain that at their first appearance each of these four roots would be in their youngest possible state, which must at least not

* *Bot. Zeitg.*, 1873, No. 1.

† *Ann. d. Jardin Botanique d. Buitzenzorg*, 4, 1884.

have been larger than my minute one referred to above; and as the independent roots of a Stigmaria coalesce at the base of an aerial stem, the diameter of the coalesced units of these organs is very much less than the aggregate of these four roots at a lower point where each root was independent of its neighbours.* Hence we are driven to the conclusion that the base of a *Lepidodendroid* stem in its youngest state can scarcely have had a diameter approaching to 24 mm. Now assuming, that the number of leaves and their associated leaf-traces, at the *base* of that stem, was always greater than at any point at a higher level where the number of the leaves encompassing a branch began to be reduced to one-half by each succeeding equal dichotomy, it again becomes difficult to account for the 6500 tracheids existing at the base of the stem of my *L. Wunschianum* on Solms-Laubach's hypothesis. Since, as we have already seen, additional leaves could not have been intercalated into any of the diagonal lines as the stems grew, whatever their number that number was fixed, and they must all have been present at the base of the stem at the outset of its growth.

The magnificent *Lepidodendroid* stem figured in Vol. III., page 203, of Lindley and Hutton's *Fossil Flora of Great Britain* seems to shew that throughout the 39 feet intervening between the base of the stem and its first bifurcation its diameter underwent but little change. Such being the case, we may fairly conclude that the number of the leaves and leaf-bases clothing its cortex, would, in like manner, undergo no material alteration. But the first dichotomy inevitably altered these conditions. Each of the two resulting branches would divide between them whatever organs existed, external or internal; and, as we have already seen, a similar division would recur at each successive dichotomy. The secondary xylem growth, commencing at the base of the primary stem, would follow the vertical

* *See* the Figs. 1 and 5 of my *Monograph.*

elongation of all the primary structures. In cases like *L. Selaginoides*, where we find this secondary tissue-system even in very young twigs, it must have followed very quickly all the primary growths. But in the type of *L. Wunschianum*, as well apparently as in *L. Harcourtii*, we find branches of considerable dimensions in which it has not yet made its appearance. In the anomalous branch of the former type (C.N. 450), which has still a diameter of 23 centimetres, though so much of its outer cortex has disappeared, its Primary Xylem cylinder has a diameter of 36·5 millimetres and its central medulla one of 24 mm. These latter internal tissue-systems are invested by a very thin ring of secondary xylem, which obviously began as a unilateral crescent like those of *L. Selaginoides*. The importance of this specimen resides in the fact that the transverse section of its Primary Xylem cylinder is composed of more than 19,000 tracheids. Contrasting the stele of this stem with C.N. 452, which latter obviously came from the base of a tree two feet in diameter, its exceptional condition becomes manifest. Whilst these conditions unequivocally give support to the views held by Solms-Laubach, and those who agree with him, they are not free from difficulties of their own. Assuming that these enormous developments of primary tissues originated at the base of the primary stem, close to a growing point, what must the diameter of that point have been? I can only conclude that we still have much more to learn about the growth and development of these remarkable trees.

If many of the *Lepidodendra* started their career from growing points of such dimensions, it is remarkable that no trace of any such growths have been discovered, and it is no reply to this difficulty to affirm that we must not expect to see such young structures in a fossil state. In fact, examples of smaller dimensions are far from uncommon. My cabinet contains a fine example enclosed in a nodule of clay ironstone, the central axis of which is but one millimetre in thickness.

As to the magnitude of the primary xylem strand, and the enormous number of the tracheids which compose it, these equally reached their largest proportions at the base of each solitary aerial stem. How such numbers of tracheids, varying in the type of *L. Wunschianum* from 4,000 to 15,000, could be produced in that position is difficult to understand. The *young* sporophyte could not possibly have contained them ; hence some process of growth, of the nature of which we have as yet no knowledge, but which was capable of producing these marvellous results, must have succeeded, if not been developed out of the sporophyte. Anyhow, it is obvious that my original hypothesis of an enlargement of the Primary Xylem proceeding from above downwards, is incapable of explaining the facts recorded in the preceding pages. Hence, that explanation appears more likely to be found in some modification of the views of Graf. Solms. But even in that direction the difficulties are almost insuperable in the present state of our knowledge. A hiatus exists between the sporophytal conditions of each plant and its enlarged state when it began to develop its aerial stem supported upon its four Stigmarian root-organs. This hiatus we have at present no prospect of filling.

Table I. *LEPIDODENDRON SELAGINOIDES.*

Cabinet Number.	Diameter of Cortex.	Diameter of Primary Cylinder.	Diameter of Medulla.	Tracheids in Primary Cylinder	Diameter of Secondary Cylinder.	Figures of the Specimen.	General Remarks.
C.N. 337	9·7 mm.	1·5 mm.	The medulla not measurable in this type.	Not capable of being counted.	None.	*Mem.* XI. fig. 2	
335	12 mm.	2·5 mm.	... ...	... ...	None.	*Mem.* XI. fig. 1	
337A	16 mm.	2·7 mm.	... ...	... ...	None.	......	
339	17 mm.	3 mm.	... ..	... ...	A small crescent 2·5 in circumference.	*Mem.* XI. figs. 3 and 8	
344	18·5 mm.	2·5 mm.	... ...	... ...	Crescent with 1·5 mm. between the points of the horns.	*Mem.* XI. fig. 4	
347	16·2 mm.	2·6 mm.	... ..	... ...	A complete circle. The wall 0·5 mm. in thickness.	*Mem.* XI. fig. 6	
338	about 27 mm	3·5 mm.	... ...	... ...	......	......	
354	28 mm.	3·5 mm.	... ...	... ...	A ring like C.N. 338. Wall of cylinder 1·5 mm.	......	
363A	50 mm.	4·8 mm.	... ...	... ...	X 10 mm.	......	
363	Cortex gone.	5· mm.	... ...	... ...	Wall of cylinder 10·5 mm. on its perfect side.	*Mem.* XI. fig. 7	
1922D	92 mm.	6· mm.	... ...	... ...	14·5 mm.	......	A dichotomising branch
Dichotomies	*—Equal.*						
340	24·5 mm.	Cylinders closed *a.* 2·5 *b.* 2·65	... ...	... ..	......	*Mem.* XI. fig. 8	
340A	Primary branch. 24 mm. Secondary branch 16 mm.	Crushed, not measurable 2·6 mm.					
1922D	Secondary branch 45 mm.	4·6 mm.					

Table II. TYPE OF *LEPIDODENDRON BREVIFOLIUM.*

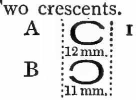
Cabinet Number.	Mean Diameter of Cortex.	Diameter of the Primary Xylem Cylinder.	Tracheids in the Primary Xylem Cylinder.	Diameter of the Secondary Xylem.	Diameter of the Medulla.	Where Figured.
480—⊙	About ·5 mm.	·24	About 40	·22 mm.	Very minute.	Similar sections. *Mem.* III. fig. 2.
535	Very minute, but crushed.	·35	57	·35 mm.	·1 mm.	
471	1·5 mm.	·27	59	·3 mm.	A mere point.	
471a	1·5 mm.	·27	62	·3 mm.	......	
473b	1·3 mm.	·35	62	·3 mm.	·1 mm.	
473c	1·7 mm.	·37	64	·32 mm.	.1 mm.	
472	1·7 mm.	·31	68	·3 mm.	A minute point.	
473d	2·3 mm.	·37	77	·33 mm.	·1 mm.	
473a	1·7 mm.	·33	78	·32 mm.	·1 mm.	
468	1·7 mm.	·42	80	·27 mm.	·1 mm.	
478	Imperfect.	·58	80	·27 mm.	·1 mm.	
466	2·2 mm.	·4	105	·4 mm.	Unconspicuous.	
482	Large, but imperfect.	·45	345	6 mm.	Large but compressed.	
470	Almost no cortex preserved.	·31	400	5·5 mm.	......	
502	Not preserved entire.	15·5	3720	......	10· mm.	
489	Not preserved.	13·5	3049	35· mm.	11· mm.	
Dichotomies	—*Equal.*					
486	......	Two circles. 1 | 2·2 mm. 2 | 1·7 mm.				
484	......	Two circles. 1 | 3·2 mm. 2 | 1·7 mm.				
503	......	Two crescents. 	Maximum thickness of the crescent wall, 1·5 mm.	Maximum thickness of the secondary xylem of A, 5·5 mm. Ditto of B, 5·.		
Dichotomy	—*Unequal.*					
502	 Length of outer curve of segment, 3 mm.; radial thickness of segment, ·5 mm.					

Table III. TYPE OF *LEPIDODENDRON WUNSCHIANUM.*

Cabinet Number.	Diameter of Cortex.	Diameter of Primary Xylem.	Tracheids in Primary Xylem.	Diameter of Secondary Xylem.	Diameter of Medulla.	Where figured.	
428 to 432	4·7	1· mm.	204 in 429	None.	None.	*Mem.* X. figs. 1 & 2	
433	Imperfect.	4 mm.	Difficult to count, but more than 700.	None.	None.	Not figured	
434	Imperfect.	5·5 mm.	729	None.	2·5 mm.	*Mem.* X. fig. 3	
456A	21 cm.	9·7 mm.	2225	None.	5·5 mm.	Not figured	Much of the outer cortex gone.
454	...	11· mm.	2238	None.	7·5 mm.	Not figured	
452	...	22· mm.	6900	69· mm.	Primary Xylem crushed in upon it.	*Mem.* X. figs. 6 & 6a	
450	23 cm.	36·5 mm.	19220	4 mm. on one side of the cylinder, 1 mm. on the opposite one.	24 mm.	*Mem.* X. fig. 5	An exceptional form.
Dichotomies	*—Equal.*						
455	69 mm.	Two crescents nearly in contact.					
456	70·2 mm. Second section of 455 developing a cortical septum	Crescents nearly 25 mm. apart.					
British Mu	*seum Branch.*						
	$20\frac{1}{2}$ in. Cortical septum formed.	Two cylinders, circumference of each 28 mm.	Not counted.	None.			
Dichotomies	*—Unequal.*						
	On Halonial	Branch.					
458 to 465	18 to 21 mm.	3·5 mm.	1251 in 465	None.	None.	*Mem.* XII. fig. 21	Secondary bundles supplying the Halonial tubercles from various parts of the primary cylinder.

Table IV. TYPE OF *LEPIDODENDRON HARCOURTII.*

Cabinet Numbers.	Diameter of Cortex.	Diameter of Primary Xylem.	Tracheids in Primary Xylem.	Leaf-traces between points of Primary Xylem.	Tracheids in leaf-traces.	*Large* Tracheids in Primary Xylem.	Small peripheral tracheids in the primary xylem and points.	Diameter of Medulla.	Secondary Xylem.	Figures.
1596A Section A	16·5 mm.	2·6 mm.	681	...	...	492	Very few "Points." 189 small	2·1 mm.	None.	*Mem.* XIX. fig. 6
1596A Section B	15· mm.	2·7 mm.	560	...	...	308	Very few points. 252	2·6 mm.	None.	
1593	Imperfect	6·5 mm.	2910	...	...	1110	1800	5·7 mm.	None.	*Mem.* XIX. fig. 5
380	82·5 mm.	12· mm.	2082	...	...	Tracheids chiefly large	Very few preserved points and leaf-traces chiefly disappeared	7·5 mm.	None.	*Mem.* XIX. fig. 3
381	Inner prosenchyma preserved. 43· mm.	9·5 mm.	4489	29.	610 in 29 traces	1572	2917	7·5 mm.	None.	
Dichotomies	—*Equal* (*none unequal*).									
380b Central branch	11·5 mm.	2·7 mm.	450 some large and small	... Giving off a Halonial bundle from either end B and C. Second section of 26B nearer apex. For other measurements see second entry at top of Table.	...	...	...	2· mm.	None.	*Mem.* XIX. fig. 26
1596A Section B	13·7 mm.	2·7 mm.	560	A nearly complete segment, 2· mm. in circumferential length being detached from a point in the periphery of the Primary Xylem cylinder.						

Table V. TYPE OF *LEPIDODENDRON FULIGINOSUM.*

Cabinet Number.	Diameter of Cortex.	Diameter of Primary Xylem.	Tracheids in Primary Xylem.	Diameter of Medulla.	Secondary Exogenous Xylem.	Figures.
379*	19· mm.	3·5 mm.	About 800	2· mm.	387·	*Mem.* XI. fig. 11 hh'.
379—⊙	27· mm.	4·5 mm.	......	2·5 mm.		
1649	67· mm.	7·2 mm.	2350	5·2 mm.		
1922A	33· mm.	6· mm.	1292	4·2 mm.		
1592A	......	7·2 mm.	2241	5·7 mm.		
1648	60· mm.	7·0 mm.	1847	5· mm.		
Dichotomy	—*Equal.*					
1653	Maximum 130 mm., minimum 60 mm.	One 8·7, one imperfect.	2195	6· mm.		
Dichotomy	—*Unequal.*					
379—⊙	27· mm.	4·5 mm.	......	......	......	*Mem.* XI. fig. 9.
1654 to 1664	......	4·2 including segment. Diameter of the final bundle 1·7 mm. Tracheids in final bundle 140.	169 in the segment, 441 in remainder of the ring. —— 610 Total.	2·2 mm.	......	*Mem.* XVI. figs. 1 to 6.

Table VI. TYPE OF *LEPIDODENDRON MUNDUM.*

Cabinet Number.	Diameter of Cortex.	Diameter of Primary Xylem.	Tracheids of Primary Xylem.	Diameter of Medulla.	Figures of the Sections.	Diameter of Secondary Xylem.
408	1 mm.	·2 mm.	26	None.	*Mem.* XVI. figs. 7 & 8	
405	3·2 mm.	·6 mm.	76	·32 mm.	*Mem.* XVI. fig. 11	
406	2 5 mm.	·3 mm.	66	·1 mm.	*Mem.* XVI. fig. 9	
407	3·5 mm.	·57 mm.	75	·3 mm.	Not figured.	
405B	2 7 mm.	·5 mm.	83	1·8 mm.	Not figured.	
416b	Absent.	·7 mm.	106	·47 mm.	*Mem.* XVI. fig. 15	6·7 mm.
416c	Crushed.	·45 mm.	93	·17 mm.	*Mem.* XIV. fig. 10	
415a	4·7 mm.	·72 mm.	123	·4 mm.		
413	7·5 mm.	1·5 mm.	190	·87 mm.	*Mem.* XVI. fig. 12	
409	4·5 mm.	·77 mm.	79	·5 mm.		
410	4·7 mm.	·75 mm.	73	·37 mm.		
Dichotomy	—*Equal.*					
416a	5· mm.	Two cylinders. *a* closed ·47 *b* nearly closed ·52	66 64	·27 mm. ·3 mm. }	*Mem.* XVI. fig. 14	
412	Outline imperfect.	...	On the combined half circles 96			

General Meeting, January 8th, 1895.

HENRY WILDE, F.R.S., President, in the Chair.

Mr. WILLIAM BARTON WORTHINGTON, B.Sc., M.Inst.C.E., Mr. CHARLES DREYFUS, Mr. GEORGE BOOTH ARMSTRONG, and Mr. CHARLES L. BARNES, M.A., were elected ordinary members.

Ordinary Meeting, January 8th, 1895.

HENRY WILDE, F.R.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

Mr. W. E. HOYLE, M.A. exhibited a specimen of *Rhizocrinus lofotensis*, a stalked crinoid from the Norwegian coast recently acquired by the Manchester Museum. A discussion ensued regarding deep-sea organisms in general, especially with respect to such as have siliceous skeletons, hexatinellid sponges and diatoms being particularly referred to.

On the Multiple Proportions of the Atomic Weights of Elementary Substances in relation to the unit of Hydrogen. By Henry Wilde, F.R.S.

(Received December 11th, 1894.)

A recent pronouncement by the noble President of the British Association at Oxford in the course of his address that, "there is not in the facts, the faintest foundation for the theory that the atomic weights of elementary substances are multiples of the weight of hydrogen," induces me to refer to the paper which I read before this Society in the year 1878,* *On the Origin of Elementary Substances and on some New Relations of their Atomic Weights*, proving that such multiple relations actually subsist.

Reference to this paper, with a recapitulation of the leading facts contained therein, is all the more desirable at the present time, as some of my views have been modified by subsequent investigators, without advancing much beyond what had already been accomplished; while, in other instances, there has been a distinct retrogression from the strong position which chemical philosophy had attained more than forty years ago.

In order that a connected view of the observations I have to make may be obtained, I will summarise very briefly the hypothesis from which the multiple proportions of the atomic weights of the elements have been established. I will also reproduce several tables of atomic weights of the elements and their classification, as representative of chemical knowledge and opinion of the present time.

Starting from the nebular hypothesis of the successive condensations of a primordial substance into planetary systems in definite proportions, as indicated by Bode's law

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* *Proceedings of the Manchester Literary and Philosophical Society*, Vol. 17, April, 1878—*Memoirs of the Society* Vol 9, 1883, Vol. 10, 1887.

of planetary distances, it is assumed (1) that elementary species have been formed from the further condensation of the nebular substance into the typical molecules H, H2, H3, H4, H5, H6, H7; (2) that the series of elements have been formed by the successive condensations of the typical molecule at the head of each series in multiple proportions; (3) that the atomic weights of each series of elements are multiples of the typical molecule at the head of the series; (4) that the ordinal number of the typical molecule determines the quantivalence and other analogous properties of each series of elements under it.

That relations such as I have indicated exist between the nebular and elementary condensations, represented by the planetary distances on the one hand, and the atomic weights of well-defined series of elementary substances on the other, will be evident on comparing the numbers in the following tables:—

0 . 0 . 4 =	4	Mercury.
1 × 3 + 4 =	7	Venus.
2 × 3 + 4 =	10	Earth.
4 × 3 + 4 =	16	Mars.
8 × 3 + 4 =	28	Ceres, Pallas, &c.
16 × 3 + 4 =	52	Jupiter.
32 × 3 + 4 =	100	Saturn.
64 × 3 + 4 =	196	Uranus.

The numbers expressing the relative distances of the planetary bodies from the sun and from each other are obtained by multiplying successively the difference (3) between the distance of the first and second members of the system by a geometric series, and adding to the products the constant distance (4) of the first member.

Now, if the atomic weight of the second member of the alkaline and silver series of metals (Na = 23) be multiplied successively by an arithmetical series, then will the products, minus the atomic weight of the first member (Li = 7), be the atomic weights of all the elements belonging to that series.

$Hn+$

$$\begin{array}{l}
0 . 0 . 7 \quad Li \quad 7 \\
1 \times 23 - 0 = Na = 23 \\
2 \times 23 - 7 = Ka = 39 \\
3 \times 23 - 7 = Cu = 62 \\
4 \times 23 - 7 = Rb = 85 \\
5 \times 23 - 7 = Ag = 108 \\
6 \times 23 - 7 = Cs = 131 \\
7 \times 23 - 7 = \text{—} = 154 \\
8 \times 23 - 7 = \text{—} = 177 \\
9 \times 23 - 7 = Hg = 200
\end{array}$$

Again, by multiplying in like manner the atomic weight of the second member of the alkaline earth and cadmium series of metals (Mg = 24) the products, minus the atomic weights of the first member, (Gl = 8) are the atomic weights of all the elements of this series.

$H2n+$

$$\begin{array}{l}
0 . 0 . 8 = Gl = 8 \\
1 \times 24 - 0 = Mg = 24 \\
2 \times 24 - 8 = Ca = 40 \\
3 \times 24 - 8 = Zn = 64 \\
4 \times 24 - 8 = Sr = 88 \\
5 \times 24 - 8 = Cd = 112 \\
6 \times 24 - 8 = Ba = 136 \\
7 \times 24 - 8 = \text{—} = 160 \\
8 \times 24 - 8 = \text{—} = 184 \\
9 \times 24 - 8 = Pb = 208
\end{array}$$

The four halogens and the four members of the oxygen series, which I have designated as negative forms of H and H2, have also well-defined multiple and other numerical relations among themselves and their homologues of position in the positive series H*n*, H2*n*, as will be seen on comparing the theoretical numbers with the accepted atomic weights as shown in the two following tables:

$Hn-$	$H2n-$
2 × Na 23 − 11 = Cl 35.	2 × Mg 24 − 16 = S 32.
4 × Na 23 − 11 = Br 81.	4 × Mg 24 − 16 = Se 80.
6 × Na 23 − 11 = I 127.	6 × Mg 24 − 16 = Te 128.

I would also direct attention (1) to the common numerical difference of 4 between the halogens and the alkaline metals in homologous positions, and (2) the common difference of 8 between the oxygen series and the alkaline earth metals in similar positions, (3) the natural arrangement and extensions of Dumas' triads, in which the sum of the atomic weights of the extremes is equal to double the weights of the means.

1	+ H*n* —		+ H2*n* —	
2	Li = 7 .. .. *7**		Gl = 8 .. .. *9·2*	
3	Na = 23 .. .. *23*	**F** = 19 .. .. *19*	Mg = 24 .. .. *24*	**O** = 16 .. .. *16*
4	K = 39 .. .. *39*	**Cl** = 35 .. .. *35·5*	Ca = 40 .. .. *40*	**S** = 32 .. .. *32*
5	Cu = 62 .. .. *63·3*		Zn = 64 .. .. *65*	
6	Rb = 85 .. .. *85*	**Br** = 81 .. .. *80*	Sr = 88 .. .. *87·5*	**Se** = 80 .. .. *79*
7	Ag = 108 .. .. *108*		Cd = 112 .. .. *112*	
8	Cs = 131 .. .. *132*	**I** = 127 .. .. *127*	Ba = 136 .. .. *137*	**Te** = 128 .. .. *128*
9	*x* = 154		*x* = 160	
10	*x* = 177		*x* = 184	
11	Hg = 200 .. .. *200*		Pb = 208 .. .. *207*	

* Accepted atomic weights.

The absolute parallelism of the positive and negative series of elements H*n* and H2*n* in their numerical, chemical and physical relations, together with their close resemblance, to homologous series, will be at once apparent to philosophical chemists. The small differences observable between the experimental and a few of the theoretic atomic weights, when distributed among the twenty-four members of the four series, only amount to 0·0036, or less than half of 1 per cent of the actual determinations. Excluding these differences, the atomic weights are a simple multiplication table, the significance of which will be understood by students in other departments of science quite as well as by the most able chemists.

The theoretic atomic weights are also in much closer agreement with experimental results than the fundamental law of atomic heats formulated by Dulong and Petit for the same series. No one doubts the general accuracy of this law because it does not hold good for boron and silicon, or from its inexactitude to fractional quantities throughout the whole number of the elements.

I would take this opportunity of remarking as a principle of scientific reasoning, that when the number of recurring facts is sufficient to establish the relation of cause and effect, or, in other words, the general accuracy of a law, the road to further discovery lies rather in the direction of explaining the causes of anomalous departures from it, than in challenging the truth of the law itself. I would also emphasise the fact, the importance of which is hardly yet realised by chemists, that as the received atomic weights are all expressed in units of hydrogen and are equivalents of this element, the multiple relations subsisting among the higher atomic weights, as shown in the above table, have an immensely greater validity in determining the question of their being whole numbers of hydrogen, than when the atomic weights were compared directly with the hydrogen unit alone by Stas and the older chemists.

It will be observed that there are gaps in the positive series H*n*, to be occupied by two elements, with atomic weights 154 and 177, and by their homologues of position in the series H2*n*, with atomic weights 160 and 184, which remain to be discovered. It will be evident that the specific gravities and other properties of these elements can be predicted with the same certainty as the atomic weights.

The multiple relations subsisting among the series H3*n* are highly interesting on account of the recent additions that have been made in it by the aid of spectral analysis, and the questions raised respecting the classification and quantivalence of some of its members, which, from their rarity, have not been sufficiently investigated. The atomic weights of this series are calculated on the same principle as those shown in the series H*n*, H2*n*, and are multiples of H3.

H3*n*

0 . 0 . 12	= C	= 12
1 × 27 − 0	= Al	= 27
2 × 27 − 12	= Sc	= 42
3 × 27 − 12	= Ce	= 69
4 × 27 − 12	= Ga	= 96
5 × 27 − 12	= Y	= 123
6 × 27 − 12	= In	= 150
7 × 27 − 12	= E	= 177
8 × 27 − 12	= Tl	= 204
9 × 27 − 12	= Th	= 231

It will be seen that where the numbers in the table differ from the experimental determinations, the differences are either multiples or submultiples of the received atomic weights; and, as the theoretic atomic weights of Th, Tl, Al, and C are identical with the actual determinations, and that triads are formed by Tl, In, Ga, Sc, and Th, E, Y, Ce, as in the series H*n*, H2*n*, there is a high degree of probability that all the theoretic atomic weights in this series are correct.

While the atomic weights of the series H4*n*, H6*n*, H7*n*, are multiples of their typical molecules, their other numerical relations differ from those in the preceding series. The possible causes of this departure from the simple law observed in the other series I have briefly stated in my former paper, and will only make mention of the two missing members of H4*n* with atomic weights = 16 and 32 and the missing members of H6*n* in homologous positions with atomic weights = 18 and 36, which I suggested may have been transformed into the negative forms of the series H2*n* and H*n* respectively. I will, however, again direct attention to the present unsatisfactory state of our knowledge respecting the atomic weight of silicon. The wide diffusion of this element in nature, constituting as it does, in combination with oxygen, more than one half of the earth's crust, makes it hardly creditable to the chemical science of the present day that there should be doubts respecting its atomic weight and position in the classification of elementary substances.

Silicon in my table is the second member of H7*n* with an atomic weight = 35 and forms with nitrogen and iron a triad similar to the first three members of H*n*, H2*n*, H3*n*, H5*n*.

The position of Si = 35 as the second member of the series not only throws new light on the disputed atomicity of this element, but also explains the anomalous atomic heat which has been assigned to it.

Since the investigation of the properties of silicon by Berzelius, who regarded silicic acid as a trioxide, much discussion has arisen as to whether the atomic weight of silicon should be 21 or 28; or the formula for its oxide Si_2O_3 or SiO_2. Chemists are now generally agreed upon the latter formula for silicic acid, and have accordingly classified silicon with titanium, as the oxide SiO_2 agrees with titanic acid TiO_2. Now, if silicon were the true analogue of titanium, the oxides of these elements should be isomorphous, whereas the crystalline form of quartz is hexagonal, while rutile, anatase, brookite, zirconia, and tinstone (similar oxides of members of the series H4*n*) are tetragonal.

Through the classical researches of Regnault the specific heat of silicon was found to be 0·176.* The determination was made with specimens of the metalloïd of considerable size, and in a state of compactness and purity to receive a polish which formed a perfect mirror. The above number multiplied by 28, the highest atomic weight assigned to Si, gives the product 4·93, while the law of Dulong and Petit requires the value 6·25.

In discussing the cause of the anomalous atomic heat of silicon, Regnault pointed out that in order that it might enter into the law of the specific heat of other elements, it would be necessary to write the formula of silicic acid Si_2O_5; it would then resemble that of nitric, phosphoric, and arsenic acid. The atomic weight of silicon would then be 35, and the product of this number and the specific heat would be nearly 6·25, which agrees with the analogous products that other simple bodies give. By assigning to silicon a higher atomic weight, and a polybasic character like that of phosphorus or nitrogen, Regnault remarked that it is easy to explain the existence of the great number of silicates which nature presents in well defined and beautiful crystals, and to understand the existence of the natural hydro-silicates.

It will be seen from my table that the atomic weights of nitrogen, silicon and iron, beside being whole numbers, are exact multiples of H7; and in all the formulæ proposed for the constitution of silica, the atomic weight of silicon is a

* *Annales de Chemie et de Physique* tome LXIII. pp. 24—31 (1861).

multiple of 7. These formulæ are given below, with the old and new atomic weights; the proportion of silicon to oxygen being in the ratio of 7:8 in all the formulæ.

1. $Si\,O = Si\ 7 : O\ 8 :: 7 : 8$
2. $Si\,O_2 = Si 14 : O 16 :: 7 : 8$
3. $Si\,O_2 = Si 28 : O 32 :: 7 : 8$
4. $Si\,O_3 = Si 21 : O 24 :: 7 : 8$
5. $Si_2O_5 = Si 35 : O 40 :: 7 : 8$
6. $Si_2O_5 = Si 70 : O 80 :: 7 : 8$

I have shown that the ordinal number of the typical molecule determines the quantivalence of each series of elements under it. When my paper was published in 1878, the only member of the series H7*n* known to be heptavalent was manganese, but I then stated that, the relation of this element to the iron group indicated a much higher quantivalence for the other members of the series H7*n* than had hitherto been accorded to them. MM. Hautefeuille and Chappuis have since formed pernitric acid, which indicates a higher quantivalence for nitrogen than had previously been obtained for this element;* and more recently, MM. Debray and Joly have shown that ruthenium is heptavalent by the formation of the heptarutheniates of potassium and sodium, which have many points of resemblance to the heptamanganates.†

One objection raised against the theory which I have propounded on the origin and nature of the elements I will remark upon, is an alleged want of causal connexion between the series of planetary distances and a series of atomic weights. Now, considering that specific gravities and atomic weights are admittedly correlated properties of the elements, and that specific gravities are fundamentally correlated with the dimensional properties of space, it follows that planetary condensations within interplanetary space,

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* *Comptes Rendus*, tome XCIV., pp. 1111, 1306, 1882.
† Ibid, tome CVI., pp. 1494, 1888.

are correlated directly with atomic condensations and atomic weights within that space. Hence the law that every increase of atomic weight, in a well-defined odd or even series of elements, is attended by an increase of specific gravity is a natural consequence of the theory. This law is well seen in my complete Table of the elements, in which are inserted the specific gravities below the numbers expressing the atomic weights.

In considering the experimental atomic weights of the series H*n* and H2*n*, one cannot but be struck with the admirable degree of precision with which these constants of nature have been determined ; but the microscopic habit of mind, induced by this extreme precision, in weighing and measuring, constitutes a real danger to the progress of chemical philosophy, and, unless guarded against, may render a good chemist as incapable of taking broad views of his own science, as a crétin in the depths of an Alpine valley would be in forming a just conception of the figure of the earth.

Dalton's fundamental law of chemical combination in definite and multiple proportions—first announced to the world through this Society*—was founded on approximations differing for the principal elements more than thirty per cent. from later determinations,† and through the doubling of many of the old atomic weights, the differences from the original determinations have largely increased.

The law of the multiple proportions of the atomic weights of the elements, in whole numbers of hydrogen, is the natural development of the law of chemical combination in multiple proportions, and just as spectral analysis has established the continuity of the phenomena of terrestrial and cosmical chemistry, so this continuity is further manifested by the mathematical relations which have been

* *Memoirs of the Literary and Philosophical Society of Manchester*, Vol. I. [2 series], pp. 250-281.

†Dalton's *New System of Chemical Philosophy*, Vol. II., p. 352, 1827.

found to subsist between planetary and molecular systems, as disclosed in my paper.

The positions of Hg = 200, and Pb = 208, as the highest members of the series H*n* and H2*n* afford me the opportunity of dealing with the question of periodicity or recurrence of properties, which has been supposed to exist when the elements are arranged in seriatim order of their atomic weights.

Newlands fixed the recurring period at every *eighth* element, commencing with hydrogen;* while Mendeleeff selected the *eighth*, *eighteenth*, and two or three other odd periods of recurrence.†

I shall now demonstrate that when the seriatim order of the atomic weights is rightly adhered to, the idea of recurring properties, or periodic functions, in terms of the vertical series of Newlands, or the horizontal series of Mendeleeff, has no real existence in nature.

In order that a clear conception may be formed of the principle of the alleged periodic law, as defined by these chemists, and shown in their respective tables at the end of this paper, I will arrange a series of consecutive numbers, with a repeating series of seven letters, to represent the elements in recurring periods, as in the table of Newlands, and at the same time apologise for the somewhat elementary character of the illustration.

A						B					
A 1	A 8	A15	A22	A29	– –	A 1	G 8	G15	F22	E29	– –
B 2	B 9	B16	B23	B30	– –	B 2	A 9	A16	G23	F30	– –
C 3	C10	C17	C24	C31	– –	*x* 3	B10	*x* 17	A24	G31	– –
D 4	D11	D18	D25	D32	– –	C 4	C11	B18	*x* 25	A32	– –
E 5	E12	E19	E26	E33	– –	D 5	D12	C19	B26	B33	– –
F 6	F13	F20	F27	F34	– –	E 6	E13	D20	C27	C34	– –
G 7	G14	G21	G28	G35	– 65	F 7	F14	E21	D28	D35	– 65

* *Chem. News*, Vol. XII., p. 83; Vol. XIII., p. 113.
† *Chem. News*, Vol. XL., pp. 243—303.

In table A, it will be seen that the elements on the horizontal lines have the same initial letter, with a difference of 7 between them, and represent families of elements possessing analogous properties, as in the alkaline, and alkaline-earth, metals. This ideal representation of recurring properties at the *eighth* element has been termed by Newlands *the law of octaves*, and by Mendeleeff *the periodic law.*

If, however, a new element x be brought into the system, between B2 and C3, for instance, as shown in table B, the order of the whole system vanishes; as x, by displacing all the elements below it, transposes the family of G from the bottom to the top of the series. The family of G, in its turn, would displace all the other families one step lower down in the table, and thereby transpose them into the next series with a higher order of quantivalence.

The system would be further disorganised if new elements x, were inserted in other parts of the table, as between B16, C17, and C24, D25, corresponding to the positions of scandium and germanium.

That a natural classification of elementary substances should rest on foundations so precarious as those above indicated, is *a priori* extremely improbable. The value of the classifications of Newlands and Mendeleeff must, therefore, be sought for on other grounds.

A comparison of Newlands' table of octaves with the atomic weights of the elements, so far as they are known, will show that, the apparent recurrence of elements of the same series, on the same horizontal line, is not so much a consequence of placing them in the regular order of their atomic weights, as the result of an arbitrary arrangement, founded on a chemist's knowledge of the analogous properties of these elements. This is abundantly evident in his table, wherein it has been found necessary (1) to transpose the order of Cr Ti, Ce Zr, U Sn. Te I, Hg Bi Os; (2) that when elements have about the same atomic weights, one of them is excluded from the system; as instanced in Co Ni, Ce La, Di Mo, Rh Ru, Pt Ir; (3) no places are left in the table for the recently discovered elements *scandium* = 44 between Ca Cr — *gallium* = 69 between Zn In — *germanium* = 72 between In As; (4) the differences between the atomic weights of consecutive elements on horizontal lines are in many places more or less than 7; as instanced in Y Ce, Cs Tl, Ba Pb where the difference is 9; Ta Th 10; Cr Y, W Hg 5; Au Os 2.

Bearing in mind the effect of inserting one or two new elements x in the ideal series A, and the discrepancies shown above in Newlands' table, there is abundant evidence to prove that, if the seriatim order of the atomic weights is rightly adhered to, the idea of octaves of recurrent properties has absolutely no foundation in nature.

The arrangement of the elements in Mendeleeff's table agrees in many respects with that of Newlands; but the line of analogous elements being vertical in the former table, and horizontal in the latter, the resemblance is not so easily seen as it would be if the direction of like series were the same in both tables.

On comparing the first and second vertical series of Newlands with the similar horizontal series of Mendeleeff, it will be observed that in the latter, hydrogen has been moved up one step, and, consequently, excluded from the system. The effect of this transposition of hydrogen has made the greatest difference possible in the two tables; for whereas F and Cl follow H at one end of the series of Newlands, these elements are at the other end of the series of Mendeleeff, as demonstrated in the ideal tables A. B. As the two series in both tables of these chemists are in seriatim order of their atomic weights, and the exclusion of hydrogen from Mendeleeff's arrangement is purely arbitrary, there is no reason for admitting that the positions of the halogens and oxygen series are correct in either table.

For like reasons the position of boron, B = 11, as the *fourth* member of Newlands' table, and the *third* member in that of Mendeleeff, cannot be admitted as correct, as this element bears a greater resemblance to phosphorus in its combinations and occurrence in nature than it does to other elements.

Since my paper was read in 1878, the position of boron in the series $H5n$ in my table has been confirmed by M. Etard, who has shown that, this element is a pentad, and has placed it at the head of the series of vanadium; the two elements presenting a great number of analogous properties.*

The transposition of boron from the third to the fifth group in Mendeleeff's table would displace nitrogen, which element would find no place in his system except to constitute itself one of his little periods, like hydrogen.

Again, the positions of N and Si in Newlands' table, as the *sixth* and *fifth* members of the first and second series respectively; and in Mendeleeff's table as the *fifth* and *fourth* of the same two series, are mutually destructive of each other; and, as these contradictions are brought about simply by the removal of hydrogen one step out of the system, no confidence can be placed in the positions of N and Si in either of the tables.

In his serious attempts to bring the whole of the elements into a periodic system, Mendeleeff found it necessary to add a series (group VIII.) to that of Newlands; but has thereby made his own system unperiodic. Now, the essence of periodicity is the recurrence of events or properties at regular intervals of time or place; but a period of 1, in the case of hydrogen, succeeded by two periods of 7; two periods of 17; and four or five periods of uncertain character, as set forth by Mendeleeff in his memoir, and

* *Comptes Rendus*, tome XCI., p. 931. 1880.

shown in his table, is equivalent to renouncing the idea of periodicity altogether.

In the conflict between the distinct ideas of periodicity, and the arrangement of the elements in natural groups, Mendeleeff has found himself in the same dilemma as Newlands in having to decide whether an element should be placed at the head or bottom of a series. This will be seen in Mendeleeff's table where he places copper, silver, and gold in both the first and eighth groups, and he has not ventured to state in his memoir to which of the groups these elements belong. No philosophical chemist would admit Au in the first group as the analogue of Ag and Cu; and the latter elements are equally inadmissible in the eighth group as analogues of iron and palladium. Moreover, the relation of gold to the platinum metals is too well established to permit of its separation from them, and the exclusion of gold from the first group would leave a place unoccupied by any element of high atomic weight in which Hg falls naturally as the analogue of Ag and Cu in my table, as well as in that of Roscoe and Schorlemmer.

Besides attributing in his table an excessive atomic weight to gold, Mendeleeff has reversed the well-established order of the atomic weights of the platinum metals, notwithstanding that their specific gravities are in accordance with the law which correlates these properties of the elements.

The requirements of the assumed periodic law also necessitate the anomalous grouping of boron with aluminium; mercury with zinc; and the separation of iron from manganese; the latter standing alone as a metallic element in group VII. Excepting manganese, this group consists of monatomic halogens only; while the intensely negative elements of the oxygen series have no analogues in group VI., either in their chemical or physical relations. The atomic weight of tellurium = 125 in this group has also been reduced abnormally to make it fall into the system.

From the numerous discrepancies and contradictions which present themselves in the classification of the elements when arranged in the regular order of their atomic weights, we have abundant reason to conclude that the notion of a periodic function, in terms of the horizontal series of Mendeleeff, has no more claim for acceptance than the octaves of recurring properties propounded by Newlands.

I will now point out in what the real value of the classifications of Newlands and Mendeleeff consists, and have to express my surprise that no chemist has, up to the present time, come forward to anticipate me in this analysis.

Long before the classifications of these chemists, the properties of the elements were compared with their atomic weights, and put together in groups. Cooke, Gladstone, Pettenkofer, Dumas, Odling, and others, subsequently compared the atomic weights of some of these groups, and found many interesting numerical relations subsisting among them. In the tables of Newlands and Mendeleeff it will be seen that there is an approximate arrangement of the elements in natural groups, and in somewhat crude order of their quantivalence. So far as I know, no attempt had previously been made to arrange *all* the elements in such an order that the relations of the several families could be seen at once. By comparing the members of one group with the homologous ones of the others Mendeleeff perceived, from the large differences among the atomic weights of some of the well-known families of elements, that certain members were missing, the existence and properties of which he was enabled to predict. Gallium, scandium, and germanium have since been discovered, and find their places approximately in the table of Mendeleeff.

The verification of this prediction has, however, no necessary connexion with the so-called periodic law, as the newly-discovered elements also find their places in my table, which makes no pretence to being a periodic arrangement.

Two of these elements in my table, Sc = 42 and Ge = 72, have been discovered since my paper was published by the Society. This paper is, consequently, entitled to some notice in connexion with the history of these elements. I have, moreover, good reason for thinking, from the multiple relations of scandium to the other members of the series, that my determination of its atomic weight = 42 is correct, as against 44, the value given in the table of Mendeleeff.

I have also shown that Sc, Ga, In, Tl, are analogues of the even series H3n, and form triads homologous with K, Rb, Cs, in the series H*n*.

The simplicity of the spectral reactions of Tl, In, Ga, Sc, which I have recently investigated and compared,* confirm the positions of these elements in relation to their homologues in H*n*. Mendeleeff has, however, placed Ga in the uneven series (Gruppe III.), homologous in position with Cu, Zn, and made Sc the analogue of Y; also, In, homologous with Ag Cd—positions which will not be admitted by philosophical chemists—and his atomic weight of gallium = 68, as I have shown, is still open to revision, and will be found ultimately to be = 96, as in my table.

A peculiar feature of the chemical philosophy of Mendeleeff is his intolerant rejection of all theories of the nature of the elements, and his entire ignorement of the multiple relations subsisting among them.†

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* Proc. Roy. Soc., vol. 53, 1893.

† Faraday Lecture delivered before the Fellows of the Chemical Society in the Royal Institution, June 4th, 1889. *Chem. Soc. Journal,* Vol. LVI., pp. 634—656, 1889. *Transactions,* 1889. The utterances of the Russian chemist on this occasion are in striking contrast to the thoughtful opinions expressed by Faraday in the same Institution in a course of six lectures delivered in the year 1852, in which he sets forth, with admirable lucidity, the reasons for his belief in the compound nature of certain groups of elements. He showed at the same time the multiple relations involved in the triads of Dumas, who, as is well known, shared the views of Faraday on the nature of the elements.

All the numerical relations among the atomic weights discovered by Cooke, Pettenkofer, Dumas, and others, are stated by Mendeleeff to be only the forerunners of the so-called periodic law, and even Newlands is said to have made only an approach to it, and discovered its germs.

A careful comparison of my table with that of Mendeleeff will show that, had he made the above pronouncement with reference to my arrangement of the atomic weights in multiple proportions, he would have been much nearer the truth; as my generalisations and classifications flow in regular sequence from the natural evolution of chemical ideas.

While an ordinary observer would see a great resemblance between my table of the elements and that of Mendeleeff—even to the extent of placing H outside the system—the discerning chemist will at once perceive how radically different they are, but chiefly in that all Mendeleeff's atomic weights are estimated quantities; while in my table, the atomic weights determine themselves from their multiple relations. Nor will the philosophical chemist fail to recognise the fact, how largely indebted I am to the labours of others for the stores of chemical knowledge which have rendered my discovery of the multiple relations of the atomic weights of the elements possible.—The greater the advance made in science by the individual, the greater is his indebtedness to those workers who have gone before him.

I regret that there is not more of novelty in this paper, but the *ad captandum* methods which have recently been adopted to dispose of the questions of the nature of the elements; the multiple relations of the atomic weights; and to establish the dogma of the so-called periodic law by the imposition of unreasoning authority, render it imperative upon me to combat these pretensions with all the means at my disposal.—To check the growth *ces, 189*

Atomic Heats.
5·9
6·4
6·5
6·8
6·4
6·4
6·2
6·5
6·6
5·9
6·7
6·4
6·9
6·3
6·2
6·3
5·9
6·4
6·5

system

Pd
Ag
Cd
U
Sn
Sb
Te

System o

Gruppe VI. RH² RO³
O = 16
S = 32
Cr = 52
Se = 78
Mo = 96
Te = 125
W = 184
U = 240

in Multiple Proportions, 1878.

H5*n*	H6*n*	H7*n*	
= 10 .. 11 2·63	— = 18	N = 14 14	
= 30 .. 31 1·82	— = 36	Si = 35 21 : 28 : 35 2·49	
= 50 .. 51·2 5·5	Cr = 54 .. .. 52·4 7·3	Fe = 56 Mn = 56 Ni = 56 Co = 56	56—8·14‖ 55—8·00 58—8·66 59—8·96
= 75 .. 75 5·63			
= 95 .. 94 6·67	Mo = 96 .. .. 96 8·6		
= 120 .. 120 6·72		Pd = 105 Rh = 105 Ru = 105 Da = 105	105·6—12·0 104·4—11·2 104·4—11·4 ... ...
= 140 .. .. 8·15	*x* = 144 .. .. .. 10·0		
= 165 .. .. 8·30‡			
= 185 .. 182 8? 9·8‡	W = 186 .. .. 184 18·26	Au = 196 Pt = 196 Ir = 196 Os = 196	196·7—19·34 197·0—21·50 198·0—22·42 198·6—22·48
= 210 .. 210 9·83			

te. ‖Electro-deposited.

—lemmer, J. P. Cooke, F. W. Clarke, and Watts'

Table of Elementary Substances, 1892.

	Atomic Weights.	Atomic Heats.		Atomic Weights.	Atomic Heats.		Atomic Weights.	Atomic Heats.
Hydrogen ...	H. 1		Glucinum ...	Gl. 9·2	5·9	Rhodium ...	Rh. 104·4	6
Aluminium...	Al. 27	5·8	Gold ...	Au. 196·7	6·4	Rubidium ...	Rb. 85	
Antimony ...	Sb. 120	6·4	Indium ...	In. 75·6:113·4	6·5	Ruthenium...	Ru. 104·4	6·3
Arsenic ...	As. 75	6·2	Iodine ...	I. 127	6·8	Scandium ...	Sc. 44	
Barium ...	Ba. 137		Iridium ...	Ir. 198	6·4	Selenium ...	Se. 79	5·9
Bismuth ...	Bi. 210	6·5	Iron ...	Fe. 56	6·4	Silicon ...	Si. 21:28:35	5
Boron ...	B. 11	4	Lanthanum...	La. 139	6·2	Silver ...	Ag. 108	6·1
Bromine ...	Br. 80	6·7	Lead ...	Pb. 207	6·5	Sodium ...	Na. 23	6·7
Cadmium ...	Cd. 112	6·3	Lithium ...	Li. 7	6·6	Strontium ...	Sr 87·5	
Cæsium ...	Cs. 132		Magnesium...	Mg. 24	5·9	Sulphur ...	S. 32	5·7
Calcium ...	Ca. 40	6·8	Manganese...	Mn. 55	6·7	Tantalum ...	Ta. 182	
Carbon ...	C. 12	5·5	Mercury ...	Hg. 200	6·4	Tellurium ...	Te. 128	6·1
Cerium ...	Ce. 92:141	6·7	Molybdenum	Mo. 96	6·9	Thallium ...	Tl. 204	6·8
Chlorine ...	Cl. 35·5		Nickel ...	Ni. 58	6·3	Thorium ...	Th. 231·4	
Chromium ...	Cr. 52·4		Niobium ...	Nb. 94		Tin ...	Sn. 117·8	6·6
Cobalt ...	Co. 58·9	6·3	Nitrogen ...	N. 14		Titanium ...	Ti. 48	
Copper ...	Cu. 63·3	6·1	Osmium ..	Os. 198·6	6·2	Tungsten ...	W. 184	6·1
Didymium ...	Di. 95	6·3	Oxygen ...	O. 16		Uranium ...	U. 240	
Erbium ...	Er. 170·6		Palladium ...	Pd. 105·6	6·3	Vanadium ...	V. 51·2	
Fluorine ...	F. 19		Phosphorus...	P. 31	5·9	Yttrium ...	Y. 61·7:89·5	
Gallium ...	Ga. 70	5·5	Platinum ...	Pt. 197	6·4	Zinc ...	Zn. 65	6·2
Germanium..	Ge. 72·7		Potassium ...	K. 39	6·5	Zirconium ...	Zr. 90	6·0

Table of Elementary Substances, according to the system of Newlands, 1865.

	No.		No.		No.		No.		No.		No.		No.		No.
H	1	F	8	Cl	15	Co&Ni	22	Br	29	Pd	36	I	42	Pt&Ir	50
Li	2	Na	9	K	16	Cu	23	Rb	30	Ag	37	Cs	44	Tl	53
G	3	Mg	10	Ca	17	Zn	25	Sr	31	Cd	38	Ba&V	45	Pb	54
Bo	4	Al	11	Cr	19	Y	24	Ce&La	33	U	40	Ta	46	Th	56
C	5	Si	12	Ti	18	In	26	Zr	32	Sn	39	W	47	Hg	52
N	6	P	13	Mn	20	As	27	Di&Mo	34	Sb	41	Nb	48	Bi	55
O	7	S	14	Fe	21	Se	28	Ro&Ru	35	Te	43	Au	49	Os	51

Table of Elementary Substances, according to the System of Mendeleeff, 1872.

Reihen	Gruppe I. — R^2O	Gruppe II. — RO	Gruppe III. — R^2O^3	Gruppe IV. RH^4 RO^2	Gruppe V. RH^3 R^2O^5	Gruppe VI. RH^2 RO^3	Gruppe VII RH R^2O^7	Gruppe VIII. — RO^4
1	H = 1							
2	Li = 7	Gl = 9,4	B = 11	C = 12	N = 14	O = 16	F = 19	
3	Na = 23	Mg = 24	Al = 27,3	Si = 28	P = 31	S = 32	Cl = 35,5	
4	K = 39	Ca = 40	— = 44	Ti = 48	V = 51	Cr = 52	Mn = 55	Fe = 56, Co = 59, Ni = 59, Cu = 63.
5	(Cu = 63)	Zn = 65	— = 68	— = 72	As = 75	Se = 78	Br = 80	
6	Rb = 85	Sr = 87	?Yt = 88	Zr = 90	Nb = 94	Mo = 96	— = 100	Ru = 104, Rh = 104, Pd = 106, Ag = 108.
7	(Ag = 108)	Cd = 112	In = 113	Sn = 118	Sb = 122	Te = 125	I = 127	
8	Cs = 133	Ba = 137	?Di = 138	?Ce = 140	—	—	—	— — — —
9	(—)	—	—	—	—	—	—	
10	—	—	?Er = 178	?La = 180	Ta = 182	W = 184	—	Os = 195, Ir = 197, Pt = 198, Au = 199.
11	(Au = 199)	Hg = 200	Tl = 204	Pb = 207	Bi = 208	—	—	
12	—	—	—	Th = 231	—	U = 240	—	— — — —

Table of Elementary Substances, arranged with their Atomic Weights in Multiple Proportions, 1878.

1	+ H*n* —		+ H2*n* —		H3*n*	H4*n*	H5*n*	H6*n*	H7*n*	
2	Li = 7 ·· ·· 7* 0·59†		Gl = 8 ·· ·· 9·2 1·64? 1·3‡		C = 12 ·· ·· 12 1·71§	— = 16	B = 10 ·· ·· 11 2·63	— = 18	N = 14 ·· ·· 14	
3	Na = 23 ·· ·· 23 0·98	F = 19 ·· ·· 19	Mg = 24 ·· ·· 24 1·74	O = 16 ·· ·· 16	Al = 27 ·· ·· 27 2·56	— = 32	P = 30 ·· ·· 31 1·82	— = 36	Si = 35 21 : 28 : 35 2·49	
4	K = 39 ·· ·· 39 0·86	Cl = 35 ·· ·· 35·5 1·3	Ca = 40 ·· ·· 40 1·58	S = 32 ·· ·· 32 2·05	Sc = 42 ·· ·· 44 3·4	Ti = 48 ·· ·· 48 4·1‡	V = 50 ·· ·· 51·2 5·5	Cr = 54 ·· ·· 52·4 7·3	Fe = 56 Mn = 56 Ni = 56 Co = 56	56—8·14‖ 55—8·00 58—8·66 59—8·96
5	Cu = 62 ·· ·· 63·3 8·9		Zn = 64 ·· ·· 65 7·2		Ce = 69 92 : 141 6·5	Ge = 72 ·· ·· 72·7 5·47	As = 75 ·· ·· 75 5·63			
6	Rb = 85 ·· ·· 85 1·52	Br = 81 ·· ·· 80 3·0	Sr = 88 ·· ·· 87·5 2·54	Se = 80 ·· ·· 79 4·8	Ga = 96 ·· ·· 70 5·95	Zr = 92 ·· ·· 90 4·15? 5·4‡	Nb = 95 ·· ·· 94 6·67	Mo = 96 ·· ·· 96 8·6		
7	Ag = 108 ·· ·· 108 10·6		Cd = 112 ·· ·· 112 8·69		Y = 123 61·7 : 89·5 8·1‡	Sn = 116 ·· ·· 117·8 7·29	Sb = 120 ·· ·· 120 6·72		Pd = 105 Rh = 105 Ru = 105 Da = 105	105·6—12·0 104·4—11·2 104·4—11·4 ... ...
8	Cs = 131 ·· ·· 132 1·88	I = 127 ·· ·· 127 4·95	Ba = 136 ·· ·· 137 3·75	Te = 128 ·· ·· 128 6·3	In = 150 75·6 : 113·4 7·42	La = 140 ·· ·· 139 6·7	*x* = 140 ·· ·· ·· 8·15	*x* = 144 ·· ·· ·· 10·0		
9	*x* = 154 ·· ·· ·· 12·2		*x* = 160 ·· ·· ·· 10·13		Er = 177 ·· ·· 170·6 9·4‡	*x* = 164 ·· ·· ·· 9·11	*x* = 165 ·· ·· ·· 8·30‡			
10	*x* = 177 2·2		*x* = 184 ·· ·· ·· 4·8		Tl = 204 ·· ·· 204 11·85	D = 188 ·· ·· 95 8·0‡	Ta = 185 ·· ·· 182 10·78? 9·8‡	W = 186 ·· ·· 184 18·26	Au = 196 Pt = 196 Ir = 196 Os = 196	196·7—19·34 197·0—21·50 198·0—22·42 198·6—22·48
11	Hg = 200 ·· ·· 200 13·6		Pb = 208 ·· ·· 207 11·44		Th = 231 ·· ·· 231·4 11·23	U = 240 ·· ·· 240 18·4	Bi = 210 ·· ·· 210 9·83			

*Accepted Atomic Weights. †Specific Gravities. ‡Estimated. §Anthracite. ‖Electro-deposited.

*** The accepted atomic weights are taken from the standard works and tables of Wurtz, Roscoe and Schorlemmer, J. P. Cooke, F. W. Clarke, and Watts' "Dic. Chem. Supp.," p. 247—Atomicity.

of error is as incumbent on an investigator of nature, as it is to enlarge the boundaries of science.

Chemists would do well to profit by the lessons to be derived from a study of the history of their science; for just as the animistic delusion of phlogiston dominated and retarded the progress of chemistry during the last century, so the notion of a periodicity in the atomic weights is the most remarkable illusion connected with the science of the present century, and equally detrimental to its future progress.

In conclusion, I would exhort all teachers of chemistry, whose aims are higher than to be mere phonographic exponents of other men's opinions, to examine for themselves the numerical relations of the atomic weights to which attention has been directed; as great responsibility rests upon those who continue the teaching of science in the Universities and Public Schools on foundations which a very limited exercise of the comparative faculty would prove to be false.

Ordinary Meeting, January 22nd, 1895.

Professor ARTHUR SCHUSTER, F.R.S., F.R.A.S.,
Vice-President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

Mr. RUPERT SWINDELLS, M.Inst.C.E., exhibited six diagrams showing the continuous markings made by a thermograph and a barograph during the three recent storms of December 22nd and 29th, and January 12th. A discussion ensued, in which Professor OSBORNE REYNOLDS, Professor H. LAMB, Sir LEADER WILLIAMS, and Professor SCHUSTER, took part.

Professor ARTHUR SCHUSTER, F.R.S., read a paper "On a Comparison of the Thermometers used by the late Dr. Joule with the Standards of the Bureau International des Poids et Mesures." The Joule thermometers, and the apparatus by means of which the comparisons were made, were exhibited.

On a Comparison of the Thermometers used by the late Dr. Joule with the Standards of the Bureau International des Poids et Mesures. By Arthur Schuster, F.R.S.

(Received January 22nd, 1894.)

The mechanical equivalent of heat being defined as the quantity of work necessary to raise unit mass of water at a stated temperature through one degree, it is clear that its value must depend on what we adopt as the unit of our temperature scale. It is not sufficient to fix on the temperature of freezing or boiling water, and to call them 0° and 100° respectively, for this leaves it still doubtful what we should take to be 50° or 60°. It has been usual for a long time to take the expansion of mercury in a glass vessel as our guide, and to fix the temperature intermediate between 0° and 100° by means of the mercury thermometer. For many purposes this is sufficiently accurate, but the irregular behaviour of such thermometers has led to some difficulties which have only been recently surmounted. The nature of the glass having a considerable influence on its coefficient of expansion, it has become necessary carefully to compare thermometers made of different kinds of glass, and those who have followed the recent development of this subject will know of the great progress which has been made in this direction by the Technische Reichs Anstalt and the Bureau International des Poids et Mesures.

Since the late Dr. Joule concluded his classical researches, several accurate re-determinations of the equivalent of heat have been made, and in order to compare the results obtained by different observers it seemed to me to be of great interest to find the scale value of Joule's thermometers in terms of some fixed or easily reproducible scale. The request which I made to Mr. B. A. Joule to allow me the use for a short time of his late father's thermometers was met at once with a most ready compliance, for which I have to offer my best thanks.

Thermometers made of hard French glass, having a definite chemical composition, have been investigated with great detail by M. Guillaume, of the Bureau International, and have been compared directly with the air thermometer by M. Chappuis.

I have thought it advisable, therefore, to compare the scale value of Joule's instrument in terms of that of a thermometer made of French standard glass.

The two thermometers which I had at my disposal were then called A and D in Joule's published papers; they were made and calibrated by Dancer in 1844. The thermometer D contains both the freezing and boiling point, while A only reaches up to about 30°C.

All observations on the equivalent were made with A, the scale value of which was determined by a comparison with the standard D. One division of A was found in mercury by Dr. Joule to correspond to 0°077214 F., which is equal to 0°042897 C.

To determine the relation between these thermometers and those now in use, it seemed sufficient to confine the investigation to the thermometer A. The thermometers having been calibrated so that the divisions are intended to represent equal volumes of the capillary tube, the distances of the divisions may serve as a test of the equality of the bore at different places. Near the freezing point the length of 50 divisions is 4·3 cms.; this length increases gradually until at the other end of the scale 50 divisions occupy a length of 5·3 cms.; the tube is therefore conical, the diameter at the top being about ten per cent smaller than at the lower end. A careful examination of successive lines on the stem shows considerable inequalities which must be due to errors of division; these irregularities are visible with the naked eye, two successive divisions differing occasionally by almost ten per cent in length. This irregularity renders an accurate comparison somewhat difficult.

The comparisons were made in a horizontal trough, containing a large quantity of water, the temperature of which was kept slowly rising by means of an electric current. It is not necessary to enter here into all the precautions taken to secure accuracy, as they are all well known to those accustomed to similar work. The readings having been taken in a horizontal position, it was necessary to find experimentally the pressure corrections necessary to reduce the indications to the vertical. Two sets of observations were made; in the first of these Joule's instrument was compared directly with a thermometer made by Tonnelot, divided into tenths of a degree and carefully calibrated by the Bureau International. By means of this instrument Joule's scale value can be directly brought into relationship with M. Chappuis' air thermometer. The second thermometer used in the comparisons was made by Baudin; it had a more open scale than the Tonnelot, being divided into fiftieths of a degree. The Baudin and Tonnelot had been most carefully compared with each other by Mr. Gannon and myself in the course of another investigation.

First Series. The Tonnelot and Joule A were compared at 19 different temperatures between 7° and 30°. The observations between 13° and 22° were reduced by the method of least squares with the following result.

If t_j means a temperature interval on the Joule thermometer reduced by means of Joule's factor and t_T the corresponding interval on the Tonnelot thermometer, all corrections having been applied, it is found that

$$t = t_T(1 - \cdot 00093) \qquad . \quad . \quad . \quad (1)$$

Hence the interval in the thermometer A as reduced by Joule is larger than that measured on the Tonnelot instrument by about one part in a thousand.

Second Series. Twenty-two comparisons were made between 14° and 20°, each comparison involving a considerable number of readings. Calling t_B the interval as measured on the Baudin thermometer

$$t = t_B(1 - \cdot 00084) \quad . \quad . \quad . \quad (2)$$

The relation between the Tonnelot and Baudin scale was found to be

$$t_T = t\ (1 - \cdot 00089) \quad . \quad . \quad . \quad (3)$$

Hence the second series would give

$$t_j = t_T(1 + \cdot 00005) . \quad . \quad . \quad . \quad (4)$$

making the Joule scale agree exactly with the scale of the French hard glass thermometer.

With respect to the difference in the results obtained in the first and second series, it is to be observed that, owing to the inequality of the divisions, we can hardly trust the Joule thermometer to give us readings which for an interval of 10° are accurate to one part in a thousand. In the second series an attempt was made to eliminate the errors of division as much as possible by taking a great number of readings in the same region, but not within the same two divisions. The second series is more to be relied upon also for the reason that it was made when considerable experience had been gained in the comparison of thermometers. I attach therefore much less importance to the second series, and believe that for all practical purposes we must take the scale value of Joule's thermometers to be identical with that of the Tonnelot instrument.

We may now reduce Joule's equivalent to the air thermometer of the Bureau International des Poids et Mesures, and then find

Equivalent as given by Joule in terms of water at 60° F. and the latitude of Greenwich...	772·55
Reduced to Chappuis' nitrogen thermometer...	774·65
" " hydrogen thermometer..	774·94

Rowland, who has contributed much to the improvement of the science of thermometry, and who is also the author of a very important determination of the equivalent of heat has reduced all his measurements to an air thermometer of his own construction. Having sent one of his thermometers to Dr. Joule, a comparison was made by the latter, which brings Joule's scale into common relation with Rowland's air thermometer. We possess no information as to how the comparison was made, but, accepting it as correct, it would be allowable to draw the conclusion that Rowland's equivalent, if referred to M. Chappuis' nitrogen thermometer, should be reduced by about one unit, so that at 15° C. it would have a value of about 777·3 as against 775 found by Joule.

Ordinary Meeting, February 5th, 1895.

EDWARD SCHUNCK, Ph.D., F.R.S., F.C.S., Vice-President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

Mr. R. E. CUNLIFFE and Mr. WILLIAM THOMSON, F.R.S. Ed., were appointed Auditors of the Society's accounts for the current year.

Reference was made to the deaths of three of the Society's honorary members, Professor ARTHUR CAYLEY, the Rev. T. P. KIRKMAN, and Sir JAMES COCKLE, all eminent mathematicians.

The following letter from the President, Mr. HENRY WILDE, F.R.S., was read to the members :—

To the Council of the Manchester Literary and Philosophical Society.

Nearly ten years have elapsed since funds were raised by the Society to provide further accommodation for its constantly increasing library and for some structural improvements in the Society's house. It was considered at the time that the enlargement of the Society's premises would serve to accommodate other kindred societies, and thereby lessen the burden of additional expense of maintenance thrown upon the Society by these extensions. The expectation of increased income from this source has not, however, been realised to the extent anticipated; and the falling-off in this revenue, together with a gradual diminution of income from other sources, must at no distant period land the Society in grave financial difficulties. Now that Manchester has become an important seat of learning, through the foundation of its noble Collegiate institutions, the reason for the existence of this Society appears to me as great, if not greater than it ever was. Numbers of men of high attainments and great mental ability are gathered round this great centre of industry, whose love of literature and science is unquenched by the absorbing business of life, and for whom the problems of nature are an ever-abiding interest. It is for such amateurs in various departments of knowledge, and the professors of academic institutions, that this Society affords a common ground for literary and philosophical research, as well as for pleasant social intercourse. While the aims and objects of the Society are sufficiently high to prevent its seeking any kind of patronage from men in high public or social positions, it has always given a welcome to such as desire to be enrolled among its members. It may be of interest for some of these to know that the Society's roll of ordinary members contains, with few exceptions, the names of all the noblest and best of those who have been identified with the public life and development of Manchester for more than a century; and its honorary members during the same period have made the world famous by their discoveries in every department of science. With the object of maintaining the high character which the Society has so long held in the estimation of the scientific world, and to increase still further its means of usefulness, I now propose to endow the Society with the sum of eight thousand pounds (£8,000) for investment, the annual income arising therefrom to be devoted to the furtherance of the purposes of the Society.

(Signed) HENRY WILDE.

Alderley Edge, February 2nd, 1895.

It was announced that the Council had gratefully accepted Mr. WILDE'S proposal, and

It was moved by Mr. MARK STIRRUP, F.G.S., seconded by Mr. WILLIAM THOMSON, F.R.S. Ed., and resolved, "That the grateful thanks of the members present be accorded to Mr. WILDE for his munificent gift."

Professor H. B. DIXON, F.R.S., gave an account of an examination of the spectrum of the newly discovered atmospheric substance, argon, at the Owens College.

Mr. BROTHERS, F.R.A.S., called attention to the fact that the planet Mercury was, for the time being, easily seen after sunset, being near Venus.

Mr. R. F. GWYTHER, M.A., read a paper on "The conditions securing the permanency of form of quantities which express physical properties in a continuous medium."

Mr. HENRY WILDE, F.R.S., read a paper on "The evidence afforded by Bode's Law of a permanent contraction of the *Radii Vectores* of the Planetary Orbits."

On the Evidence afforded by Bode's Law of a permanent Contraction of the *Radii Vectores* of the Planetary Orbits. By Henry Wilde, F.R.S.

(*Received February 5th, 1895.*)

In my paper on the multiple proportions of the atomic weights,* in which a geometric series of planetary distances, or condensations, was compared with an arithmetical series of atomic weights, it was laid down as a principle of scientific reasoning that, when a number of recurring instances was sufficient to establish the relation of cause and effect, or, in other words, the general accuracy of a law, the road to further discovery lay rather in the direction of explaining the anomalous departures from it, than in challenging the truth of the law itself.

Although this principle will be very generally admitted by philosophic thinkers, yet, a number of specialists in the natural sciences tacitly reject or openly deny it altogether. The cause of this divergence of opinion between different classes of thinkers and workers is not far to seek.

Next in order of importance to the discovery of the phenomenal properties of matter, is the accurate determination of the numerical relations subsisting among them. It is from close observation of these properties and their mathematical relations, that the physical sciences have attained their present high state of perfection, and on which their future progress will still further depend.

Through the laborious researches of an army of scientific workers, the physical constants of nature have been determined with a degree of accuracy which is truly marvellous.

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* *Memoirs and Proceedings of the Manchester Literary and Philosophical Society*, 4th Series, Vol. IX.

So closely has this work been followed up in some departments of science, by a laudable spirit of emulation engendered by various scientific organisations, that the reputation of some specialists rests almost entirely upon the determination of a small fractional difference in a dimension, or in some fundamental property of an elementary substance.

The microscopic habit of mind induced by this extreme precision in weighing and measuring, as I have already pointed out, constitutes a real danger to the progress of natural knowledge, as it may render a specialist totally incapable of taking broad views of his own science. For let some one of these be told that, from a theory founded upon numerous observations and resting upon a basis as unassailable as the law of gravitation, that a particular numerical relation which he has determined with so much care and labour, and for which he has, perhaps, been rewarded by some academic distinction, so far from being correct to a fractional quantity, is not even correct to the unit's place, all the arguments that can be used will be as little able to prevail with him, as the wind did with the traveller to part with his cloak, which he only held the faster.*

Happily for the progress of science the numerical constants of nature are not the property of the class of specialists who determine them, as is too often assumed, but belong to the commonwealth of learning which the cultivators of every department of knowledge are free to use and reason upon, for the general advancement of science and the good of mankind.

* Lest it should be inferred that I unduly subordinate the arduous labour of exact measurements to theories derived from observation, I may say that much of my own experimental work in several branches of science has been of this character:—*Phil. Trans.*, 1867. *Memoirs Lit. Phil. Soc., Manch.*, Vol. XXX. *Phil. Mag.*, 1885, 1886. *Roy. Soc. Proc.*, 1891, 1893, 1894.

I have shown in my previous papers that the theoretic atomic weights of several allied series of elements so closely agree with those obtained experimentally, that the differences amount to less than half of 1 per cent. of the whole of these series. It will, therefore, be evident to philosophic thinkers in every department of science, that the experimental atomic weights, or any other property of matter which the same numbers represent, are only approximations and subordinate to the theoretic law itself, just as the actual planetary orbits differ from those perfectly elliptical, as deduced from the law of gravitation.

It is not a little remarkable that in my comparison of the atomic weights and the *radii vectores* of the planetary orbits, I should have to encounter the same kind of objection against a law of multiple proportions of planetary distances as that which has been advanced against the multiple proportions of the atomic weights.

As the quantitative determinations of observational astronomy and molecular physics require the same qualities of mind and methods of investigation, it is not surprising to find that, when a number of recurring instances approaching the nature of a law are brought under the notice of an astronomical computer, he will pronounce for, or against, the assumed law according to his particular bias or idiosyncrasy. Hence it is that Bode's law of planetary distances is considered by some only as an aid to astronomical research, while others reject it altogether.

This law, briefly stated, is as follows :—The *radii vectores*, or the relative mean distances of the planets from the sun, proceed in multiple proportions ; each one after the second being double the one which precedes it, and by adding 4 to each progression, we obtain approximately the distances of the planets, as shown in the following table :—

	Bode's Numbers.	Astronomical Units. Earth=1.	Observation Distances.	Differences.	Diff. + ·024.
Mercury	0 + 4 = 4	0·0 + ·4 = 0·400	0·387	− 0·013	− 0·037
Venus	3 + 4 = 7	0·3 + ·4 = 0·700	0·723	+ 0·023	− 0·001
Earth	6 + 4 = 10	0·6 + ·4 = 1·000	1·000	0·000	− 0·024
Mars	12 + 4 = 16	1·2 + ·4 = 1·600	1·523	− 0·077	− 0·101
Minor Planets	24 + 4 = 28	2·4 + ·4 = 2·800	2·750	− 0·050	− 0·074
Jupiter.........	48 + 4 = 52	4·8 + ·4 = 5·200	5·202	+ 0·002	− 0·022
Saturn.........	96 + 4 = 100	9·6 + ·4 = 10·000	9·539	− 0·461	− 0·485
Uranus	192 + 4 = 196	19·2 + ·4 = 19·600	19·183	− 0·417	− 0·441
Neptune	384 + 4 = 388	38·4 + ·4 = 38·800	30·036	− 8·764	− 8·788

At the time when the multiple proportions of the planetary distances were discovered, all the minor planets were unknown, when Bode, having noticed the void between the distances 16 and 52, ventured to predict the discovery of a new planet with a distance of 28. Such was the confidence in the existence of this body that a number of German astronomers formed themselves into a society for the express purpose of searching for it. The discoveries of Ceres by Piazzi, Pallas and Vesta by Olbers, and of other minor planets were, doubtless, due to the well-grounded conviction of the existence of a planet between the orbits of Mars and Jupiter, as predicted by Bode.

Another important application of Bode's law was made by Adams and Leverrier in their first determinations of the elements of the unknown planet Neptune. The late Astronomer Royal (Sir George B. Airy), in his historical review of the circumstances connected with the discovery of this planet, says that, "if the mathematicians, whose labours I have described, had not adopted Bode's law of distances, they would never have arrived at the elements of the orbit,"* or, in other words, would never have discovered Neptune.

The parallelism of the discovery of new planets through the law of the multiple proportions of the planetary distances, and the discovery of new elements through the law of the multiple proportions of the atomic weights, as shown in my former papers, will not fail to be evident to all investigators in natural science.

Notwithstanding the brilliant results which followed the application of the law of the multiple proportions of the *radii vectores* of the planetary orbits, the admission made of the truth of the law was only wrested from Airy by the irresistible logic of facts; for, in the same review, he states that, "it is a law for which no physical theory of the rudest kind has ever been suggested, and the assumption of the law was only an aid to calculation that did not compel the computer to confine himself to the condition assigned by it, as instanced in the ultimate change of mean distance made by Adams and Leverrier, who used the law to give the first approximation of the mean distance."

Sir John Herschel also says of Bode's law that "no account *a priori*, or from theory, was to be given of this singular progression, which is not, like Kepler's laws, strictly exact in numerical verification." While admitting the value of Bode's law as a useful auxiliary to serve as a stepping stone in the path to discovery, Herschel repudiates it as a fundamental truth because of its discordance with the distance of Neptune. In his forensic ardour to discredit the law, he has made this discrepancy appear twice as great as it really is, since he compares the orbit of Neptune with the orbits of Uranus and Mercury instead of Bode's

* *Proc. Roy. Astronomical Society*, Nov. 13, 1846.—*Phil. Mag.* [3], Vol. XXI., p. 537.

numbers for Neptune with the actual distance of the planet.*

The latest and most uncompromising objector to Bode's law is the eminent astronomical computer, Simon Newcomb, who says that, "before the discovery of Neptune the agreement was so close as to suggest the existence of an actual law of distances; but the discovery of this planet in 1846 completely disproved the supposed law, and there is now no reason to believe that the proportions of the solar system are the result of any exact and simple law whatever." †

In the opinions expressed by the eminent astronomers here referred to, we see the same mental attitude towards approximate laws which inclines to reject them absolutely, as in the case of the law of multiple proportions in the atomic weights, rather than to search for the causes of differences.

So accustomed are astronomical computers to viewing the exact relations of Kepler's laws with the law of gravitation, and the extreme refinements of measurement employed in connexion with these relations, that their power of forming a just estimate of probabilities becomes atrophied by disuse, to the great hindrance of the science which they endeavour to advance. This habit of mind is all the more deplorable in its consequences, from the fact of its being unsuspected, and associated with attainments of the highest order in men occupying important positions in observatories and in seats of learning, where the influence of their peculiar idiosyncrasies makes itself felt through a long course of years. ‡

* *Outlines af Astronomy*, pp. 334—336.

† *Popular Astronomy*, p. 233.

‡ A remarkable combination of the habit of exact observation with the power of generalising is seen in the discovery, by Sir Edward Sabine, of the direct connexion of the eleven-year dark sun-spot period with the same period of terrestrial magnetic disturbances—a generalisation which is justly considered to be one of the finest examples of inductive philosophy that has ever been presented to the world. Nevertheless, a mathematician of reputation (Lord

Airy and Herschel rightly said that Bode's law is not founded upon any theory which correlates it either with Kepler's laws, the gravitating force, or any other known physical law. This want of connexion, however, is no reason for rejecting it, any more than the law of gravitation is to be rejected because natural philosophers are not yet agreed whether the orbital moving force of planetary bodies is to be measured by the simple velocity, or the square of the velocity.

Notwithstanding the departure from the law of multiple proportions of the planetary distances in the case of Neptune, where the difference between the theoretic and actual numbers is as 38 to 30, no seriously reflective mind can consider the approximate binary progression of distances shown in the table as entirely fortuitous. For, just as the trained eye of a geologist, from his observation of a few mammillated rocks and the distribution of moraine matter, perceives with the certainty of a geometrical demonstration the former existence of glaciers in many an English valley, when all other record is obliterated, so abundant evidence of exact purposive law is revealed in the close approximation of the planetary distances to a law of multiple proportions.

I am quite sensible of the danger of importing teleological arguments into strictly scientific discussions, from their liability to abuse, but the idea of purposiveness comes out so strongly in this law, from its complete isolation from all known physical laws, the correlation of which originates the idea of necessary connexion, that I was induced to

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Kelvin), after warmly supporting Sabine's conclusions so recently as April, 1891 (*Popular Lectures and Addresses*, vol, 3, p. 276), by an elaborate computation, wholly unsupported by observational evidence, persuaded himself, in the following year, that "the connection between sun-spots and terrestrial magnetic disturbances is unreal, and that the seeming agreement between the periods has been a mere coincidence."—Address delivered at the Anniversary Meeting of the Royal Society. *Roy. Soc. Proc.*, vol. lii., p. 308.

examine the law more closely with a view to ascertain the causes of the anomalous departures from it.

On comparing the theoretic with the actual planetary distances, it will be seen that most of the differences have the same *minus* sign, or, in other words, are less than the theoretic distances. So close, in fact, is this relation that, the $\frac{1}{1800}$ part of the radius vector of Jupiter; an indefinitely small amount of the earth's mean distance; and $\frac{1}{30}$ part of the radius vector of Venus, would make all the actual planetary distances less than the theoretic distances. The addition of the small fraction 0·024 to Bode's constant 0·4, also makes the *minus* differences absolute, without materially affecting the theoretic distances, as shown in the last column of the table.

So far as I know, these numerical differences have never before been recognised by astronomers, and add immensely to the evidence in favour of the absoluteness of the primordial law of multiple proportions of the planetary distances.

On comparing the actual *radii vectores* of the planetary orbits with Bode's numbers, it will be seen that the greatest *minus* differences are in the outer planets. Thus the difference of Saturn is 0·46; Uranus 0·41; and, notably Neptune, which has the anomalous *minus* difference of 8·74.

The relative order, motions, and magnitude of these bodies point to their mutually disturbing attractions as the primary cause of the departure from the exact multiple proportions of their mean distances, although the influence of a resisting medium is not necessarily excluded.

Suggestions have been made that there may still be another planet outside the orbit of Neptune; but as there is no evidence to indicate the existence of such a body, we may conclude that Neptune is the outermost member of the solar system, and, consequently, is subject to the disturbing influences of all the major planets to contract his radius vector to a much greater extent than any of the others. The large amount of this contraction is strong presumptive evidence against the existence of a planetary body beyond Neptune.

The contraction of the orbit of Uranus would appear to have been greatly influenced by the counter attraction of the larger mass of Neptune, so that the difference from Bode's numbers does not amount to more than 0·41, as shown in the table. For like reasons, through the joint attraction of Uranus and Neptune, the contraction of the radius vector of Saturn only amounts to 0·46, notwithstanding his comparative nearness to the enormous mass of Jupiter.

The very near coincidence of Bode's numbers with the actual radius vector of Jupiter is equally interesting with the abrupt variation in the magnitude and order of the intra-jovial planets, the united masses of which are insufficient to overcome the counter attraction of Saturn, Uranus, and Neptune. Hence the radius vector of Jupiter remains without change up to the present time, or is even extended by the small fractional quantity shown in the table.

The minor planets also offer an interesting case of contraction of the *radii vectores* by their interaction on each other. Out of the total number of these bodies which have so far been discovered (more than 300) only one-fourth of them have orbits above the theoretic distance 2·8; the actual mean distance of the whole number being 2·75.

The very near agreement of the Earth's mean distance with Bode's numbers may be regarded as the result of the equilibrium established by the opposite attractions of Venus and the outer planets. The small mass of Mars in relation to the Earth and Venus would appear to be the cause of the contraction of his radius vector within the theoretic distance; while the joint attractions of the Earth and exterior planets increase the radius vector of Venus a fraction above the amount required by Bode's law, as is seen in the orbit of Jupiter.

By the like reasoning the radius vector of Mercury ought to be extended above the theoretic amount, whereas the orbit has a difference less than Bode's numbers. But Leverrier found that the perihelion of this planet increased above that computed from the gravitation of the other planets, and he attributed the anomalous increase to the action of a planet, or group of small planets, between Mercury and the Sun. It appears, however, much more probable that this increase in the motion of the perihelion is caused by Mercury revolving in a resisting medium, extending some distance from the Sun, as suggested by other astronomers, rather than from the action of one or more small planetary bodies; but either supposition is sufficient to explain the permanent contraction of the radius vector of Mercury in opposition to the attractions of the outer planets.

Having shown the high degree of probability there is, that Bode's numbers are the expression of an exact law, which has been modified by the mutual attractions of the planetary bodies among themselves, and possibly to some extent by the influence of a resisting medium; and if, notwithstanding the brilliant discoveries of the minor planets and Neptune through the application of this law, it should still be maintained that these numbers are arbitrary, the most mechanical of computers will, I think, hardly consider the series of *minus* differences shown in the table as fortuitous, when taken in conjunction with the evidence of law in the binary progression of the mean distances.

In the law of the multiple proportions of the *radii vectores* of the planetary orbits, shining forth amidst the chaotic vortices of immensity, we have the primordial expression of intelligent purpose in the universe revealed directly to the mind of man, and destined hereafter to become part of the broad cosmological foundation on which the natural development of religious ideas will ultimately rest.

The permanent contraction of the planetary orbits brings us again into contact with the question of the final dissolution of the visible universe, which has exercised the greatest minds from the very dawn of philosophy. Mathematicians of the last century endeavoured to establish the dogma of the invariability of the mean distances and the absolute stability of the planetary system. Nevertheless, the conviction still remains that the present order of the universe is not eternal, and the evidence afforded by Bode's law of a permanent contraction of the planetary orbits indicates that the dissolution of the solar system will be brought about by causes now operating within the system itself, although at a rate so slow as to be imperceptible in the past records of astronomical observation.

From the fact that there has been so little change in the multiple proportions of the orbits of Jupiter and the Earth from the period of their resolution into spherical bodies, the time of the final transformation of the solar system into its primordial elements appears so extremely remote, that all previsions with regard to it, belong rather to the poetry of science than to the domain of philosophy. The heroic and polished lines of Darwin, however, so happily express the subject of my paper, that no apology is needed in quoting them before a Society which is both literary and philosophical :—

"Roll on, ye stars! exult in youthful prime,
Mark with bright curves the printless steps of Time ;
Near and more near your beamy cars approach,
And lessening orbs on lessening orbs encroach ;
Flowers of the sky! ye, too, to age must yield,
Frail as your silken sisters of the field !
Star after star from heaven's high arch shall rush,
Suns sink on suns, and systems systems crush,
Headlong, extinct, to one dark centre fall,
And Death, and Night, and Chaos mingle all !
Till o'er the wreck, emerging from the storm,

Immortal Nature lifts her changeful form,
Mounts from her funeral pyre on wings of flame,
And soars and shines, another and the same.*

In following up to their ultimate issue cosmical theories of the transformations of the universe, some minds may naturally shrink from forming conclusions involving apparently the absolute annihilation of man as a sentient being. But there are abundant means of knowing that such nirvanian conclusions are not a necessary consequence of the dissolution of planetary systems. For just as the conscious intelligence of man perceives the workings of purposive intelligence animating the universe—cosmos and microcosmos—through countless ages; so the well-grounded conviction is established in his mind that, whatever happens, the principle of conscious intelligence within himself is of the same nature as that manifested in the universe around him, and is, therefore, immortal and eternal.

Another of our own poets, whose noble hymns† enter deeply into the religious life of English-speaking peoples throughout the world, has expressed man's ultimate relation to the cosmos in the striking language with which I shall now conclude this paper :—

"The stars shall fade away, the sun himself
Grow dim with age, and nature sink in years ;
But thou shalt flourish in immortal youth,
Unhurt amidst the war of elements,
The wrecks of matter, and the crush of worlds."
ADDISON'S *Cato*, Act V.—Scene 1.

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* Darwin's *Botanic Garden*, Canto IV., 367—380.
† *Spectator*, Nos. 441, 453, 465.

ELEMENTS OF THE PLANETARY SYSTEM.

	Mean distance from the Sun.		Periodic Time.		Diameter in Miles.	Mass.	Axial Rotation.		
	Astronomical Units.	Miles.	Years.	Days.			H.	M.	S.
Mercury	0·3870	35,392,000	0·240	87·969	2,992	0·065	24	5	30 ?
Venus	0·7233	66,131,000	0·615	224·700	7,660	0·785	23	21	23
Earth	1·0000	91,430,000	1·000	365·256	7,918	1·000	23	56	4
Mars	1·5236	139,312,000	1·880	686·979	4,211	0·124	24	37	23
Minor Planets	2·7500	251,432,500	4·561	1665·765	214 to 18	,,	,,	,,	,,
Jupiter	5·2028	475,693,000	11·862	4332·584	86,000	300·857	9	55	21
Saturn	9·5388	872,134,000	29·458	10759·219	70,500	90·032	10	29	17
Uranus.........	19·1827	1,753,851,000	84·018	30686·820	31,700	12·641	,,	,,	,,
Neptune	30·0362	2,746,271,000	164·622	60126·710	34,500	16·761	,,	,,	,,
							D.	H.	M.
Sun	,, ,,	,, ,,	,, ,,	,, ,,	860,000	314,760,000	25	7	48

Ordinary Meeting, February 19th, 1895.

Professor OSBORNE REYNOLDS, M.A., LL.D., F.R.S., Vice-President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

Reference was made to the death of the MARQUIS DE SAPORTA, one of the Society's honorary members.

A communication from Mr. J. W. BLACK, of Edinburgh, on the fall of soot and ash in a garden in George Square, in that city, was read by one of the Secretaries. The average fall during the year in which the observations were made was 77 grains per square foot, per month.

Professor ARTHUR SCHUSTER, F.R.S., opened a discussion on the new atmospheric constituent, argon, in which Professor H. B. DIXON, F.R.S., Professor OSBORNE REYNOLDS, F.R.S., Dr. J. BOTTOMLEY, F.C.S., and Professor H. LAMB, F.R.S., took part, special reference being made to the possibility of the new "element" filling a gap in MENDELEEFF'S periodic series.

A conversation on the recent severe weather ensued, during which a question as to whether birds suffer most from hunger or thirst during prolonged frost arose. Mr. F. NICHOLSON, F.Z.S., Mr. J. J. ASHWORTH, and Mr. R. F. GWYTHER, M.A., took part, and evidence was given that thirst, rather than hunger, is the chief cause of distress to birds under such circumstances.

On *Kaloxylon Hookeri*, Will. and *Lyginodendron Oldhamium*, Will. By Thomas Hick, B.A., B.Sc., A.L.S., Assistant Lecturer in Botany, Owens College. Communicated by F. E. Weiss, B.Sc., Professor of Botany at the Owens College.

(*Received May 31st, 1894.*)

In the VIIth and XIIIth of his *Memoirs* "On the Organisation of The Fossil Plants of the Coal Measures,"* Prof. Williamson describes a number of fossilised plant remains under the name of *Kaloxylon Hookeri.* The fossils obviously represent fragments of the axial parts of some plant or other, and the structure they exhibit is somewhat striking even among Carboniferous plants. Practically, there are three series of specimens described, which represent three stages of development of one and the same structure, though, as we shall see, this is not apparent from Williamson's descriptions.

Taking first those which have reached the highest stage of development, the main structural peculiarities, which they present, as described by Williamson, are as follows :—

1. A central cylinder composed of vascular elements intermingled with delicate thin-walled cells. The former are of a type which Williamson calls reticulated, but which I should prefer to call pitted, and those at the periphery are usually of smaller diameter than those nearer the centre.

2. Enclosing the central cylinder are a variable number, usually from four to six, of secondary, collateral, vascular bundles, separated from one another by broad medullary rays, whose cells are radially elongated. Each bundle has a well-marked phloem, from which the centrifugally developed xylem was presumably

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* *Phil. Trans.*, 1876. Ditto, 1887.

separated by a layer of cambium, and secondary medullary rays are present. The vascular elements of the xylem are of the same character as those of the central cylinder.

3. Outside the zone formed by the secondary vascular bundles is the cortex, which is differentiated into distinct layers. Nearest the phloem of the bundles it consists of a thin walled parenchyma composed of cells of unequal size and irregular shape, among which are numerous elements which Williamson describes as elongated canals or cells containing a black substance. This substance is either in the form of a solid rod, or a hollow cylinder, and the elements in which it is found give the cortex a character which is remarkably distinctive.

4. At the outer periphery of the cortex are two somewhat irregular rows of cells, which are very clearly distinguishable from the tissue within. Both these Williamson appears to regard as forming a distinct epidermal layer.

The second series of Williamson's specimens have no secondary vascular bundles. In them he describes the following structures :—

1. A central cylinder, pentagonal or hexagonal in outline, composed like that of the preceding specimens, of vascular elements intermingled with thin-walled cells. The vascular elements are again pitted, and those at the periphery are again smaller in diameter than those nearer the centre.

2. A cortex of thin-walled, irregularly-shaped cells, interspersed among which the elements with black contents are again met with.

3. A so-called epidermal layer, two cells in thickness, having the same characters as that of the first series of specimens.

The specimens of the third series are small in comparison with the others, and, as described by Williamson, have a peripheral layer, two cells thick, and a cortex, which have the same characters as those of the other series. The central cylinder strongly resembles that of a rootlet, having three, four, or more xylem strands arranged as in recent rootlets. As to the nature of this group of specimens, Williamson expresses himself somewhat doubtfully, but concludes with the remark that it is difficult to believe that they have been other than roots.

Such is a brief description of the anatomical structure of the different forms of *Kaloxylon Hookeri*, Will., as given by Williamson. It is not proposed to revise that description on this occasion, but rather to discuss the morphological nature of the fossils to which it applies.

Taking the last series of specimens first, I think there can be no doubt that, as Williamson found it difficult to doubt, they are really roots. This conclusion has been reached after a careful comparison of Williamson's description and figures with a large number of specimens in my own cabinet and in the cabinets of friends. The structures that have given origin to the fossils were so delicate, however, that they are rarely preserved in a perfect condition, and have, besides, generally suffered more or less from compression. Still, where the central cylinder is fairly complete, it is unmistakeably triarch, tetrarch, or pentarch, &c., and both the structure and the appearance points to a centripetal development of the xylem strands. In a few cases, what appears to be a pericycle and endodermis may be seen between the outer edges of the xylem plates and the cortex.

The two peripheral layers of cells which Williamson seems to combine as an epidermal layer, should, I think, be interpreted differently. The outermost is not characterised in the way we should expect in a true epidermis, and rather resembles the piliferous layer of roots, while the subjacent layer is not unlike the suberous layer of the same organs.

Passing on to the specimens of which the type is figured by Williamson in the XIIIth *Memoir** the root-like appearance is unmistakeable, and the structure harmonises better with that of a root than that of a stem.† The variation of the shape of the central cylinder or stele,

* *Phil. Trans.*, 1887. Pl. 24, Fig. 27. † Pl. II., Fig. 2.

being pentagonal in some cases and hexagonal in others, is only what we know to occur in recent roots. Moreover, in well-preserved specimens it is difficult to resist the conclusion that the vascular elements have developed centripetally from the peripheral angles, as they are often arranged in radial plates which converge towards the centre and increase in size from without inwards.* In most cases these plates actually meet in the centre, and more or less of metaxylem is developed between them before secondary thickening sets in, and in this way the mode of development is somewhat obscured. But less advanced stages are quite demonstrative and readily enable us to make out the interpretation of the older.

In the angles between the xylem plates, a group of thin-walled elements is usually distinguishable,† and though the preservation of the fossils is scarcely so perfect as to show distinctive phloem characters, there can be little doubt that each group represents a phloem strand.

The periphery of the stele is not as clearly marked as in most recent roots, but in the place it should occupy there are two, three, or a few layers of cells which are so distinct from the cortical tissue outside them, that they may without much danger of error, be regarded as representative of the pericycle and endodermis.‡

The cortex itself, in its relative bulk, the absence of marked thickening of the cell-walls—with the exception of the elements with special contents—and the absence of mechanical tissue in the hypodermal region, is also far more suggestive of a root than a stem.§ In addition to this the two peripheral layers, like those of the first type, accord better with the piliferous and suberous layers of roots than with the epidermal and sub-epidermal layers of stems.||

Finally Williamson's figure shows a rootlet arising from

* Pl. II., Fig. 2. a. † Pl. II., Fig. 2. p. ‡ Pl. II., Fig. 2. d.
§ Pl. II., Fig. 2. b. || Pl. II., Fig. 2. c.

the specimen, and it will be noticed that, as is the general rule in recent roots, it arises endogenously at the periphery of the stele and stands opposite to one of the xylem plates.

Coming now to the last series of specimens, we find quite a number of root characteristics, which appear to be conclusive of their morphological nature. In the figures given by Williamson in the VIIth* and XIIIth† *Memoirs* there are no indications that the centrifugally developed secondary xylem is superimposed on a stele whose structure is that of a typical root, unless it be the last, and even this is not free from ambiguity. But in several specimens which have passed through my hands this is clearly shown, and in the Cash Collection of Fossil Plants at the Manchester Museum, Owens College, there is one preparation which is demonstrative.‡ In this the stele or central cylinder is hexarch, but two of the initial points of development of the xylem are very near to one another. The six groups of protoxylem are still easily distinguishable, and the original six xylem plates can be made out without much difficulty, embedded in conjunctive parenchyma.§ The secondary xylem consists of five broad, nearly oblong masses and a much smaller sixth, each standing opposite the sinus between two plates of the primary xylem, while opposite the latter are broad medullary rays, which widen as they approach the cortex.|| A lenticular mass of phloem, normally placed externally, accompanies each mass of secondary xylem, so that the secondary bundles are collateral.¶ Enclosing the ring of collateral bundles, are two or three layers of cells, which are not well preserved, but which certainly differ from those of the cortex. These I take to be the representatives of the pericycle and endodermis.

The cortex retains its primary structure for some time

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* *Phil. Trans.*, 1876, Pl. 5, Figs. 2, 3, and 26 and Pl. 7, Figs. 37, 38.
† *Phil. Trans.*, Pl. 23, Figs. 20, 26. ‡ Pl. II. Fig. 1. § Fig. 1. a. || Fig. 1. b. m. ¶ Fig. 1. p.

after secondary thickening has set in.* Whether it is ultimately thrown off as in recent roots is not actually proved by my preparations, but one of them suggests that this is the case. Here the cortex is reduced to a relatively narrow zone, only slightly thicker than that which represents the pericycle and endodermis, and is composed of somewhat similar cells. At the periphery there are indications of a separation layer of periderm, but these are too vague to justify a more definite statement.

Reviewing the whole of the characters presented by the various forms of *Kaloxylon Hookeri*, Will., they seem to me to fully warrant the conclusion that the fossils so named are all roots, in the morphological sense at least, and that the three types are merely different stages of development, Whether every root passed through all the three stages, or whether some of them remained permanently in the primary condition, it is impossible to say, but this point is of secondary importance. A more pressing question is whether it is possible to connect these roots with any of the stems which are found associated with them in the Lower Coal Measures of Yorkshire and Lancashire. In what follows an attempt is made to answer this question in the affirmative, and to advance reasons for regarding *Kaloxylon Hookeri*, Will., as the root of *Lyginodendron Oldhamium*, Will.

Among the details of structure which distinguish *Kaloxylon Hookeri* from most other Carboniferous plants are the markings on the walls of the tracheae of the primary and secondary xylem. As already mentioned, these elements are of the pitted type, and the type is so constant that in his VIIth *Memoir* Williamson tells us that at the time of writing he had not discovered in any of his sections a single barred or spiral vessel. Without asserting that all other kinds of tracheae are altogether absent, the fact that the pitted form is the prevailing one prompts us to look for

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*Fig. 1. c.

the stem, to which *Kaloxylon Hookeri* served as a root, among those stems in which there is a preponderance of the same kind of tracheae. Among such stems those referred to the genera *Heterangium* and *Lyginodendron* are the most conspicuous, and as it happens they are not infrequently found in the same localities as *Kaloxylon Hookeri.* As a first approximation, then, we may say that *Kaloxylon Hookeri* may possibly be the root of either *Heterangium* or *Lyginodendron.*

A still closer examination and comparison of the various tissues met with in these three genera of fossil plants enables us, however, to go much further than this. For it shows that the cortex of *Lyginodendron Oldhamium*, is characterised by an inner parenchyma *which is identical* with the corresponding tissue of *Kaloxylon Hookeri.* It has been pointed out that in the cortex of all the three types of the latter plant, we have a thin-walled parenchyma, in which are scattered, singly or in small groups, elongated canals or cells containing some black substance. This structure gives quite a special character to this plant and enables us to recognise it and even fragments of it, without any difficulty, among the multitude of other plants associated with it. Now, in well-preserved specimens of *Lyginodendron Oldhamium* the inner zone of the cortex is composed of an identical thin walled parenchyma in which are exactly similar elements with black contents, scattered singly or in small groups in the same manner as in *Kaloxylon Hookeri.* The whole tissue is so peculiar to, and characteristic of, this *Kaloxylon*, that its presence in *Lyginodendron Oldhamium* seems sufficient, when combined with the identity of their vascular elements, to warrant the conclusion that the latter, and *Kaloxylon Hookeri*, are the stem and the root of one and the same plant. The fact that in the hypoderma of the former we have a characteristic stereom which is absent from the latter, is nc objection to this combination, as it is well known that the arrangement of the mechanical tissues of stems generally differs from that of roots.

Note added October 16th, 1894.

When the preceding paper was completed and Professor Weiss had undertaken to communicate it to the Society, I learnt from Professor Williamson that he and Dr. Scott, working upon the same plants, had also reached the conclusion that *Kaloxylon* is the root of *Lyginodendron.* They sent a joint paper on the subject to the Royal Society, which was read on the 31st of May, and on July 12th, in reporting the proceedings of the Society, *Nature* gave a brief abstract of the same. From this it appears that these authors have obtained specimens of *Kaloxylon* "in actual continuity with the stem of *Lyginodendron,*" and arising from it in a manner which proves the former to be the adventitious root of the latter.

Meanwhile, Professor Weiss had forwarded my paper to this Society on May 31st, so that the two papers are perfectly independent of one another. This fact is of itself additional proof of the truth of the conclusion reached in both cases, but it is all the stronger from the further fact that the methods employed are different. Nothing, of course, can be more conclusive than the evidence of specimens which are found in organic connection with one another, and on this account the conclusions reached by Williamson and Scott need no confirmation. But in the case of fossil plants evidence of this kind is not always to be had, and we are driven to rely largely upon the method of comparative anatomy. This is the method followed in the preceding paper, which, whatever be its merits or demerits in other respects, at least shows the utility of that method when carefully applied.

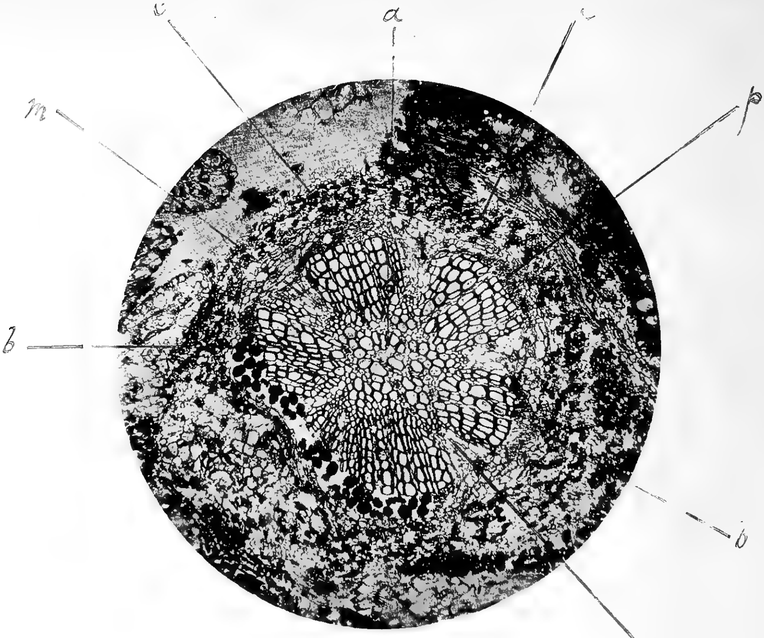

FIG. 1.

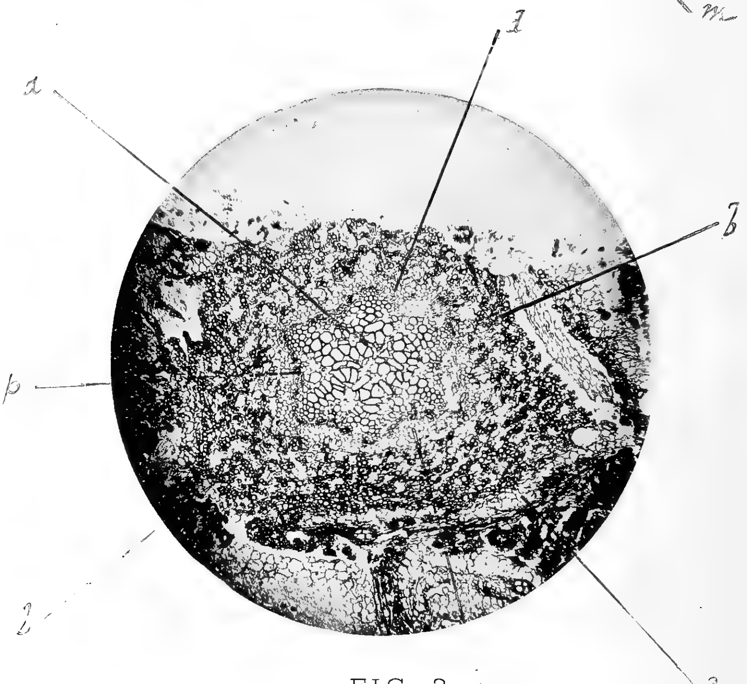

FIG. 2.

S.B.Bolas & Co Collotype

EXPLANATION OF THE FIGURES.

Plate II.

Fig. 1. Transverse section of *Kaloxylon Hookeri*, Will., with secondary vascular bundles.

a. Primary xylem of the stele or central cylinder with conjunctive parenchyma.

b. Xylem of secondary vascular bundles.

p. Phloem of secondary vascular bundles, including perhaps elements of the primary phloem.

m. Medullary rays separating the secondary vascular bundles.

c. Inner zone of cortex with the characteristic elements with special contents.

Fig. 2. Transverse section of *Kaloxylon Hookeri*, Will., in the primary condition.

a. Primary xylem of the stele or central cylinder, with conjunctive parenchyma.

p. Primary phloem of the stele.

d. Zone of parenchyma representing the pericycle and endodermis.

b. Inner zone of cortex.

c. Peripheral zone of cortex.

[*Microscopical and Natural History Section.*]

Ordinary Meeting, January 14th, 1895.

JOHN BOYD, Esq., President of the Section, in the Chair.

Mr. THOMAS HICK, B.Sc., B.A., was elected an Associate of the section.

Mr. OLDHAM exhibited a collection of stone implements, shells, beads, and seeds, arranged as ornaments, from the Sandwich Islands.

Mr. MARK STIRRUP, F.G.S., exhibited cones of pine trees planted along the west coast of France, from Bordeaux to Pau, to prevent the shifting of the sand dunes; specimens of *Helichrysum stœchas*, a plant growing in these pine forests; and the fruit of the Magnolia, from the same district.

Mr. THOS. ROGERS, exhibited three species of land shells from Lord Howe Island, Australia, one being named after Mr. Whitelegge, a naturalist, formerly of Manchester, viz.:—*Helix Whiteleggii*, *H. How-insula*, *Nanina Sophia;* also shells from New South Wales, viz.:—*Rhytida confusa*, *Helix globosa*, and a very rare *Cypræa tesseleta*, from the Sandwich Islands.

A Sketch of the Limitations which are enforced upon the Mathematical Forms of the Expressions for Physical Quantities in a Continuous Medium in consequence of the necessity for their Permanence of Form. By R. F. Gwyther, M.A.

(*Received February 5th, 1895*).

In all parts of Applied Mathematics we find the same forms of expressions occurring, and I propose in this sketch to show how this recurrence arises from the fact that the expression for a force, velocity or stress, must retain the properties of such quantities, however we may shift our axes of reference. The neglect of any consideration of this kind at one time led to erroneous physical views, since this similarity in form was connected with the physical quantities themselves, instead of being treated as a mere similarity of the mathematical expressions for their variations. The well known example is the ancient error of considering electricity to be a fluid, because in the measurement of its effects we obtain expressions which look like, and can be spoken of as if they were, those obtained by the motion of a fluid.

There is a mass of material which might be used in illustration of this subject, and I have to choose between the two plans of bringing illustrations from all sources, which might be the more interesting, and of selecting them from one subject so as to form a more continuous chain. As the latter seems the more instructive I have chosen it, and confine myself to questions of displacements and stresses in a continuous medium.

As an introduction, I take a case in which we deal with co-ordinates only. The method is not quite the same as is developed in the rest of the paper, but it will, I hope, help to explain the more complex portion which follows. Except in connecting expressions on the basis of permanence of form, the paper contains no original results, unless it is in the introductory example.

1. As a first example of the condition of permanency of form of the expressions for a physical quantity in a continuous medium, I take one which is simple—in the sense that it deals with the mode in which the co-ordinates themselves enter the expression considered (whereas at a later stage the arguments will be functions of the co-ordinates)—and which is also definite in its statement, while later I shall consider quantities generically;—namely, the case of a plane polarised wave of light falling perpendicularly on and diffracted by a circular aperture of any size.

Consider the wave to travel in the positive direction along the axis of x, take the centre of the circular aperture as the origin and as axes of y and z two lines at right angles in the plane of the aperture, and let the displacement in the incident wave make an angle a with the axis of y.

Our object is to determine, as far as the permanency of form conditions will allow, the mathematical forms which must be taken to represent the displacement in the secondary wave on the positive side of the plane of yz. Consider the displacement at a point in the secondary wave which corresponds to the component $\cos a$ along the axis of y, and write its components

$$U = f(x, r, \theta)\cos a$$
$$V = \phi(x, r, \theta)\cos a$$
$$W = \psi(x, r, \theta)\cos a$$

where x, r and θ are the cylindrical co-ordinates of the point.

It follows at once that the components of the displacements at the point, in the secondary wave which represents the component *sin*a along the axis of z, are

$$U' = f\left(x, r, \theta - \frac{\pi}{2}\right)\sin a$$

$$V' = -\psi\left(x, r, \theta - \frac{\pi}{2}\right)\sin a$$

$$W' = \phi\left(x, r, \theta - \frac{\pi}{2}\right)\sin a.$$

Now consider a new set of axes y and z such that the new axis of y is coincident with the direction of the original displacement. The change in the co-ordinates of the point considered will simply be that we have $\theta - a$ instead of θ. Then, by the principle of superposition, we have

$$U + U' = f(x, r, \theta - a),$$
$$(V + V')\cos a + (W + W')\sin a = \phi(x, r, \theta - a),$$
$$(W + W')\cos a - (V + V')\sin a = \psi(x, r, \theta - a),$$

or

$$f(x, r, \theta)\cos a + f\left(x, r, \theta - \frac{\pi}{2}\right)\sin a = f(x, r, \theta - a) \quad . \quad (1)$$

$$\phi(x, r, \theta)\cos^2 a + \phi\left(x, r, \theta - \frac{\pi}{2}\right)\sin^2 a + \left\{\psi(x, r, \theta) - \psi\left(x, r, \theta - \frac{\pi}{2}\right)\right\}\sin a\cos a, = \phi(x, r, \theta - a) \quad . \quad . \quad (2)$$

$$\psi(x, r, \theta)\cos^2 a + \psi\left(x, r, \theta - \frac{\pi}{2}\right)\sin^2 a - \left\{\phi(x, r, \theta) - \phi\left(x, r, \theta - \frac{\pi}{2}\right)\right\}\sin a\cos a = \psi(x, r, \theta - a). \quad . \quad . \quad (3)$$

Since the left hand side of each equation is to be a function of $(\theta - a)$ we conclude

$$\left.\begin{aligned} f(x, r, \theta) &= f_1\cos\theta + f_2\sin\theta \\ \phi(x, r, \theta) &= \phi_1 - \psi_2\sin\theta\cos\theta + \phi_2\sin^2\theta \\ \psi(x, r, \theta) &= \psi_1 + \psi_2\cos^2\theta - \phi_2\sin\theta\cos\theta. \end{aligned}\right\} \quad . \quad (4)$$

where the several functions f, ϕ, ψ on the right are functions of x and r only.

These are the sole conditions which arise out of the permanency of form condition, and, although reasons can be given why ψ_1, ψ_2 and f_2 should vanish, as this is not my present theme, I proceed to the more general cases to which this is an introduction.

2. I shall consider in the first place the conditions that functions of a scalar or vector function of a point may themselves be scalar or vector functions, and, when I use these expressions which are now so common, and which were introduced by Hamilton with his quaternions, it seems a proper place to note the origin of the simplicity which attends the equations of physics when expressed in the forms introduced by Hamilton. This simplicity arises, I believe, from the fact that the vectors and vector functions such as

$$ix + jy + kz,\ \ iu + jv + kw,\ \ i\frac{d}{dx} + j\frac{d}{dy} + k\frac{d}{dz},\ \text{etc.}$$

possess the permanency of form with which I propose to deal, while their cartesian components x, y, z, etc., taken separately, do not. In the general equations of physics we meet with expressions which demand this permanency of form, and, therefore, Hamilton's notation is a most suitable mode of expressing them.

Let u, v, w be the components, along a set of axes, of a vector function of a point in a continuous medium, and let ϕ be some scalar function, and consider that these functions are not related to any directions fixed in the medium but only to the axes.

Let some new set of axes be chosen, and let the new co-ordinates of the point be X, Y, Z, then the new components U, V, W, of the vector function and the new scalar function Φ can be found from the original values by substituting for x in terms of X, Y, Z, and the three angles which give the position of the new axes, regarded as a rigid system, relative to the original system.

I shall, however, consider only a new set of axes differing infinitesimally from the original axes, so that

$$X = x + y\theta_3 - z\theta_2, \text{ etc.},$$

$$U = u + v\theta_3 - w\theta_2, \text{ etc.},$$

$$\frac{d}{dX} = \frac{d}{dx} + \theta_3\frac{d}{dy} - \theta_2\frac{d}{dz}, \text{ etc., and } \Phi = \phi.$$

I propose to consider the conditions under which a function

$$\psi(X, Y, Z, U, V, W, \ldots\Phi, \ldots) \text{ or shortly } \psi(X, Y, Z)$$

(whereby I wish to indicate a function of the co-ordinates, the components of a vector function, and their differential coefficients, and of a scalar function and its differential coefficients) will be unaltered in form by the infinitesimal change of co-ordinates:—and also the conditions under which three functions of the same quantities (ψ_1, ψ_2 and ψ_3) may have the character of three components of a vector function.

In the first case, $\psi(X, Y, Z)$ must become $\psi(x, y, z)$; and in the latter case, $\psi_1(X, Y, Z)$ must become

$$\psi_1(x, y, z) + \theta_3\psi_2(x, y, z) - \theta_2\psi_3(x, y, z), \text{ etc.}$$

The conditions are found immediately from considering

$$\frac{d^{p+q+r}}{dX^p dY^q dZ^r}U = \frac{d^{p+q+r}}{dx^p dy^q dz^r}u$$

$$+ \theta_1\left\{q\frac{d^{p+q+r}}{dx^p dy^{q-1} dz^{r+1}}u - r\frac{d^{p+q+r}}{dx^p dy^{q+1} dz^{r-1}}u\right\}$$

$$+ \theta_2\left\{r\frac{d^{p+q+r}}{dx^{p+1} dy^q dz^{r-1}}u - p\frac{d^{p+q+r}}{dx^{p-1} dy^q dz^{r+1}}u - \frac{d}{dx^p dy^q dz^r}w\right\}$$

$$+ \theta_3\left\{p\frac{d^{p+q+r}}{dx^{p-1} dy^{q+1} dz^r}u - q\frac{d^{p+q+r}}{dx^{p+1} dy^{q-1} dz^r}u + \frac{d}{dx^p dy^q dz^r}v\right\}.$$

If we put Φ for U and ϕ for u, omitting the terms in v and w, we obtain the correponding terms for $\frac{d_{p+q+r}}{dX^p dY^q dZ^r}\Phi$.

In the first case to be considered, where $\psi\ (x, y, z)$ is to be a scalar invariant, we have, writing the small letters, and putting $u_{p,q,r}$ as an abbreviation for $\frac{d^{p+q+r}}{dx^p dy^q dz^r}u$,

$$z\frac{d}{dy} - y\frac{d}{dz} + w\frac{d}{dv} - v\frac{d}{dw} + \ldots\ldots$$

$$+ \left\{ q u_{p,q-1,r+1} - r u_{p,q+1,r-1} \right\} \frac{d}{du_{p,q,r}}$$

$$+ \left\{ q v_{p,q-1,r+1} - r v_{p,q+1,r-1} + w_{p,q,r} \right\} \frac{d}{dv_{p,q,r}}$$

$$+ \left\{ q w_{p,q-1,r+1} - r w_{p,q+1,r-1} - v_{p,q,r} \right\} \frac{d}{dw_{p,q,r}}$$

$$+ \left\{ q \phi_{p,q-1,r+1} - r \phi_{p,q+1,r-1} \right\} \frac{d}{d\phi_{p,q,r}},$$

with two similar expressions, as the operators which act as annihilators upon ψ. We will write these conditions

$$\left.\begin{array}{l} \Omega_1\psi = 0 \\ \Omega_2\psi = 0 \\ \Omega_3\psi = 0 \end{array}\right\} \quad . \quad . \quad . \quad . \quad (5).$$

In the second case, when $\psi_1\ (x, y, z)$, $\psi_2\ (x, y, z)$, $\psi_3\ (x, y, z)$ are to be the components of a vector invariant, we have, writing Ω_1, Ω_2, Ω_3, for the same operators as before,

$$\left.\begin{array}{lll} \Omega_1\psi_1 = \ \ 0, & \Omega_1\psi_2 = \ \ \psi_3, & \Omega_1\psi_3 = -\psi_2, \\ \Omega_2\psi_1 = -\psi_3, & \Omega_2\psi_2 = \ \ 0, & \Omega_2\psi_3 = \ \ \psi_1, \\ \Omega_3\psi_1 = \ \ \psi_2, & \Omega_3\psi_2 = -\psi_1, & \Omega_3\psi_3 = \ \ 0. \end{array}\right\} \quad . \quad . \quad (6).$$

The conditions sought are all expressed in these equations.

The expansion of these operators, even when we limit ourselves to the second order of differential coefficients, is somewhat long, but I will give the expansion for Ω_1 leaving the others to be expanded by symmetry. Thus, altering the notation,

$$\Omega_1 = z\frac{d}{dy} - y\frac{d}{dz} + w\frac{d}{dv} - v\frac{d}{dw}$$

$$+ u_z\frac{d}{du_y} - u_y\frac{d}{du_z}$$

$$+ v_z\frac{d}{dv_y} - v_y\frac{d}{dv_z}$$

$$+ w_z\frac{d}{dw_y} - w_y\frac{d}{dw_z}$$

$$+ w_x\frac{d}{dv_x} + w_y\frac{d}{dv_y} + w_z\frac{d}{dv_z}$$

$$- v_x\frac{d}{dw_y} - v_y\frac{d}{dw_y} - v_z\frac{d}{dw_z}$$

$$+ u_{xz}\frac{d}{du_{xy}} - u_{xy}\frac{d}{du_{xz}} + 2u_{yz}\frac{d}{du_{yy}} + (u_{zz} - u_{yy})\frac{d}{du_{yz}} - 2u_{yz}\frac{d}{du_{zz}}$$

$$+ v_{xz}\frac{d}{dv_{xy}} - v_{xy}\frac{d}{dv_{xz}} + 2v_{yz}\frac{d}{dv_{yy}} + (v_{zz} - v_{yy})\frac{d}{dv_{yz}} - 2v_{yz}\frac{d}{dv_{zz}}$$

$$+ w_{xz}\frac{d}{dw_{xy}} - w_{xy}\frac{d}{dw_{xz}} + 2w_{yz}\frac{d}{dw_{yy}} + (w_{zz} - w_{yy})\frac{d}{dw_{yz}} - 2w_{yz}\frac{d}{dw_{zz}}$$

$$+ w_{xx}\frac{d}{dv_{xx}} + w_{xy}\frac{d}{dv_{xy}} + w_{xz}\frac{d}{dv_{xz}} + w_{yy}\frac{d}{dv_{yy}} + w_{yz}\frac{d}{dv_{yz}} + w_{zz}\frac{d}{dv_{zz}}.$$

$$- v_{xx}\frac{d}{dw_{xx}} - v_{xy}\frac{d}{dw_{xy}} - v_{xz}\frac{d}{dw_{xz}} - v_{yy}\frac{d}{dw_{yy}} - v_{yz}\frac{d}{dw_{yz}} - v_{zz}\frac{d}{dw_{zz}}$$

$$+ \phi_z\frac{d}{d\phi} - \phi_y\frac{d}{d\phi_z}$$

$$+ \phi_{xz}\frac{d}{d\phi_{xy}} - \phi_{xy}\frac{d}{d\phi_{xz}} + 2\phi_{yz}\frac{d}{d\phi_{yy}} + (\phi_{zz} - \phi_{yy})\frac{d}{d\phi_{yz}} - 2\phi_{yz}d\phi_{zz}.$$

It is easy to find examples of the results which flow from these conditions ; for example

(*a*) There is no linear scalar function of the second differential coefficients of ϕ which satisfies the conditions of permanency of form except

$$\frac{d^2\phi}{dx^2} + \frac{d^2\phi}{dy^2} + \frac{d^2\phi}{dz^2}.$$

(β) There is no linear vector function of the second differential coefficients of u, v, and w, which satisfies the conditions except that whose components are

$$m\frac{d}{dx}\left(\frac{du}{dx}+\frac{dv}{dy}+\frac{dw}{dz}\right)+n\left(\frac{d^2u}{dx^2}+\frac{d^2u}{dy^2}+\frac{d^2u}{dz^2}\right),\text{ etc.}$$

From this latter we see that the equations of equilibrium of an elastic solid, on the hypothesis of isotropy, have their form fixed by these considerations, and that, as I have indicated earlier, these are exactly the forms which are derived from a vector by the use of Hamilton's operator.

3, I shall proceed to draw some other examples from the subject of elasticity, and, finally, to extend the conditions beyond those for isotropy.

If we confine our attention to the first differential coefficients of a vector function, which I shall look upon as the displacement at a point in an isotropic solid, and if we replace these differential coefficients by the elements of the strain (e, f, g, a, b, c) and the components ξ, η, ζ of the rotation, the forms of the operators are sufficiently indicated by

$$\Omega_1 = a\left(\frac{d}{df}-\frac{d}{dg}\right)+2(g-f)\frac{d}{da}-c\frac{d}{db}+b\frac{d}{dc}$$

$$+\zeta\frac{d}{d\eta}-\eta\frac{d}{d\zeta}. \qquad (7).$$

From these we obtain easily the usual invariants of the strain

$$e+f+g,\text{ etc.}$$

and, if we take the origin at the point and consider also a point whose vector components or co-ordinates are x, y, z, we find the usual strain quadric as a covariant.

Covariants of a more general character will be noticed later. The potential energy of the strain (V) reckoned per unit volume, must be an invariant, and must, therefore, be a function of the invariants of the strain. Following Green, and writing P, Q, R, S, T, U for the elements of the corresponding stress, we shall have

$$P = \frac{dV}{de}, \ldots S = \frac{dV}{da}, \ldots$$

If we retain Ω_1, etc. as the operator accompanying θ_1, etc., when we consider now a function of P, Q, R, S, T, U subject to an infinitesimal variation in the axes, we have

$$\left.\begin{array}{c} \Omega_1 = 2S\left(\frac{d}{dQ} - \frac{d}{dR}\right) + (R-Q)\frac{d}{dS} - U\frac{d}{dT} + T\frac{d}{dU}, \\ \text{etc.} \end{array}\right\} \quad . \quad (8)$$

From these we obtain readily the invariants and the covariant quadrics of the stress.

It is also easy to prove that

$$\frac{dP}{dx} + \frac{dU}{dy} + \frac{dT}{dz}, \text{ etc.}$$

namely the components corresponding to the body-force due to the stress, are the only possible components of a vector of permanent form which can be formed linearly from their first differential coefficients.

As an example, we may consider Maxwell's mathematical expressions to explain the transmission of gravity or electric forces by a state of stress in the intervening ether.

The body force is now to be of the form

$$\rho\frac{d\phi}{dx} \text{ or } \nabla^2\phi\frac{d\phi}{dx}$$

per unit of volume.

Let us consider P, Q, etc., to be quadratic functions of the components u, v, w of some vector.

We must have from

$$\begin{array}{lll} \Omega_1 P = 0, & \Omega_1 S = R - Q, & \\ \Omega_2 P = -2T, & \Omega_2 S = U, & \text{etc.} \\ \Omega_3 P = 2U, & \Omega_3 S = -T, & \end{array}$$

and we find

$$P = Au^2 + B(v^2 + w^2), \quad S = (A - B)vw, \text{ etc.}$$

To arrive at the required form for the body force, we must put $A+B=0$, giving the form of Maxwell's result.

It is easy to see that this stress can not be maintained by displacements in an isotropic solid, nor, in fact, in any medium of which we have any knowledge.

4. Lastly, whatever be the character of a body of continuous matter under strain, the potential energy of the strain at any point per unit volume must be a function V, of a scalar character possessing permanency of form. Also, if the strain is small, and the body acts for it as a conservative system, V is a quadratic function of the elements of the strain, and P is found from it by

$$P = \frac{dV}{d}, \text{ etc.}$$

The coefficients in the expansion of V may now be related to some directions fixed in the body, and will, therefore, vary with the change of the axes.

In the most general case, V will contain twenty-one elastic coefficients, say

$$\begin{aligned} 2V = K_{11}e^2 &+ 2K_{12}ef + 2K_{13}eg + 2K_{14}ea + 2K_{15}eb + 2K_{16}ec \\ &+ K_{22}f^2 + 2K_{23}fg + 2K_{24}fa + 2K_{25}fb + 2K_{26}fc \\ &+ K_{33}g^2 + 2K_{34}ga + 2K_{35}gb + 2K_{36}gc \\ &+ K_{44}a^2 + 2K_{45}ab + 2K_{46}ac \\ &+ K_{55}b^2 + 2K_{56}bc \\ &+ K_{66}c^2 \end{aligned}$$

The conditions that this may be an invariant scalar function, considering the coefficients as varying, have now to be expressed. Write Δ_1, for the differential operator as far as it enters connected with the coefficients, and retain

Ω_1, etc., as the operator upon the elements of the strain. We then find, from the permanency of form,

$$\Delta_1 = 2K_{14}\frac{d}{dK_{12}} - 2K_{14}\frac{d}{dK_{13}} + (K_{13} - K_{12})\frac{d}{dK_{14}} - K_{16}\frac{d}{dK_{15}} + K_{15}\frac{d}{dK_{16}}$$
$$+ 4K_{24}\frac{d}{dK_{22}} + 2(K_{34} - K_{24})\frac{d}{dK_{23}} + (2K_{44} - K_{22} + K_{23})\frac{d}{dK_{24}}$$
$$+ (2K_{45} - K_{26})\frac{d}{dK_{25}} + (2K_{46} + K_{25})\frac{d}{dK_{26}}$$
$$- 4K_{34}\frac{d}{dK_{33}} - (2K_{44} - K_{33} + K_{23})\frac{d}{dK_{34}}$$
$$- (2K_{45} + K_{36})\frac{d}{dK_{35}} - (2K_{46} - K_{35})\frac{d}{dK_{36}}$$
$$+ 2(K_{34} - K_{24})\frac{d}{dK_{44}} + (K_{35} - K_{25} - K_{46})\frac{d}{dK_{45}} + (K_{36} - K_{26} + K_{45})\frac{d}{dK_{46}}$$
$$- 2K_{56}\frac{d}{dK_{55}} + (K_{55} - K_{66})\frac{d}{dK_{56}}$$
$$+ 2K_{56}\frac{d}{dK_{66}}$$

From the equation $\Delta_1 = 0$ and the two similar equations we obtain by solution the invariantal connections between the elastic constants, and by adding to Δ_1 the terms

$$z\frac{d}{dy} - y\frac{d}{dz}, \text{ etc.,}$$

we obtain the covariant surfaces which indicate elastic qualities at the point.

Among the most remarkable of these which have already been found is the ellipsoid found by Haughton in 1846, and called by Rankine *orthotatic.* Its equation is

$$(K_{11} + K_{12} + K_{13})x^2 + (K_{12} + K_{22} + K_{23})y^2 + (K_{13} + K_{23} + K_{33})z^2$$
$$+ 2(K_{14} + K_{24} + K_{34})yz + 2(K_{15} + K_{25} + K_{35})zx + 2(K_{16} + K_{26} + K_{36})xy$$
$$= 1$$

and it implies three invariantal relations. Its properties are easily seen. The remarkable point is that it only contains 15 of the 21 constants.

A quartic surface was also given by Haughton, and called by Rankine *tasinomic.* Its equation is

$$\begin{aligned}&K_{11}x^4 + K_{22}y^4 + K_{33}z^4\\ &+ 2(K_{23} + 2K_{44})y^2z^2 + 2(K_{13} + 2K_{55})z^2x^2 + 2(K_{12} + 2K_{66})x^2y^2\\ &+ 4(K_{14} + 2K_{56})x^2yz + 4(K_{25} + 2K_{46})xy^2z + 4(K_{36} + 2K_{45})xyz^2\\ &+ 4K_{24}y^3z + 4K_{34}z^3y + 4K_{35}z^3x + 4K_{15}x^3z + 4K_{16}x^3y + 4K_{26}y^3x = 1,\end{aligned}$$

which contains fifteen terms, and introduces all the constants. Both surfaces have been considered by Haughton, Rankine, and Saint-Venant.

Of a character remarkable in the same way as is the orthotatic ellipsoid, is the equation of the ellipsoid

$$\begin{aligned}&(K_{23} - K_{44})x^2 + (K_{13} - K_{55})y^2 + (K_{12} - K_{66})z^2\\ &\qquad + 2(K_{56} - K_{14})yz + 2(K_{46} - K_{25})zx + 2(K_{45} - K_{36})xy = 1.\end{aligned}$$

Rankine gives this ellipsoid the name *heterotatic.*

If, also, we write

P' for x^2, Q' for y^2, R' for z^2, S' for yz, T' for xz, U' for xy,

we notice that the operator Ω_1 acting on a function of x, y, z becomes

$$2S'\left(\frac{d}{dU'} - \frac{d}{dR'}\right) + (R' - Q')\frac{d}{dS'} - U'\frac{d}{dT'} + T'\frac{d}{dU'}$$

and hence we conclude, comparing with (8), that

$$\begin{aligned}&(K_{11} + K_{12} + K_{13})P + (K_{12} + K_{22} + K_{23})Q + (K_{13} + K_{23} + K_{33})R\\ &\quad + 2(K_{14} + K_{24} + K_{34})S + 2(K_{15} + K_{25} + K_{35})T + 2(K_{16} + K_{26} + K_{36})U,\end{aligned}$$

and

$$\begin{aligned}&(K_{23} - K_{44})P + (K_{13} - K_{55})Q + (K_{12} - K_{66})R\\ &\qquad + 2(K_{56} - K_{14})S + 2(K_{46} - K_{25})T + 2(K_{45} - K_{36})U,\end{aligned}$$

are also expressions enjoying a permanence of form.

The question of the number of the elastic constants will not be settled by these conditions of form, but there are points in which they may serve for a guide. For example, Saint-Venant, though holding the rari-constant opinion that

$$K_{56}=K_{14},\ K_{46}=K_{25},\ K_{45}=K_{36} \text{ and } K_{23}=K_{44},\ K_{13}=K_{55},\ K_{12}=K_{66},$$

endeavours to make an investigation more general by taking only

$$K_{56}=K_{14},\ K_{46}=K_{25},\ K_{45}=K_{36}$$

and assuming

$$\frac{K_{23}}{K_{44}}=\frac{K_{13}}{K_{55}}=\frac{K_{12}}{K_{66}}=i.$$

But, if the first of these equations holds, the heterotatic ellipsoid becomes a sphere, and

$$K_{23}-K_{44}=K_{13}-K_{55}=K_{12}-K_{66}=\text{an invariant}.$$

This is, therefore, the proper assumption intermediate between the rari-constant and multi-constant hypothesis.*

If we write

$$\begin{aligned} K_{23}&=K_{44}+\lambda_{23}, & K_{56}&=K_{14}+\mu_{56},\\ K_{13}&=K_{55}+\lambda_{13}, & K_{46}&=K_{25}+\mu_{46},\\ K_{12}&=K_{66}+\lambda_{12}, & K_{45}&=K_{36}+\mu_{45}, \end{aligned}$$

the part of the operator Δ_1 which affects the λ's and μ's only is

$$2\mu_{56}\left(\frac{d}{d\lambda_{13}}-\frac{d}{d\lambda_{12}}\right)+(\lambda_{12}-\lambda_{13})\frac{d}{d\mu_{56}}-\mu_{45}\frac{d}{d\mu_{46}}+\mu_{46}\frac{d}{d\mu_{45}},$$

and we see that in order that the μ's may remain 0, we must have the λ's equal. If the λ's are taken equal, they will only remain so if the μ's vanish.

I have taken the illustrations chiefly from the subject of

* I have not made myself clear on this point. Saint-Venant is treating of "ellipsoidal symmetry." This will require that the orthotatic and heterotatic ellipsoids should be co-axial or that the heterotatic ellipsoid should be a sphere. As his conditions are not those requisite in the first case, I have expressed those necessary for the latter.—Feb. 27, 1895.

elasticity, to make the sketch of the subject more compact, but illustrations may be found throughout the subjects of Applied Mathematics, shewing that quantities subject to permanency of form are limited in their form of mathematical expression, and by this means we can, not of course explain, but, at least, place in one connection the various analogies which shew themselves throughout the subject of applied mathematics even in cases where the reason of the analogy is far to seek. I hope, however, to have shown in what way mathematical results may be independent of the physical hypotheses which may have been employed to obtain them, but it would require too much space to treat this question fully, or to discuss its bearing upon the modern treatment of the principles of mechanics.

[*Microscopical and Natural History Section.*]

Ordinary Meeting, February 11th, 1895.

JOHN BOYD, Esq., President of the Section, in the Chair.

Mr. HYDE exhibited a specimen of Laboradorite, showing prismatic colours on a polished surface.

Mr. G. H. BROADBENT drew attention to the question of oysters and typhoid.

Mr. THOMAS HICK, B.A., B.Sc., read the following communication "On a method of double-staining plant-tissues;" and exhibited a large number of specimens prepared by his method under the microscope :—

"Those who have given any attention to the methods of modern histology as applied to plants are aware that they involve the use of a large number of micro-chemical and staining reagents. With regard to the latter, botanists are not all agreed as to the advisability of their regular use, some holding that stained preparations are misleading and otherwise objectionable to ordinary students, however valuable they may be in research and in cases of exceptional difficulty. Prof. Bower lays down the excellent rule that colouring matters should never be used without a definite purpose, and if we adhere to this we shall at once avoid the danger of their abuse, and yet find them deserving of more general application than some botanists are at present prepared to allow. At any rate, speaking for myself, I am satisfied from my own experience, that even with elementary students stained preparations may be used with good effect for the attainment of certain desired ends. Among these I only need to mention one of the most obvious, viz. :

the differentiation of structures and tissues, which junior students have a difficulty in distinguishing in unstained sections, and which more advanced students want to see clearly and readily without hesitation or loss of valuable time. For this object, the method of double staining, which I am about to describe, appears to me to be one of the most useful. I may go further, and say that of the many methods I have used during the last twelve or fifteen years, this one has been found the most generally applicable, the most reliable in its results, and the most permanent. There are other advantages, in addition to these, but they will be best considered when the method has been described. The colours used are a blue and a red, the one being the well known aniline blue, and the other, known in some dye works as cotton red, is, I believe, a form or derivative of carthamine. Both are used in aqueous solution. To the blue solution a definite quantity of saturated solution of picric acid is added, so that it may be termed the picric and blue solution. The composition of the solutions is usually made up as follows, though slight deviations are not material, and in some cases may be desirable :—

Picric and Blue Solution :	
Aniline Blue	0·1 gram.
Water	35 c.c.
Saturated Solution of Picric Acid	15 c.c.
Cotton Red or Carthamine Solution :	
Cotton Red or Carthamine	0·1 gram.
Water	25 c.c.

The Picric and Blue solution is ready for use as soon as made, and so is that of the Cotton Red. But sometimes the latter is not quite clear, owing to the presence in the dye of some insoluble material. In that case it may be filtered, though this is not really necessary, as the presence of the insoluble substance does not interfere with the action of the dye and is removed from the sections in the subsequent stages of the process. An important point to be noted is that the sections should be cut from material that has been kept for some time in alcohol, as is usually done in botanical laboratories. If cut from fresh material the results are neither so satisfactory, nor quite in agreement with those described. To make the method of using the dyes as intelligible as possible it may be divided into the following stages:—

1. Place the sections in the Red solution in a watch glass, which should be covered to keep out the dust, and leave for at least an hour. For some sections a longer time is required, and none suffer from being overstained.

2. Wash out the superflous dye with methylated alcohol, and then

3. Place the sections in a little of the Picric and Blue solution in a watch glass, covered, as before, and allow them to remain in it for two or three minutes.

4. Transfer the sections to methylated alcohol, and give them two or three washes in the same, and a final one in absolute; then

5. Clear in oil of cloves, and mount in balsam in the usual way.

Sections that have been treated successfully in the way described, will be found on examination to have several of their tissues sharply differentiated, and to have quite a number of minute details strongly emphasised. In the first place, all the elements which have lignified walls, and which constitute the major part of the conducting system and the whole of the mechanical, have their walls of a red colour, more or less uniform in tint, though slight shades of difference are occasionally met with. Thus we can distinguish at a glance:—(*a*) the xylem elements of the vascular bundles, (*b*) the sclerenchyma of the stereom, and (*c*) any individual elements that have lost their vitality and become lignified. Secondly, all the elements which were living at the time the specimen was gathered, have their cell contents pricked out with blue, and stand out clearly separated from the dead mechanical elements and the xylem parts of the conducting bundles. Among the tissues so differentiated are:—(*a*) the phloem of the conducting bundles, (*b*) the living cells of the cortex, pith, medullary rays, xylem parenchyma, &c. Of the more delicate structures, chorophyll corpuscles, leucoplasts, and sometimes the nuclei, are stained of a deeper blue than the cytoplasm of the cell, and can be clearly distinguished from it, while the red stains the cuticular layers of the epidermal cells, the walls of cork cells, the thickening layers of the endodermis, the contents of resin and tannin cells, and the granules of starch, at least in some cases. Lastly, in well stained preparations, several details of the complex structure of the nucleus are often brought out by this method of treatment, though not perhaps in all cases. Thus in many instances we can distinguish, by their *red* colour:—(*a*) the chromatin granules or threads in the linin threads, (*b*) the nucleolus, and (*c*) the karyokinetic figures of the dividing nucleus, from the (*d*) nuclear wall which is blue, and (*e*) the nuclear sap which is colourless. Among the many plant structures that are specially suitable for illustrating the effects producible by this method of double staining, the following may be recommended as easily accessible and requiring no exceptional treatment:—i. Rhizome of *Pteris aquilina;* ii. Stem of *Lycopodium clavatum;* iii. Root of *Phœnix dactylifera;* iv. Root of *Vicia Faba;* v. Leaf of *Pinus pinaster;* vi. Stem of *Cyperus;* vii. Stem of *Ranunculus repens;* viii. Tuber of *Phajus maculata;* ix. Root of *Abies;* x. Anther of *Lilium croceum* in young condition."

Mr. OLDHAM read an extract from "A brief History of the Hawaiian People," by W. D. Alexander, New York, page 89, describing the game played with the rounded stones exhibited at the preceding meeting. He also exhibited a specimen of *Stenopteryx hirundinus*, parasitic on the swift.

General Meeting, March 5th, 1895.

JAMES BOTTOMLEY, B.A., D.SC., F.C.S., Member of the Council, in the Chair.

Mr. S. J. HICKSON, M.A., D.Sc., Professor of Zoology, the Owens College, Manchester; Mr. GUSTAV BEHRENS, Merchant, Manchester; Mr. IVAN LEVINSTEIN, Chemical Manufacturer, Manchester; and Dr. A. W. WARD, Principal of the Owens College, and Vice-Chancellor of the Victoria University, Manchester, were elected as ordinary members.

Ordinary Meeting, March 5th, 1895.

JAMES BOTTOMLEY, B.A., D.SC., F.C.S., Member of the Council, in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

The details of the agreement between the Council and Mr. Henry Wilde, F.R.S., with respect to the employment of the income to be derived from the endowment fund presented by Mr. Wilde to the Society, were communicated to the members by one of the Secretaries, as follows :—

(1) To provide the salary of an assistant secretary and librarian, who shall devote the whole of his time to the duties of the office. (2) To found a Gold Medal of the Society of the value of fifteen

guineas, to be awarded annually to the author of any discovery in nature, or valuable invention in applied science, or for an original paper on a literary or philosophical subject that may be published in the Society's *Memoirs*. The award to be made to authors of all nationalities, and may be retrospective. (3) To found an annual premium of fifteen guineas and the Dalton silver or bronze medal of the Society, to be awarded to the author of an original paper on a literary or philosophical subject—not necessarily a member of the Society;—such paper to be published in the Society's *Memoirs*. (4) To provide an honorarium of fifteen guineas annually to be awarded to a gentleman eminent in some department of literature or science, for the delivery of a lecture before the Society. (5) To provide for the loss of income from the abolition of the entrance fee of two guineas. (6) To provide one half the amount of the annual subscription of such members of the Society on whom the payment of two guineas is too onerous for their means—the number of such reduced subscriptions not to exceed ten. (7) To remit the annual subscription of those members of the Society who through unavoidable circumstances are unable to continue it—the number of such non-paying members not to exceed five. (8) To compound for the rent paid by two societies, whose requirements and libraries interfere unduly with the working arrangements of the Society and the development of its own library. (9) The remainder of the annual income to be devoted to the increase and maintenance of the Society's library, and the repairs and decoration of its premises.

Mr. J. FRITH read a paper on "The back Electro-motive Force of the Voltaic Arc."

Professor A. SCHUSTER, F.R.S., read a note on Mr. FRITH'S paper.

Professor A. SCHUSTER, F.R.S., read a paper "On some Curious Passages in the writings of Benjamin Franklin."

On the True Resistance and on the Back Electromotive Force of the Electric Arc. By Julius Frith, 1851 Exhibition Scholar, The Owens College, Manchester. Communicated by Arthur Schuster, F.R.S.

(*Received March 14th, 1895.*)

The following research on the true resistance of the electric arc was carried out in the Electrical Laboratory of the Owens College under the direction and with the occasional assistance of Mr. Lees, Senior Demonstrator and Lecturer of the Owens College.

The question of the real resistance and the allied problem of the back E.M.F. of the arc has received the attention of several investigators, most of whom have attempted to determine the value of the back E.M.F. if it existed, by measuring the true resistance of the arc.

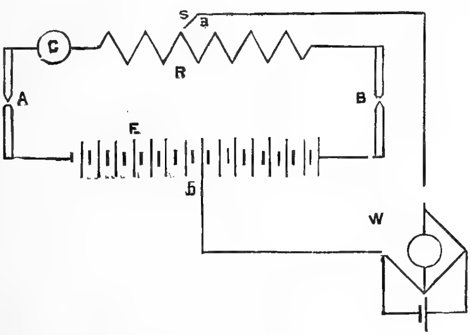

Fig. 1.

A and B represent arc lamps.
E „ a battery of cells.
C „ an ammeter.
R „ resistances.
S „ a switch to bring the points A and B to the same potential.
W „ Wheatstone's bridge to measure the resistance between A and B.

The most conclusive of these experiments are those of Von Lang and Arons.

Von Lang,* with an apparatus represented in Fig. 1, using carbons 5 mm. in diameter and 3 mm. apart, with a current of 4·3 amperes, found the back E.M.F. to be 39 volts.

Arons† worked with a Wheatstone bridge, of which two branches, P and Q, Fig. 2, contained fixed resistances, the third a variable resistance R, the fourth in series, a battery B, Key K, variable resistance S, ammeter C and an arc lamp L, the carbons of which can be short circuited by the Key K′.

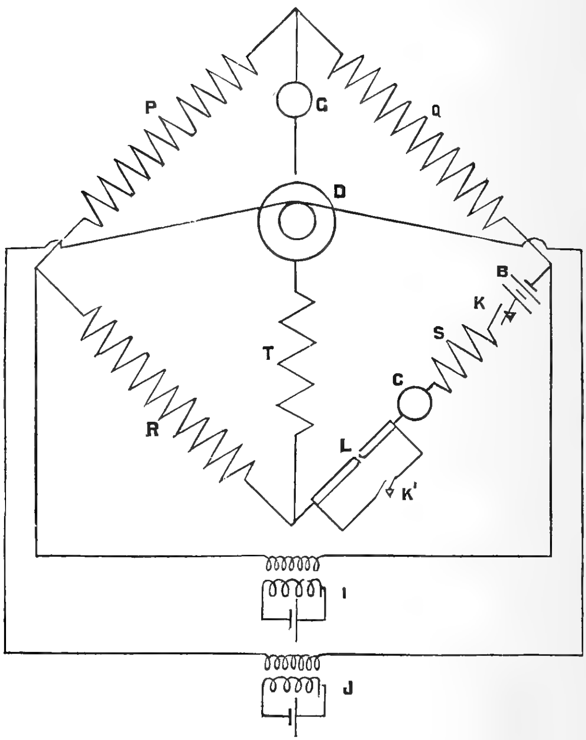

Fig. 2.

* *Centralblatt für Elektrotechnik*, vol. 7, p. 443 (1885).
† *Wied. Ann.* Vol. XXX., p. 95 (1887).

One diagonal contained a Galvanometer G, the fixed coil of an Electro-dynamometer D, and a variable resistance T.

The other diagonal contained the secondary coil of an induction apparatus I. The swinging coil of the dynamometer was joined in series to the secondary of another induction coil J, the primary of which was in circuit with a Dubois apparatus and an interrupter.

With the arc in circuit, the resistances were arranged so that the deflection of the dynamometer remained constant when the induction apparatus was set to work. The carbons were then short circuited, and the equivalent resistances inserted at S.

Arons gives two measurements.

At 3·4 amperes the back E.M.F. was 40·6 volts and the resistance 2·1 ohms.

At 4·1 amperes the back E.M.F. was 39·6 volts and the resistance 1·6 ohms.

Although the results of these experiments seem to show decisively that in the arc we have to deal with a back electromotive force, one often finds doubts expressed in the technical press as to whether this back E.M.F. really exists. In order to throw additional light on the subject the following experiments were commenced on arcs corresponding more nearly to the arcs in common use than those experimented on by Von Lang and Arons.

A number of methods were tried in order to measure the real resistance of the arc. The first was a modification of Mance's method, by placing the arc in one side of a Wheatstone's bridge, a galvanometer in one diagonal and a key in the other, and adjusting the resistances in the sides till closing the key had no effect on the galvanometer. This, however, had to be abandoned on account of the alteration in current through the arc on closing the key.

A method devised by Mr. Lees was next tried, in which the primary of a transformer was put in series with the arc lamp, dynamo, and galvanometer. On a current being made or broken in the secondary of the transformer, a kick should be observed on the galvanometer which is only dependent on the resistance in circuit and not on any back E.M.F. should such exist in the arc. It was found, however, that owing to the continual minute variations in the current through the arc, this kick, though observed, was rendered unavailable for purposes of measurement.

Then methods were tried involving the measurement of resistance between two points in the arc circuit which could be kept at the same potential.

Fig. 3 shows the simplest arrangement for this purpose, and out of it the final arrangement was evolved. It is analogous to Von Lang's method. $D_{,}$ and $D_{,,}$ are two shunt wound dynamos in series with a resistance R and an arc lamp. By an adjustment of R the points A and B can be brought to the same potential, as shown by the high resistance galvanometer G.

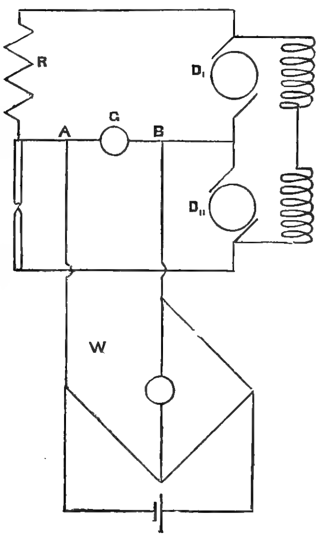

Fig. 3.

When this is the case the resistance between them is measured by the Wheatstone's bridge W.

This gives the resistance of R and one dynamo in parallel with the arc and the other dynamo, from which the resistance of the arc can be obtained.

First it was found that a continuous current could not be used for the testing circuit, for any slight deviation from equality of potential at A and B caused a current to flow through the galvanometer which prevented the balancing of the resistances being carried out. This led to the use of an alternating E.M.F. instead of the battery, and a pair of telephones instead of the galvanometer in the balancing circuit. It was soon found, however, that to render the telephones serviceable a condenser had to be placed in series with them, thus preventing any continuous current passing through the telephone circuit when A and B differed in potential.

The use of alternating current involved the balancing of self induction as well as of resistance to obtain silence in the telephones. This was effected by making the circuit as symmetrical as possible, by balancing the working dynamo in one side of the bridge by an idle armature in the other, and by the use of an adjustable self induction formed by inserting an iron cylinder more or less into a solenoid.

Fig. 4 represents, diagrammatically, the apparatus with these alterations introduced.

On the right is the working continuous current circuit, consisting of a shunt wound dynamo $D_{,}$, in series with 26 accumulators E, an arc lamp X, an ammeter C, and a resistance R.

The Voltameter V can be connected through the key K either to the terminals of the lamps or to the battery.

On the left is the testing circuit, made to resemble the other as much as possible. It consists of a stationary dynamo $D_{,,}$ exactly similar to $D_{,}$, a resistance $R_{,,}$, equal to $R_{,}$, a variable self induction L, and an adjustable resistance $R_{,,,}$.

These two circuits are in the arms of a Wheatstone's bridge, the other two arms bring the two halves of a stretched platinoid wire PQ, P being kept equal to Q.

Across one diagonal of this bridge is a condenser M in series with a pair of telephones T. The other diagonal has wires which can be moved along a stretched wire, the ends of which are connected to the alternator $D_{'''}$. This

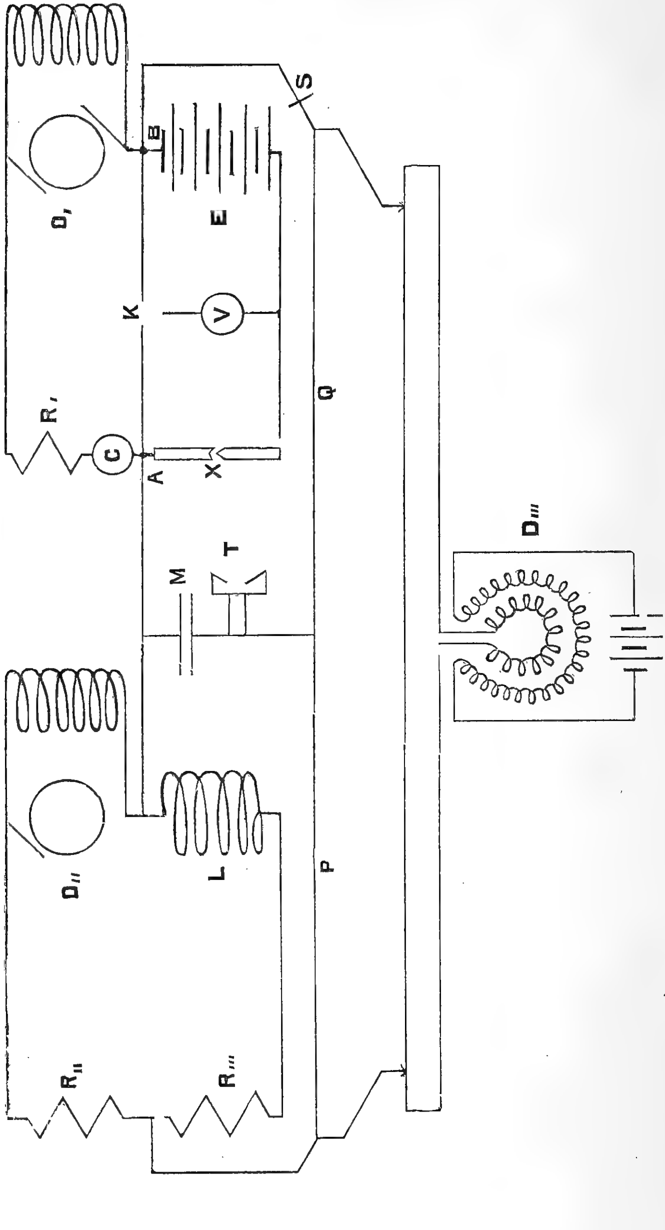

Fig. 4.

arrangement gives any desired alternating E.M.F. in the testing circuit. In practice an E.M.F. of about 5 volts was found to give the best results.

The experiment is conducted thus: The right hand continuous current circuit is run with the switch S open, till the potential at the terminals of the arc exactly equals the potential of the cells, while the lamp is at the same time taking the required current as measured by the ammeter C. This is effected by altering the speed of the engine driving $D_{,}$ in the first place, and finally by feeding the lamp, which is done by hand.

When this adjustment is made, the points A and B are at the same potential and the switch S is closed. $R_{,,,}$ and L are then adjusted till there is silence in the telephones T, which are protected from the effects of any slight lack of adjustment of the continuous current circuit by the condensor M.

In practice complete silence is never obtained in the telephones, it is replaced by a minimum which is accompanied by a change of note in the humming produced by the alternator.

That the position of this minimum is identical with the position for complete silence, was proved by replacing the arc by its apparent resistance, when, by a proper adjustment of L, an absolute silence was obtained. L was then altered till a minimum could be found; this minimum, however, gave the same value for $R_{,,,}$, as in the former case.

This balance having been obtained, all the resistances being known, the resistance of the battery being found by its drop of potential when giving current, the real resistance of the arc is readily found.

A number of experiments were made under increasingly favourable conditions, all of which showed that the true resistance lay somewhere about ·6 ohms. As the circuit was made more and more symmetrical, the self inductions more accurately balanced, the telephones enabled the exact value of $R_{,,,}$ to be determined, and the following figures were arrived at:—

$R_{,} = 8$ ohms. $R_E = \cdot 25$ ohms.
$R_{,,} = 8$ ohms. $R_D = \cdot 04$ ohms.
$R_{,,,} = \cdot 6$ ohms. $P = 5 \cdot 35$ ohms.
$R_L = 3$ ohms. $Q = 5 \cdot 35$ ohms.

This gives the true resistance to be ·6 ohms.

The back E.M.F. V′ is given by

$$V' = V - RC,$$

where V is the potential difference at the carbons, R the true resistance of the arc, and C the current.

$$V' = 39 \text{ volts.}$$

The carbons were solid 11mm. in diameter. The arc was 2mm. long from the end of the negative carbon to the edge of the crater.

In order to check this result another method, represented in Fig. 5, was adopted.

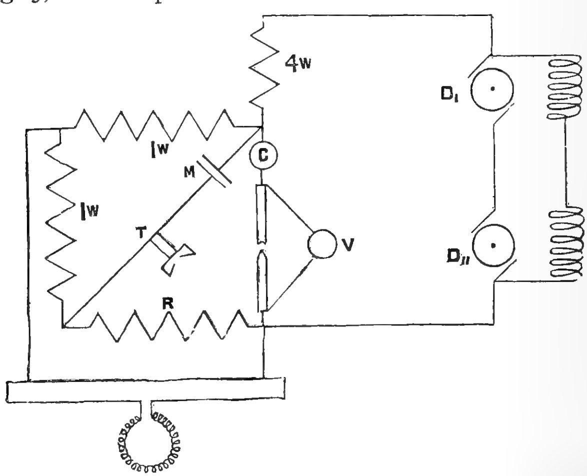

Fig. 5.

In this $D_{,}$ and $D_{,,}$ are two continous current shunt wound dynamos, coupled in series with a resistance of 4 ohms., an ammeter, and an arc lamp.

The lamp was made to form one side of a Wheatstone's bridge, the other two sides being two resistances of 1 ohm each, and a variable resistance. In one diagonal was a condensor and telephones. The alternating apparatus, as in the last experiment, was placed in the other diagonal.

In this case the silence was not so good as in the former experiment, but there was a decided minimum when R was about ·6 ohm.

The values of the back E.M.F. from these experiments with ordinary arcs agree closely with those found by Von Lang and Arons for small arcs. This constancy leads to the conclusion that the back E.M.F. is due to some process which goes on in the arc independently of the magnitude of the current which the arc is taking. Whether this process is the vaporisation of carbon and whether the back E.M.F. has its seat at the crater or in other parts of the arc, remains yet to be determined.

Note on Mr. Frith's paper "On the True Resistance and on the Back Electromotive Force of the Electric Arc." By Arthur Schuster, F.R.S.

(*Received March 14th, 1895.*)

The good agreement which has been obtained by different observers in measuring the so-called "back electromotive force" of the voltaic arc seems to shew that there must be some real meaning in the result, but it would be rash to take that agreement as a proof that the arc is the seat of something analogous to electrolytic polarisation, as the term would seem to imply. At any rate it is of importance to be clear as to what is really proved and what assumed in such experiments as those described in the previous paper.

Consider part of a circuit lying between two points, P and Q, and only containing metallic conductors and electrolytes or voltaic cells. The difference of potential e between the points P and Q, is connected with the current strength i, the resistance r, and the sum of electromotive forces included (E) by the equation

$$e = E + ir \quad . \quad . \quad . \quad . \quad (1)$$

If we vary the current and observe the change in the fall of potential, a second equation is obtained which, together with (1), determines both E and r. Thus, if the changes are small, we obtain from (1)

$$\frac{de}{di} = r \quad . \quad . \quad . \quad . \quad (2)$$

and hence E may be found by

$$E = e - i\frac{de}{di} \quad . \quad . \quad . \quad . \quad (3)$$

This method of determining the electromotive force included in a circuit by means of measurements taken at the terminal points gives correct results as long as Ohm's law holds for all parts of the conducting system. But although we cannot speak of Ohm's law when the electric current passes through a gas, it is yet assumed in all discussions of this so-called back electromotive force that equation (2) gives what is called the "true" resistance. We need only analyse the various devices which have been adopted to separate resistance and electromotive force in the arc to see that they all depend on *defining* the resistance as the ratio of an increase of electromotive force to an increase of current. Generally the arc is maintained by an independent battery, and is increased or diminished by a small additional current; the change produced is then made to affect the measuring instruments. The difficulty is inherent, and I do not see how it can be overcome by any measurements made outside the arc. A special case will shew that the objection raised is a serious one. I will imagine that an experimenter wishes to decide whether there is a "back electromotive force" in a vacuum tube and in order to do so adopts such methods as have been assumed to give correct results for the voltaic arc. A series of measurements supplied by Hittorf* will allow us to calculate the results he would get.

In the following table the first column gives the number of the experiment, the second the measured difference of potential between the ends of a vacuum tube, and the third the corresponding current in micro-amperes.

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* *Wied. Ann.*, Vol. XX. p. 727.

These three columns are copied from Hittorf's Paper.

Experiment	*e.*	*i.*	Δ*e.*	Δ*i.*	*r.*	E.
1	133	244	—	—	0	133
2	132	814	—	—	0	132
3	133·5	1282	—	—	0	133·5
4	141·5	3175	8	1893	4230	132·3
5	150	5189	8·5	2014	4230	132·3
6	157	7000	7	1811	4250	133·4
7	165	8791	8	1791	4470	129·7
8	173	11192	8	2401	3330	139·7

In the fourth and fifth columns I have placed the differences Δ*e* and Δ*i* of electromotive force and currents in successive experiments after the third, the fall of potential in the first three being practically constant. The next column gives *r* and E calculated by means of the equations

$$\frac{\Delta e}{\Delta i} = r$$

$$E = e - ir$$

where for *i* the arithmetical mean of the currents observed in two successive experiments is taken.

The last column shews a remarkable consistency; the first six experiments have given practically identical values for the "back electromotive force," although the current has increased in the ratio of 1 : 34. The mean of the two last experiments also gives the same result, so that increasing the current nearly fifty times we always obtain the same value for E. Such a coincidence, our imaginary experimenter would argue, must prove the correctness of his method, and he would further draw the remarkable conclusion that the "true" resistance of his vacuum tube was zero up to a certain current intensity, and then suddenly rose and remained nearly equal to 4,200 ohms. Now we know from investigations made *inside* the vacuum tube that all these conclusions would be incorrect, and the consideration of this case brings out the weak spot in the argument which has been applied to the voltaic arc. It is obviously impossible to separate a fall of potential due to an electromotive force from one due to other causes, as long as the fall is independent of the current intensity. Now we know that in vacuum tubes the fall of potential in the glow, as long as it does not cover the electrode, is constant, and also that the fall in the positive part of the discharge is, to a great extent, independent of the current. Hence, as long as the glow has room to expand on the kathode, the difference of potential between the electrodes does not rise, although the current may increase considerably. This was the case in the first three experiments quoted, and here we have the explanation why the whole difference of potential appears as "back electromotive force" and the "true" resistance seems to vanish.

Our familiarity with Ohm's law renders it difficult for us to imagine that the gradient of potential may remain the same though the current intensity varies, but experiments show that it is often the case in a gas. If we imagine the current to be due to a diffusion of ions it is easily seen that if more ions are set free at the electrodes, the same fall of potential must mean a greater current strength.

We should be cautious, therefore, in the interpretation of the experimental results obtained by Von Lang, Arons, and Mr. Frith.

Mr. Firth is correct in stating, at the end of his paper, that the constancy of the results obtained shews that it is due to some process which is independent of the current strength, but that process need only be a dissipation of energy, according to Joule's law, such as takes part in the positive part of the discharge in a vacuum tube, and does not necessarily imply any chemical or physical work done.

On Some Remarkable Passages in the Writings of Benjamin Franklin. By Arthur Schuster, F.R.S.

(*Received March 14th, 1895.*)

I have recently had occasion to peruse more carefully than I had previously done the works of Benjamin Franklin. His life, partly described by himself, as well as the contents of his letters and papers, offer us matter which is of great interest. Perhaps the selection of a few passages may best show the author's width of knowledge and keenness of intellect, but only a complete study of his works can give an idea of the great number of subjects which he discussed and helped to elucidate. Franklin's scientific work seems to have originated in the trial of some electrical apparatus which Mr. Peter Collinson, F.R.S., sent from England, in 1845, as a present to the public library founded by Franklin in Philadelphia. In a letter, dated March 28th, 1747, he gave an account of some experiments in which, for the first time, he describes the action of points in discharging electricity; then follows this passage :*

" *Works,*" page 5.

"The repellency between the cork ball and the shot is "likewise destroy'd. 1. By sifting fine sand on to it; this

*The quotations refer to the following publications :

(1) "Experiments and observations on Electricity, made at Philadelphia, in America," by Benjamin Franklin, LL.D. and F.R.S. (London : Printed for David Henry, MDCCLXIX).

(2) "The Complete Works of the late Dr. Franklin," in 3 volumes (second edition). London : Printed for Longmans, etc.

They will for shortness' sake be referred to as "Experiments" and "Works."

"does it gradually. 2. By breaking on it. 3. By making "a smoke about it from burning wood. 4. By candle light, "even though the candle is at a foot distance: these do it "suddenly.—The light of a bright coal from a wood fire; "and the light of red hot iron do it likewise; but not at so "great a distance. Smoke from dry rosin dropt on hot "iron, does not destroy the repellency; but is attracted by "both shot and cork ball, forming proportionable atmospheres "round them, making them look beautifully, somewhat like "some of the figures in Burnet's or Whiston's theory of "the earth.

"N.B.—This experiment should be made in a closet, "where the air is very still, or it will be apt to fail.

"The light of the sun thrown strongly on both cork and "shot by a looking glass for a long time together, does not "impair the repellency in the least. This difference between "fire-light and sun light is another thing that seems new "and extraordinary to us."

FOOTNOTE: "This different effect probably did not arise from any difference "in the light, but rather from the particles separated from the candle, being first "attracted and then repelled, carrying off the electric matter with them; and "from the rarefying the air, between the glowing coal or red hot iron, and the "electrified shot, through which rarified air the electric fluid could more "readily pass."

It will be noticed that Franklin was the discoverer of the action of flames, as well as of the discharging properties of red hot iron, which seem to have been forgotten until re-discovered by Guthrie, in 1873 (*Phil. Mag.* XLVI., p. 257).

Another matter of interest is the experiment intended to try the action of sunlight. Had Franklin used a clean piece of zinc instead of iron shot he might have anticipated Hertz's discovery of the action of strong light on the discharge of gases.

Franklin gives in one of the letters the first mention in his note book of the line of thought which led him to the invention of the lightning conductor.

"*Experiments*," page 323.

"Nov. 7, 1749. Electrical fluid agrees with lightning in "these particulars: 1. Giving light. 2. Colour of the light. "3. Crooked direction. 4. Swift motion. 5. Being con- "ducted by metals. 6. Crack or noise in exploding. 7. Sub- "sisting in ice or water. 8. Rending bodies it passes "through. 9. Destroying animals. 10. Melting metals. "11. Firing inflammable substances. 12. Sulphureous "smell.—The electric fluid is attracted by points.—We do "not know whether this property is in lightning.—But "since they agree in all the particulars wherein we can "already compare them, is it not probable they agree "likewise in this? Let the experiment be made."

During the succeeding year he formulates more clearly how the observations may be carried out, and in an article forwarded to Peter Collinson on July 29, 1750 (*Experiments*, p. 54, *Works*, Vol. I., p. 216), writes as follows:—

"To determine the question whether the clouds that "contain lightning are electrified or not, I would propose an "experiment to be try'd when it may be done conveniently. "On the top of some high tower or steeple, place a kind of "sentry box big enough to contain a man and electrical "stand. From the middle of the stand let an iron rod rise "and pass bending out of the door and then upright 20 or "30 feet, pointed very sharp at the end. If the electrical "stand be kept clean and dry, a man standing on it when "such clouds are passing low, might be electrified and afford "sparks, the rod drawing fire to him from a cloud. If any "danger to the man should be apprehended (though I think "there would be none) let him stand on the floor of his box "and now and then bring near the rod the loop of a wire "that has one end fastened to the leads, he holding it by a "wax handle; so the sparks, if the rod is electrified, will "strike from the rod to the wire, and not affect him."

The experiment was first performed by d'Alcibard, at

Marly, on May 10, 1752, and in the same year by others in England and France, as well as by Franklin himself.

A passage referring to the action of lightning conductors may be quoted. It is contained in a letter dated June 29, 1755 (*Experiments*, p. 161, *Works*, Vol. I., p. 309.)

"As to the effect of points in drawing the electric matter "from the clouds and thereby securing buildings, etc., "which, you say, he seems to doubt, I must own I think he "only speaks modestly and judiciously. I find I have "been but partly understood in that matter. I have "mentioned it in several of my letters, and except once, "always in the *alternative*, viz., that pointed rods erected "on buildings, and communicating with the moist earth, "would either *prevent* a stroke, or, if not prevented, "would conduct it, so that the building should suffer no "damage. Yet whenever my opinion is examined in Europe, "nothing is considered but the probability of those rods "preventing a stroke or explosion, which is only a *part* of "the use I proposed for them; and the other part, their "conducting a stroke, which they may happen not to "prevent seems to be totally forgotten, though of equal "importance or advantage."

"*Experiments*," page 50, "*Works*," Vol. I., p. 213).

"Dangerous, therefore, is it to take shelter under a "tree, during a thunder-gust. It has been fatal to many, "both men and beasts.

"It is safer to be in the open field for another reason. "When the cloaths are wet, if a flash in its way to the "ground should strike your head, it may run in the water "over the surface of your body; whereas if your cloaths "were dry, it would go through the body.

"Hence a wet rat cannot be killed by the exploding "electrical bottle, when a dry rat may."

FOOTNOTE: "This was tried with a bottle, containing about a quart. It is since "thought that one of the large glass jars, mentioned in these papers, might "have killed him though wet."

It was not long before Franklin's work found its appreciation, as the following letter addressed to him will show:

"*Experiments*," page 396.

"And now, Sir, I must heartily congratulate you on the "pleasure you must have in finding your great and well-"founded expectations so far fulfilled. May this method "of security from the destructive violence of one of the "most awful powers of nature, meet with such further "success, as to induce every good and grateful heart to bless "God for the important discovery! May the benefit thereof "be diffused over the whole globe! May it extend to the "latest posterity of mankind, and make the name of "Franklin, like that of Newton, immortal.

"I am, Sir, with sincere respect,

"Your most obedient, most humble servant,

"EBEN: KINNERSLEY."

In the answer to this letter, Franklin describes experiments which he has made to discover the source of atmospheric electricity, and it is of interest to find that he had thought of the possibility that "negative electricity might be produced by evaporation only." His experiments, however, did not shew any effects.

To those who believe that our own age has a special claim to be called the "electrical age," the following may be of interest.

"*Experiments*," page 37.

"Chagrined a little that we have been hitherto able to "produce nothing in this way of use to mankind; "and the hot weather coming on, when electrical experi-"ments are not so agreeable, it is proposed to put an end to "them for this season, somewhat humorously, in a party of "pleasure, on the banks of Skuylkil. Spirits, at the same "time, are to be fired by a spark sent from side to side "through the river, without any other conductor than the "water; an experiment which we sometime since performed, "to the amazement of many. A turkey is to be killed for "our dinner by the electric shock, and roasted by the "electrical jack, before a fire kindled by the electrified "bottle; when the healths of all the famous electricians in "England, Holland, France, and Germany are to be drank "in electrified bumpers, under the discharge of guns from "the electrical battery."

FOOTNOTE: "An electrified bumper is a small thin glass tumbler, near "filled with wine, and electrified as the bottle. This when brought to the lips "gives a shock, if the party be close shaved, and does not breathe on the "liquor."

Various experiments were made to determine the strength of spark necessary to kill various animals, and although human beings could not be dealt with in the same way, he is evidently anxious to know whether electric sparks can be obtained sufficiently strong to kill them.

"*Experiments*," page 324.

"The knocking down of the six men was performed with "two of my large jars not fully charged. I laid one end of "my discharging rod upon the head of the first; he laid his "hand on the head of the second; the second his hand on "the head of the third, and so to the last, who held, in his "hand, the chain that was connected with the outside of the "jars. When they were thus placed, I applied the other "end of my rod to the prime conductor, and they all dropt "together. When they all got up they all declared they "had not felt any stroke and wondered how they came to "fall; nor did any of them either hear the crack, or see the "light of it. You suppose it a dangerous experiment; "but I had once suffered the same myself, receiving by "accident, an equal stroke through my head, that struck "me down without hurting me: I had seen a young woman "that was about to be electrified through the feet (for some "indisposition) receive a greater charge through the head, by "inadvertently stooping forward to look at the placing of her "feet, till her forehead (as she was very tall) came too near "my prime conductor: she dropt, but instantly got up "again, complaining of nothing. A person so struck, sinks "down doubled or folded together as it were, the joints "losing their strength and stiffness at once, so that he drops "on the spot where he stood, instantly, and there is no "previous staggering, nor does he ever fall length-wise. "Too great a charge might, indeed, kill a man, but I have "not yet seen any hurt done by it. It would certainly, as "you observe, be the easiest of all deaths."

But electricity was by no means the only subject which occupied his mind, and some passages may be quoted to shew the wideness of his range of thought. It is well known that the undulatory theory of light originated before Franklin's time, but he seemed to be unaware of this, and the way in which he independently thought of and argued in favour of the same idea at a time when most philosophers held to the corpuscular theory deserves quotation in full. It must not be forgotten, however, that Franklin did not probably realise the difficulties in the way of the wave theory which led Newton to pronounce against it.

"*Experiments*," page 264.

"I thank you for communicating the illustration of the "theorem concerning light. It is very curious. But I "must own I am much in the *dark* about *light*. I am not "satisfied with the doctrine that supposes particles of matter "called light, continually driven off from the sun's surface, "with a swiftness so prodigious! Must not the smallest "particle conceivable, have with such a motion, a force "exceeding that of a twenty-four pounder, discharged from "a cannon? Must not the sun diminish exceedingly by "such a waste of matter; and the planets, instead of draw-"ing nearer to him, as some have feared, recede to greater "distances through the lessened attraction. Yet these par-"ticles, with this amazing motion, will not drive before "them, or remove the least or lightest dust they meet with. "And the sun, for aught we know, continues of his antient "dimensions, and his attendants move in their antient "orbits.

"May not all the phænomena of light be more con-"veniently solved by supposing universal space filled with a "subtle elastic fluid, which, when at rest, is not visible, but "whose vibrations affect that fine sense in the eye, as those "of air do the grosser organs of the ear? We do not, in "the case of sound, imagine that any sonorous particles are "thrown off from a bell, for instance, and fly in straight "lines to the ear; why must we believe that luminous "particles leave the sun and proceed to the eye? Some "diamonds if rubbed shine in the dark, without losing any "of their matter. I can make an electric spark as big as "the flame of a candle, much brighter, and therefore visible "further; yet this is without fuel; and, I am persuaded, no "part of the electric fluid flies off in such case, to distant "places, but all goes directly, and is to be found in the "place to which I destine it. May not different degrees of "the vibration of the above-mentioned universal medium, "occasion the appearance of different colours? I think "the electric fluid is always the same; yet I find that "weaker and stronger sparks differ in apparent colour, some "white, blue, purple, red; the strongest white; weak ones "red. Thus different degrees of vibration given to the air, "produce the seven different sounds in music, analogous to "the seven colours, yet the medium, air, is the same.

"If the sun is not wasted by expence of light, I can "easily conceive that he shall otherwise always retain the "same quantity of matter; though we should suppose him "made of sulphur constantly flaming. The action of fire "only *separates* the particles of matter, it does not *annihilate* "them. Water, by heat raised in vapour, returns to the "earth in rain; and if we could collect all the particles of "burning matter that go off in smoke, perhaps they might, "with the ashes, weigh as much as the body before it was "fired: And if we could put them into the same position "with regard to each other, the mass would be the same as "before, and might be burnt over again. The chymists "have analised sulphur, and find it composed, in certain "proportions, of oil, salt, and earth; and having by the "analysis discovered those proportions they can, of those "ingredients make sulphur. So we have only to suppose, "that the parts of the sun's sulphur, separated by fire, "rise into his atmosphere, and there being freed from the "immediate action of the fire, they collect into cloudy "masses, and growing by degrees, too heavy to be longer "supported, they descend to the sun, and are burnt over "again. Hence the spots appearing on his face which are "observed to diminish daily in size, their consuming edges "being of particular brightness.

"It is well we are not, as poor Galileo was, subject to "the Inquisition for Philosophical Heresy. My whispers "against the orthodox doctrine, in private letters, would be "dangerous; but your writing and printing would be highly "criminal. As it is you must expect some censure, but one "Heretic will surely excuse another.

"I am heartily glad to hear more instances of the "Poke-Weed, in the cure of that horrible evil to the human "body, a Cancer. You will deserve highly of mankind for "the communication. But I find in Boston they are at a "loss to know the right plant, some asserting it is what they "call Mechoachan, others other things. In one of their late "papers it is publickly requested that a perfect description "may be given of the plant, its places of growth, etc. I "have mislaid the paper, or would send it to you. I "thought you had described it pretty fully.

"I am, Sir, etc., B. F."

Travelling back from England to America Franklin noticed in the lamps on board ship, in which the oil was kept floating on a surface of water, a peculiar agitation at the surface of separation between the oil and the water. On his return home he made experiments on the subject, which he describes:

"*Experiments*," page 439.

"Since my arrival in America, I have repeated the "experiment frequently thus: I have put a pack-thread "round a tumbler, with strings of the same, from each side, "meeting above it in a knot at about a foot distance from the "top of the tumbler, Then putting in as much water as "would fill about one-third part of the tumbler, I lifted it up "by the knot, and swung it to and fro in the air; when the "water appeared to keep its peace in the tumbler as steadily "as if it had been ice.—But pouring gently in upon the water "about as much oil, and then swinging it in the air as "before, the tranquility before possessed by the water, was "transferred to the surface of the oil, and the water under "it was agitated with the same commotions as at sea.

"I have shewn this experiment to a number of "ingenious persons. Those who are but slightly acquainted "with the principles of hydrostatics, &c., are apt to fancy "immediately that they understand it, and readily attempt "to explain it; but their explanations have been different "and to me not very intelligible.—Others more deeply "skill'd in those principles, seem to wonder at it, and promise "to consider it. And I think it is worth considering: For "a new appearance, if it cannot be explain'd by old "principles, may afford us new ones, of use perhaps in "explaining some other obscure parts of natural knowledge.

"I am, &c,, B. F."

I do not know whether it is generally known that water-tight compartments of ships are an ancient invention, as the following passage will shew :—

"*Works*," vol. II., p. 171.

"While on this topic of sinking, one cannot help "recollecting the well-known practice of the Chinese, to "divide the hold of a great ship into a number of separate "chambers by partitions tight caulked (of which you gave "a model in your boat upon the Seine) so that if a leak "should spring in one of them, the others are not affected "by it; and though that chamber should fill to a level with "the sea, it would not be sufficient to sink the vessel . .

" . . . .

"But our sea-faring people are brave, despite danger, and "reject such precautions of safety, being cowards only in "one sense, that of *fearing* to be *thought afraid*."

Finally I give a few quotations which will illustrate his lines of thought on general topics, and shew the quiet humour with which he could occasionally put his thoughts into words.

"*Experiments*," page 62.

"Nor is it of much importance to us, to know the manner "in which nature executes her laws; 'tis enough if we know "the laws themselves. 'Tis of real use to know that china "left in the air unsupported will fall and break; but *how* it "comes to fall, and *why* it breaks, are matters of speculation. "'Tis a pleasure indeed to know them, but we can preserve "our china without it."

To a lady who asked him the reason for a certain alleged fact, he answers:—

"*Experiments*," page 449.

"Your first question, What is the reason the water at "this place, though cold at the spring, becomes warm by "pumping? It will be most prudent in me to forbear "attempting to answer, till, by a more circumstantial "account, you assure me of the fact. I own I should "expect that operation to warm, not so much the water "pumped, as the person pumping.—The rubbing of dry "solids together, has been long observed to produce heat; "but the like effect has never yet, that I have heard, been "produced by the mere agitation of fluids, or friction of "fluids with solids.

" . . . .

" . . . .

"This prudence of not attempting to give reasons before "one is sure of facts, I learnt from one of your sex, who, as "Seldon tells us, being in company with some gentlemen "that were viewing, and considering something which they "called a Chinese shoe, and disputing earnestly about the "manner of wearing it, and how it could possibly be put on; "put in her word, and said modestly, Gentlemen, are you "sure it is a shoe? Should not that be settled first?"

Speaking of a friend who was exceptionally fond of argument he says:—

" *Works*," vol. 1, p. 17.

"This contentious temper, I would observe by the way, "is in danger of becoming a very bad habit; and frequently "renders a man's company insupportable as being no other- "wise capable of indulgence than by an indiscriminate "contradiction . . . .

"I have since remarked that men of sense seldom fall "into this error: lawyers, fellows of universities, and persons "of every profession educated at Edinburgh, excepted."

Quoting the lines of Pope:—

> "Immodest words admit of no defence,
> For want of decency is want of sense."

He remarks:—

"Now is not want of sense, when a man has the mis- "fortune to be so circumstanced, a kind of excuse for want "of modesty? and would not the verses have been more "accurate if they had been construed thus:—

> "Immodest words admit but this defence,
> That want of decency is want of sense".

" *Works*," vol. II., page 223.

"I have seen an instance of common flies preserved in a "manner somewhat similar. They had been drowned in "Madeira wine, apparently about the time when it was "bottled in Virginia, to be sent hither to London. At the "opening of one of the bottles, at the house of a friend "where I then was, three drowned flies fell into the first "glass that was filled. Having heard it remarked that "drowned flies were capable of being revived by the rays of "the sun, I proposed making the experiment on these: they "were therefore exposed to the sun upon a sieve, which had "been employed to strain them out of the wine. In less than "three hours, two of them began by degrees to recover life. "They commenced by some convulsive motions of the "thighs, and at length they raised themselves upon their "legs, wiped their eyes with their forefeet, beat and brushed "their wings with their hind-feet, and soon after began to fly, "finding themselves in Old England, without knowing how "they came thither. The third continued lifeless until sunset, "when, losing all hopes of him, he was thrown away.

"I wish it were possible, from this instance, to invent a "method of embalming drowned persons, in such a manner "that they may be recalled to life at any period, however "distant; for having a desire to see and observe the state "of America an hundred years hence, I should prefer to "any ordinary death, the being immersed in a cask of "Madeira wine, with a few friends until that time, to be "recalled to life by the solar warmth of my dear country! "But since in all probability we live in an age too early and "too near the infancy of science, to hope to see such an art "brought in our time to perfection, I must for the present "content myself with the treat, which you are so kind as to "promise me, of the resurrection of a fowl or turkey cock.

"I am, &c.,

"B. FRANKLIN."

In conclusion I give an epitaph written on himself many years previous to his death:—

"*Works*," vol. I., p. 155.

The Body
of
Benjamin Franklin
printer
(like the cover of an old book,
its contents torn out,
and stript of its lettering and gilding)
lies here food for worms;
Yet the work itself shall not be lost,
for it will (as he believed) appear once more
in a new
and more beautiful edition
corrected and amended
by
The Author.

General Meeting, March 19th, 1895.

HENRY WILDE, F.R.S., President, in the Chair.

The following resolutions, of which due notice had been given, were carried *nem. con.* :—

Proposed by the PRESIDENT, and seconded by Mr. Alderman THOMPSON :—

That Clause 15 of the Articles of Association be rescinded, and that in lieu thereof the following be one of the Clauses of the said Articles ;—

> "15. The Certificate shall be audibly read by the Secretary "at one Ordinary Meeting, or, if required by the Council, at "two Ordinary Meetings previous to the General Meeting at "which the election is to take place."

Proposed by the PRESIDENT, and seconded by Mr. F. J. FARADAY, F.L.S. :—

That Clause 21 of the Articles of Association be rescinded, and that in lieu thereof the following be one of the Clauses of the said Articles :—

> "21. Every ordinary member, if elected in any month "from April to December, both inclusive, shall pay the full "amount of his annual subscription for the then current year, "but if elected in January, February, or March, he shall pay "only one-half his subscription for the then current year."

Proposed by the PRESIDENT, and seconded by Professor OSBORNE REYNOLDS, F.R.S. :—

That clause 26 of the Articles of Association be rescinded, and that in lieu thereof the following be one of the Clauses of the said Articles :

> "26. The Society shall hold a session annually, begin-"ning with the month of October and ending at a time to be "fixed by the Council, not later than the month of May "in the year following, and may hold such intermediate "ordinary meetings as the Society or the Council may from "time to time determine."

Proposed by the PRESIDENT, and seconded by Professor ARTHUR SCHUSTER, F.R.S. :—

That Clause 27 of the Articles of Association be rescinded, and that in lieu thereof the following be one of the Clauses of the said Articles :—

"27. The first ordinary meeting of the Session shall be "held the first week in October, and the subsequent ordinary "meetings in every alternate week up to such time (not being "later than the end of May) on such days and at such hours "as the Council may from time to time determine."

Proposed by the PRESIDENT, and seconded by Professor OSBORNE REYNOLDS F.R.S. :—

That Clause 28 of the Articles of Association be rescinded, and that in lieu thereof the following be one of the Clauses of the said Articles :—

"28. If at any time Christmas Day, or the week following "it, or Easter week shall so fall as to make the holding of an "ordinary meeting in accordance with the last preceding "Clause in the opinion of the Council inconvenient, then the "date of such meeting may be altered as the Council shall "think fit."

Proposed by the PRESIDENT, and seconded by Mr. F. J. FARADAY, F.L.S. :—

That Clause 90 of the Articles of Association be rescinded, and that in lieu thereof the following be one of the Clauses of the said Articles :—

"90. Each section shall pay to the Treasurer such sum "annually as the Council may from time to time determine."

Ordinary Meeting, March 19th, 1895.

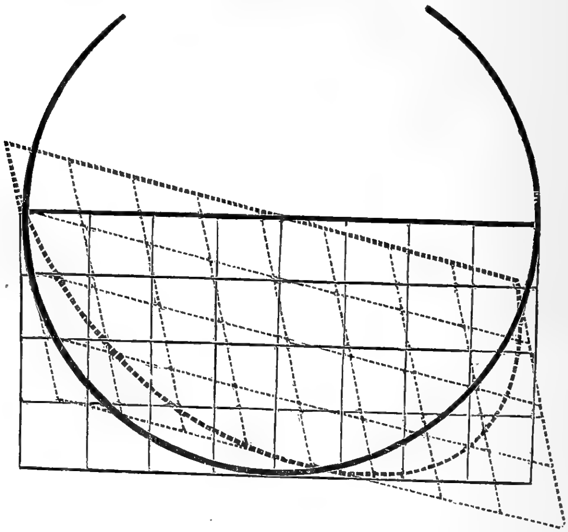
HENRY WILDE, F.R.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

Mr. A. BROTHERS, F.R.A.S., gave a description of a supposed display of Aurora borealis as seen at Higher Poynton, near the Manchester, Sheffield, and Lincolnshire Railway, on Wednesday, March 13th. The display was of an unusual kind. As there was an irregularly shaped cloudy mass of light with auroral streamers flickering past and finally collecting in narrow bands of light. The long irregular cloud then moved towards the west and formed in a bright column of light, faint at first, but it became intensely white. The upper part then spread out in the form of a fan, having very much the appearance of Donati's comet when at its brightest. The column of light formed and disappeared almost due west.

Professor OSBORNE REYNOLDS, F.R.S., exhibited some experiments illustrating the behaviour of the surface of separation of two liquids of different densities, and read the following note on the subject :—

"The paradox first noticed by Benjamin Franklin which was brought before the Society by Dr. Schuster at the last meeting, namely, that when a glass vessel containing water and oil, so that the oil floats on the top of the water, forming two surfaces, one the upper surface of the water and lower surface of the oil, the other the surface between the oil and the air, is moved with a periodic motion, the surface separating the two fluids is much more sensitive and much more disturbed than the upper surface, is very striking, even when the motion of the vessel is somewhat casual—such as may be imparted by the hand. And the paradox becomes even more pronounced when the vessel is, by suspension or otherwise, subject to regular harmonic motion in one plane, and compared with a vessel in all respects and similarly situated, except that it contains one fluid only. For while the upper surface of the oil appears to follow the motion of the vessel, remaining very nearly perpendicular to the line of suspension, as it would if the whole mass were a solid, the free surface of the water in the vessel without oil has a decidedly greater amplitude than that of the line of suspension, though the oscillations are exactly in the same phase and the amplitude is still small. On the other hand the surface separating the oil and water has an oscillatory motion about the line of suspension much greater in magnitude than that of the surface of the water in the vessel without oil and in exactly the same or the opposite phase. Another very striking fact is that all the surfaces appear to remain plane surfaces when the motion is within certain considerable limits. These motions, however, do depend on the relations between the length of the pendulum, the size of the vessel, and the depths of the fluids, the phase of the separating surface changing from the same to the phase opposite to that of the line of suspension as the pendulum is shortened. The solution of the problem presented by this paradox, although not altogether confirmed or fully worked out, appears to be indicated by the fact that the oscillations of all the surfaces are *steady*, and in the same or opposite phase with the line of suspension, that is, in the same or opposite phase with the disturbance, together with the fact that the free surfaces of the fluids remain nearly plane. For if any material system is, when disturbed, capable of oscillating in a particular period (its natural period), and such oscillation is subject to a viscous resistance, then if subject to a very gradually increasing disturbance, having a period longer than the natural period, the system will oscillate in the period of disturbance always in the same phase as the disturbing force. But if the disturbance has a period shorter than the natural period, the system will oscillate in the same period as the force, but in the opposite phase. Now, in the vessel with oil and water three systems of oscillation, or wave motions, are possible. If the vessel were completely full, so that there were no free surface, and if there were no oil, no oscillation would be possible except (1) the pendulous motion. If half full of oil and filled up with water, then, if disturbed and left, a wave motion (2) in its natural period would be set up in the surface between the oil and water. In the same way (3) if the vessel were half full of water without oil. But in the latter case (3) the natural period would be two or three times less than (2) between the oil and water. Now, when the vessel contains oil and water, disturbances (2) and (3) will both be set up, and might continue, till destroyed by viscosity, in their natural periods if these were the same, but the periods being different, the oscillations in the period (3) would cause periodic disturbance in (2), and the natural period of (3) being much shorter than that of (2), the oscillation so maintained in (2) would be in opposite phase to (3), but, owing to viscosity, such maintenance would be of short duration. If, however, the natural period of the pendulous motion (1) of the vessel were in magnitude between the periods 3 and 2, smaller than (2) greater than (3), then it would maintain an oscillation in the same period as the pendulous motion in (3) and also in (2), that in (3) having the same phase as the pendulum, that in (2) having the opposite phase. So far this explanation is only partial, as it is assumed that there will be a disturbance in (2) in the same phase as in (3). That this must be the case, however, becomes evident when it is considered that the motion of the water cannot be that of a solid, but must be irrational, and that the disturbance arises from the non-spherical form of the surfaces of the fluids. If the surface of the vessel were flexible, the motion of the fluids would be essentially that of a particular portion of the water in a long wave adjacent to the surface



as shown in the figure. In this, the plain lines indicate lines in the water at rest, which take the position of the dotted lines when the wave surface has the position of the thick dotted line. The black circle indicates the surface of the spherical vessel; and the dotted curve shows the shape this surface would become if it were subject to the same distortion as the water. In fact, the vessel is rigid, and the surface of the water must conform to it, which requires further internal distortional motion of the water. It is seen there is an excess of water at the top on the higher side and a deficiency on the lower, to supply which the upper surface must be still further tipped, while there is a deficiency on the higher side below and an excess on the lower side, to remedy which the lower surface must tip in the opposite direction. This is exactly what is seen with the oil and water, and is there though it cannot be seen in the water, although not to so great an extent because there is no possibility of an internal wave as between the oil and water."

In the discussion which followed this paper, Professor LAMB, F.R.S., suggested that the phenomena could probably all be interpreted on the basis of the general theory of forced oscillations, combined with the fact, pointed out long ago by Sir G. Stokes, that the surface of separation of two liquids of slightly different densities has greater inertia and less stability than a free surface of similar extent, so that the natural periods of oscillation are comparatively long. According to the calculation of Stokes (*Camb. Trans.*, vol. 8, 1847), the superposition of a liquid of density ρ' on one of density ρ will diminish the speed of the oscillations of the common surface in the ratio $\sqrt{\{(\rho-\rho')/(\rho+\rho')\}}$. For example, in the case of oil of density ·8, over water, the free oscillations will be three times as slow as in the case of an air-water surface.

[*Microscopical and Natural History Section.*]

Ordinary Meeting, March 18th, 1895.

JOHN BOYD, Esq., President of the Section, in the Chair.

Mr. MARK STIRRUP, F.G.S., read a paper describing the geology of the Island of Barbadoes, and with Mr. R. E. CUNLIFFE exhibited under the miscroscope slides of the well-known Barbadoes earth containing siliceous organisms.

Mr. OLDHAM exhibited and described two new species of fresh-water shells, *Pisidium cruciatum* and *P. punctatum*, illustrated in the *Nautilus*, a monthly magazine published in Philadelphia (Vol. viii., No. 9, 1895), and another, not yet described, from New Philadelphia, Ohio.

Mr. COWARD exhibited two skulls, stone weapons, and hardened wood club, from Islands in the Pacific.

Ordinary Meeting, April 2nd, 1895.

HENRY WILDE, F.R.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

Professor F. E. WEISS, B.Sc., exhibited specimens of *Ramalina reticulata* and of *Phallus impudicus*, recently added to the Manchester Museum, Owens College. The former is a lichen, which grows in a net-work form and shows the small cup-like processes which contain the characteristic spores. The genus was first described by Agardh as a marine alga, and though this description was corrected by Asa Gray long since, it is still often described as such, even in recent botanical works. The common stinkhorn (*Phallus*) was represented by several specimens, showing different stages of growth, and mounted in spirits, a plan which has great advantages over the usual method of drying.

Mr. W. E. HOYLE, M.A., exhibited illustrations of the method which is being adopted in the Museum for the illustration of the different natural orders of the vegetable kingdom. For each a printed label giving the characters of the family, diagrams of the morphology of the flowers and a map showing the geographical distribution are displayed, with examples of the more prominent genera and species suitably preserved.

Mr. CHARLES BAILEY, F.L.S., in commenting on the exhibits, alluded to a case in which the powerful and unpleasant odour of the *Phallus* had given rise to a suspicion of imperfect drainage.

Dr. A. HODGKINSON read a paper "On the Germination of Orchidaceous Seeds," in which he showed that terrestrial orchids differ from epiphytal orchids in an important way during the process. The former, on the addition of water, show no special change, while in the case of the latter a peculiar cellular process suddenly protrudes from the microphyle. As an explanation of this phenomenon Dr. HODGKINSON suggested that it was probably for the purpose of fixing the seed to the trunk or branch of the tree on which it might alight, and so preventing it from falling to the ground. Such a provision would not, of course, be necessary in the case of terrestrial orchids. Another important fact is that it may probably be taken as a proof of the vitality of the seed.

In the discussion which ensued, Professor WEISS said that he was inclined to agree with Dr. HODGKINSON'S explanation, and suggested that the case was one of adaptability to a second function, the original function of the process having been that of feeding the embryo plant.

General Meeting, April 9th, 1895.

HENRY WILDE, F.R.S., President, in the Chair.

This was an extraordinary general meeting summoned to confirm the resolutions relating to the Articles of Association passed at the general meeting on March 19th, and to elect new members. The resolutions, as detailed below, were confirmed *nem. con.* :—

Proposed by the PRESIDENT and seconded by Mr. FRANCIS NICHOLSON, F.Z.S. :—

That Clause 15 of the Articles of Association be rescinded, and that in lieu thereof the following be one of the Clauses of the said Articles :—

"15. The Certificate shall be audibly read by the "Secretary at one Ordinary Meeting, or, if required by the "Council, at two Ordinary Meetings previous to the General "Meeting at which the election is to take place."

Proposed by the PRESIDENT and seconded by Mr. R. F. GWYTHER, M.A. :—

That Clause 21 of the Articles of Association be rescinded, and that in lieu thereof the following be one of the Clauses of the said Articles :—

"21. Every ordinary member, if elected in any month from "April to December, both inclusive, shall pay the full amount "of his annual subscription for the then current year, but if "elected in January, February, or March, he shall pay only "one-half his subscription for the then current year."

Proposed by the PRESIDENT and seconded by Mr. J. C. MELVILL, M.A., F.L.S. :—

That Clause 26 of the Articles of Association be rescinded, and that in lieu thereof the following be one of the Clauses of the said Articles :—

"26. The Society shall hold a session annually, beginning "with the month of October, and ending at a time to be fixed "by the Council, not later than the month of May in the "year following, and may hold such intermediate ordinary "meetings as the Society or the Council may from time to "time determine."

Proposed by the PRESIDENT and seconded by Professor HORACE LAMB, M.A., F.R.S. :—

That Clause 27 of the Articles of Association be rescinded, and that in lieu thereof the following be one of the Clauses of the said Articles :—

"27. The first ordinary meeting of the Session shall be "held in the first week in October, and the subsequent "ordinary meetings in every alternate week up to such time "(not being later than the end of May) on such days and at "such hours as the Council may from time to time determine."

Proposed by the PRESIDENT and seconded by Mr. ALFRED BROTHERS, F.R.A.S. :—

That Clause 28 of the Articles of Association be rescinded, and that in lieu thereof the following be one of the Clauses of the said Articles :—

"28. If at any time Christmas Day, or the week following "it, or Easter week shall so fall as to make the holding of an "ordinary meeting in accordance with the last preceding "Clause in the opinion of the Council inconvenient, then the "date of such meeting may be altered as the Council shall "think fit.

Proposed by the PRESIDENT and seconded by Mr. FRANCIS JONES, F.R.S.E. :—

That Clause 90 of the Articles of Association be rescinded, and that in lieu thereof the following be one of the Clauses of the said Articles :—

"90. Each section shall pay to the Treasurer such sum "annually as the Council may from time to time determine.

The following gentlemen were elected ordinary members: WILLIAM BOYD DAWKINS, M.A., F.R.S., Professor of Geology at the Owens College, Manchester; JAMES WHITEHEAD, Gentleman, Lindfield, Fulshaw Park, Wilmslow; R. A. TATTON, Engineer to the Mersey and Irwell Joint

Committee, Manchester; HENRY A. ERSKINE, Sub-Manager, Branch Bank of England, Manchester; ARTHUR G. GREEN, Scientific Chemist, Manchester; WILLIAM H. CLAUS, Chemical Manufacturer, 31, Mauldeth Road, Fallowfield, Manchester.

Ordinary Meeting, April 16th, 1895.

HENRY WILDE, F.R.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

The PRESIDENT made some remarks on the two recently discovered "elements," argon and helium, and a short discussion ensued.

Annual General Meeting, April 30th, 1895.

HENRY WILDE, F.R.S., President, in the Chair.

The following resolution, of which due notice had been given, was proposed by the PRESIDENT, seconded by Mr. R. F. GWYTHER, M.A., and carried *nem. con.* :—

That the following Clause be inserted in and be one of the Clauses of the Articles of Association of the Society :—

"82A. All deeds and documents which require the seal "of the Society to be attached shall be signed by the President "and one or more Vice-Presidents, or by two or more Vice- "Presidents, and countersigned by one of the Secretaries, and "and the power of appointing a substitute, given by Clause "82, shall not apply to this Clause."

The following gentlemen were elected honorary members of the Society :—EDOUARD SUESS, Professor of Geology, University of Vienna; G. MITTAG-LEFFLER, Professor of Mathematics, Stockholm; F. BEILSTEIN Professor of Chemistry, St. Petersburg; JOSEPH JOHN THOMSON, Professor of Experimental Physics, Cambridge; H. DE LACAZE DUTHIERS, Professor of Zoology at the Sorbonne, Paris; KARL A. VON ZITTEL, Professor of Geology and Palæontology, Munich; J. ELSTER, Science Master, Wolfenbüttel; H. GEITEL, Science Master, Wolfenbüttel.

The following gentlemen were elected ordinary members of the Society :—A. W. FLUX, M.A., Lecturer in Political Economy, the Owens College; EDWARD PYEMONT COLLETT, Surgeon-Dentist, Chorlton-cum-Hardy; Dr. G. ADOLF LIEBMANN, Consulting Chemist, Didsbury; JAMES EDWARD CORNISH, Bookseller and Publisher, Manchester.

The annual report of the Council was presented and amended, and it was moved by Mr. MARK STIRRUP, F.G.S., seconded by Mr. J. B. MILLAR, M.E., and resolved, "That the annual report as amended be adopted and printed in the Society's *Memoirs and Proceedings*."

It was moved by Mr. J. B. MILLAR, M.E., seconded by Mr. MARK STIRRUP, F.G.S., and resolved, "That the system of electing Associates of Sections be continued during the ensuing Session."

The following gentlemen were elected officers of the Society and members of the Council for the ensuing year:

President.—HENRY WILDE, F.R.S.

Vice-Presidents.—EDWARD SCHUNCK, Ph.D., F.R.S., F.C.S.; OSBORNE REYNOLDS, M.A., LL.D., F.R.S.; ARTHUR SCHUSTER, Ph.D., F.R.S., F.R.A.S.; FRANCIS NICHOLSON, F.Z.S.

Secretaries.—FREDERICK JAMES FARADAY, F.L.S., F.S.S.; REGINALD F. GWYTHER, M.A.

Treasurer.—CHARLES BAILEY, F.L.S.

Librarian.—W. E. HOYLE, M.A., M.Sc., M.R.C.S.

Other Members of the Council.—J. C. MELVILL, M.A., F.L.S.; JAMES BOTTOMLEY, B.A., D.Sc., F.C.S.; HAROLD B. DIXON, M.A., F.R.S.; ALEXANDER HODGKINSON, M.B., B.Sc.; Alderman JOSEPH THOMPSON; FRANCIS JONES, F.R.S. Ed., F.C.S.

Ordinary Meeting, April 30th, 1895.

HENRY WILDE, F.R.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

Mr. MARK STIRRUP, F.G.S., read a paper, illustrated by a series of maps and prints, on "The Geological Antiquity of Insects," a review of M. Charles Brongniart's recent work on the subject.

Mr. THOMAS HICK, B.A., B.Sc., A.L.S., read a paper "On the structure of the Leaves of *Calamites*."

On the Structure of the Leaves of *Calamites*. By Thomas Hick, B.A., B.Sc., A.L.S., Assistant Lecturer in Botany, the Owens College, Manchester. Communicated by F. E. Weiss, B.Sc., Professor of Botany at the Owens College.

[*Received April 30th, 1895.*]

INTRODUCTION.

The accounts hitherto published of the leaves of *Calamites* are almost exclusively confined to their form, size, arrangement on the stem, and other external characters, and have little or nothing to say with regard to the internal structure. Even in the well-known *Memoirs** of Williamson, the histology of the leaves in not brought under consideration, and the same may be said of the *Memoir*† recently published by him and Dr. Scott, in which further observations on the organisation and development of *Calamites* are recorded.

On the other hand, the anatomy of the root, the stem, and the fruits of *Calamites* has been worked out with much detail, and were it not for the lack of knowledge with respect to the structure of the leaves, we should be able to form a tolerably correct and complete conception of the whole organisation of these interesting plants.

To bridge over this gap in our knowledge, at least in part, is the object of the present communication. In a sense, it is the outcome and continuation of the paper "On the Primary Structure of the Stem of *Calamites*,"‡ read

* *Phil. Trans.*, 1871–1893. † *Phil. Trans.*, 1894.

‡ *Memoirs and Proceedings of the Manchester Lit. & Phil. Soc.* Series IV., Vol. VIII., pp. 158-170.

before the Society in the early part of last year. In the preparation of that paper my attention was frequently arrested by the presence of leaf sections intermingled with those of young Calamitean stems, and from certain well-marked characters I concluded that they were the leaves of *Calamites*. Since then ample proof of the truth of this conclusion has been obtained, and it is now possible to describe the general structure of these, and to give some account of their histological peculiarities.

DESCRIPTION OF THE SPECIMENS.

1. Among the preparations of *Calamites* in the Cash Collection of Sections of Carboniferous Plants, now in the Manchester Museum, at Owens College, are a few which contain pieces of Calamitean twigs with portions of the leaves still attached. They are very fragmentary, and not in good condition for reproduction as illustrations, but they are sufficiently well preserved for identification. One of them, prepared by Mr. James Binns, of Halifax, is represented in Fig. 1, Pl. III., which is reproduced from a photograph, and gives a fair picture of the specimen, though it is not so clear and sharp as the specimen itself. At *a* we have the outer part of the cortex of the twig, and at *b* the inner part, with the elongated elements carrying black contents described in the paper on "The Primary Structure of the Stem."* Within this is the vascular strand, whose protoxylem elements, in the usual fragmentary form, are seen at *x*. Then comes the pith *p*, followed towards the right by a repetition of these tissues, but in reverse order. The pith is interrupted at the node, where we see at *n* the converging strands of xylem from the two neighbouring bundles. On the left side of the node the basal part of a

* *Loc. cit.*, p. 162. As the tissue formed by these cells will be referred to again and again, it will be convenient to speak of it simply as "Melasmatic" tissue (μελασμα, a black spot).

leaf is still attached. In it we may recognise, with the aid of a hand-lens, the following details: at *e*, the cells of the epidermis, with thick outer walls, apparently cuticularised; at *f*, the assimilating tissue, composed of thin-walled cells; at *g*, a small fragment of protoxylem; and at *m* a layer of "melasmatic" tissue similar to that in the inner cortex of the stem.

From the appearance of the specimen, it would seem that a second leaf originally existed at the same node on the right side of the twig, and at *n*, we have probably the point of origin of a third. Assuming that this was so, and that the third anterior leaf was opposite a posterior one, the whorl will originally have had four members, a condition of things which is suggested by other specimens.

2. A specimen in my own cabinet, also prepared by Mr. Binns, and for which I am indebted to the generosity of Mr. William Cash, of Halifax, is represented in Fig. 2. The difficulty of photographing was, however, greater than usual, and in consequence the figure does not do it full justice. It represents a longitudinal section of a portion of a very young twig of *Calamites*, with five short internodes within a length of 3½ millimeters. At each node are smaller or larger portions of a pair of leaves, also cut longitudinally, one on each side of the twig. From the appearances it presents I am inclined to think that, as in the preceding case, each node carried a whorl of four leaves, and that the members of successive whorls were not directly superposed. This, however, is rather an inference than an observation. At this stage of development the leaves had an outward and upward curvature, the concavity being on the upper side.

Coming to the structure, the twig shows a cortex, whose inner layer is distinguished from the outer by the presence of the characteristic "melasmatic" tissue seen in the previous specimen. This tissue is continued into the leaves, where it preserves the same characters. Here it occupies the centre of the leaf section *m*, but stops short below the tip, a condition which is due to the fact that the section is not quite median. A layer of assimilating tissue lies both above and below the "melasmatic" tissue, and is continued beyond it, while the whole is enclosed in an ill-defined epidermis.

3. After these descriptions there can be no hesitation in recognising in Fig. 3 a longitudinal section of the same kind of leaf, although there is no twig in connection with it. It is taken from a photograph of a specimen in the Cash Collection, prepared by Mr. Binns from material collected at Halifax. Here again we have an epidermis *e*, with the outer cell-walls cuticularised; an assimilating tissue *f*, beneath both the upper and the lower epidermis; two layers of "melasmatic" tissue *m*; and a clear central line. That this last represents the track of a vascular strand is suggested by the presence of tracheal fragments at *x*, and is made certain by other sections in which it is better preserved. In some of these it is further made clear that the xylem is composed of annular and spiral tracheae, while the elements that represent the phloem are merely thin-walled elongated cells.

Allowing for the curvature, the length of the leaf figured is over 2½ millimeters ($\frac{1}{10}$ of an inch), but it is imperfect at the tip and, perhaps, also at the base.

4. Passing from longitudinal to transverse sections of the leaf, one of the best and most perfect hitherto met with is shown in Fig. 4, which is from a photograph of a specimen prepared by Mr. James Lomax, of Radcliffe. From other preparations which contain Calamitean buds cut transversely, it is known that the convex side of the section corresponds to the lower surface of the leaf, and the more flattened side to the upper.

By using a hand-lens in the examination of this figure there will be little difficulty in making out the following histological details :—

(i). The epidermis is a single layer of cells, uniform in size, whose outer walls are thickened. Some of the walls seem to be thickened all round, but others are not so, and there are no definite traces of stomata. A comparison of the epidermal cells of this specimen with those of longitudinal sections in other preparations brings out the fact that the cells were elongated in the longitudinal direction, a detail which is vaguely shown in Fig 1.

(ii.) Beneath the epidermis is a layer of assimilating tissue, which is continuous round the whole section, and widens out laterally to form two obtuse opposite wings. This tissue is composed of thin-walled cylindrical cells, resembling the palisade cells of existing plants, in some of which the contents appear to be granular. In the middle of the upper and lower surfaces of the leaf the cells stand with their long axes at right angles to the epidermis, and in a single row, but in the lateral wings they become oblique, and the number of rows is increased. The lateral connections of the assimilating cells, *inter se*, are very slight, comparatively large intercellular spaces often separating them entirely, except at the extremities, where the dilated ends are in contact with one another. These intercellular spaces are specially developed in the lateral wings, where the cells of successive rows unite end to end, and form filaments, which are separated from one another by the spaces in question for considerable parts of their length.

(iii.) Within the assimilating tissue lies the central portion of the leaf, which has a circular outline. Externally it carries a layer of "melasmatic" tissue, for the most part one cell thick, which, as we have already seen, is continuous with the same tissue of the stem. At the middle point of the upper side this tissue is interrupted by the intercalation of an element of a different kind, which is the outermost of four similar elements arranged in a radial line. These have somewhat thickened walls, and are clearly distinguishable from the elements around them.

In dealing with the Primary Structure of the Stem of *Calamites* reasons were adduced* for regarding the "melasmatic" tissue as a part of the cortex and not of the central cylinder or stele. Hence in the leaf it must be referred to the mesophyll and not to the strand of tissue which contains the vascular bundle.

(iv.) Within the "melasmatic" layer we have a circular group of apparently cellular elements, in which is placed, excentrically and nearer to the lower side, the transverse section of a very delicate vascular bundle. The xylem part of this may be recognised, but the accompanying elements can scarcely be distinguished as phloem, and the orientation is, therefore, doubtful in this instance. In other sections, however, the xylem is seen on the upper side of the strand and the phloem on the lower.

Summarising this description, it may be said that the leaf-section here represented has a radial rather than a dorsiventral organisation, and that it is made up of the following parts :—

(*a*) A central cylinder or stele, in which is a single, delicate, excentrically placed vascular strand of the collateral type.

(*b*) A zone surrounding this, corresponding to the cortex of the stem, in which we can distinguish

  (α) An inner layer composed of "melasmatic" tissue, and

  (β) An outer, thicker layer, composed of assimilating tissue.

(*c*) A single-layered epidermis.

It may be added that the section measures $\frac{2}{3}$ of a milli-

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* *Loc. cit.*, p. 162.

meter ($\frac{2}{75}$ of an inch) from side to side, and $\frac{5}{12}$ of a millimeter ($\frac{1}{60}$ of an inch) from the middle of the upper surface to that of the lower. If we may combine these dimensions with those of the leaf shown in Fig. 3, we shall get a leaf measuring upwards of $2\frac{1}{2}$ millimeters ($\frac{1}{10}$ inch) in length, $\frac{2}{3}$ millimeter ($\frac{2}{75}$ inch) in breadth, and $\frac{5}{12}$ millimeter ($\frac{1}{60}$ inch) in thickness. As a very moderate sized *Chara* leaf would exceed this, at least in length, it is obvious that the Calamitean leaves here dealt with are extremely small, a point to which I shall return.

5. The specimen last described is so well preserved and complete that I have taken it as a standard of reference with which others might be compared, in order to see whether the form and structure described were at all modified, either in different leaves or in different parts of the same leaf. A large number of such comparisons have been made, with the result of showing that in both respects modifications are not uncommon.

Fig. 5 shows one of the more extreme modifications met with in the form of the transverse section. It is taken from a preparation in the Cash Collection by Mr. Binns, and represents a leaf section whose lower half has a triangular form while the upper half carries a strong median elevation, flanked by a smaller one on each side. The assimilating tissue has been destroyed, but it seems to have been developed on all sides, and the "melasmatic" tissue forms a complete ring. The tissue of the central cylinder has not been preserved.

In Fig. 6, from the same preparation, we have a leaf section with a single median and two marginal ridges projecting from the upper surface, while the lower half of the section has a rounded rather than a triangular outline. The assimilating tissue and the "melasmatic" are again continuous. Within the central cylinder is the delicate vascular bundle, which presents itself in an extremely interesting form. At *h*, we see the "fascicular"* canal, enlarged somewhat by the destruction of the peripheral elements, and at *x*, two protoxylem elements projecting into it. Here, then, we have a vascular bundle of the true Calamitean type, and a confirmation of the conclusion that the leaves under consideration are the leaves of *Calamites.*

Besides these and other less pronounced differences in the form of the transverse section, certain differences of structure are also met with. In the two sections last dealt with both the "melasmatic" and the assimilating tissues are continuous, but in that of Fig. 4 the former appears to be interrupted at the middle point on the upper side by an element which is probably sclerenchymatous. In Fig. 7, taken from a preparation for which I am indebted to Mr. Binns, we have a case where the interruption is greater, and extends to the assimilating tissue also. In other words, we see the assimilating and the "melasmatic" tissues thinning out towards the middle line of the upper surface of the leaf, where they are replaced by elements of a different kind. A comparison of this and similar sections with fragments of longitudinal sections, teaches that these elements are sclerenchymatous and, where they are present, they form a strand which runs beneath the epidermis along the middle line of the upper surface of the leaf.

It is an interesting question whether these differences are due to hetrophylly or to the fact that the sections are taken at different points along the length of the leaf. With some reservation I adopt the latter view as more in accordance with observed facts, and am disposed to regard the sections shown in Figs. 5 and 6 as taken near the base of the leaf, that of Fig. 4 as taken at some distance from the base, and that of Fig. 7 as taken nearer the tip. As to this last, there is little doubt that

* In using this very convenient term I follow the example set by Prof. Williamson and Dr. Scott. *Phil. Trans.*, 1894, p. 870.

the position assigned to it is the correct one, as several longitudinal sections show that the sclerenchymatous strand becomes more and more pronounced towards the apex of the leaf where it runs out on the upper surface. Transverse sections in this region show the assimilating and the "melasmatic" tissues reduced to the form of circular ares, convex towards the lower surface of the leaf, while a large part of the upper surface of the section is occupied by sclerenchyma.

In view of the recent discussions on the affinities of *Calamostachys Binneyana*,* it is deserving of notice that the modification last described renders the leaf of *Calamites* very similar in structure to the sterile bracts of the *Calamostachys*. If, in fact, we suppose a large extension of the sclerenchyma on the upper side of the leaf and a great reduction of the assimilating tissue of the lower, while the "melasmatic" tissue retains its special characteristics, the leaf of *Calamites* would become the bract of *Calamostachys Binneyana*.

General Observations and Conclusions.

The leaves described in the preceding paragraphs are those of the small ultimate branches of *Calamites*, and are the only ones which, after much searching, I have been able to find. Hence my observations throw no light upon the structure of those leaves which are occasionally seen in casts and impressions attached to the larger Calamitean stems and which are referred to by descriptive palæobotanists.

It might be supposed from the small size of the leaves

* Hick: "*Calamostachys Binneyana*": Proc. Yorkshire Geological and Polytechnic Soc., 1893: also, "The Fruit-Spike of *Calamites*." Natural Science. Vol. 2, 1893.

Williamson & Scott: "Further Observations on the Organisation of The Fossil Plants of the Coal-Measures. Part I. *Calamites*, *Calamostachys*, and *Sphenophyllum*." *Phil. Trans.*, 1894.

that they were young and immature, but the histological structure shows few or no indications of the embryonic condition. Figures 5 and 6 are, perhaps, a little doubtful on this point, and it may be that the leaves of Fig. 2 have not reached their full development. But there is nothing to indicate immaturity in the structure of the leaves shown in Figs. 3, 4, and 7, and the same may be said of a large number of similar sections that have been passed in review.

In the literature, it is generally stated that the members of each whorl of leaves are quite free, and destitute of any cohesion at the base comparable to that seen in *Equisetum*. My observations on the structure of the leaves is in full accord with this statement, and show that they were simple uni-nerved structures. The vascular bundle, however, is so delicate, and occupies such a position within the mesophyll, that it could scarcely give rise to the appearance of a midrib in cases where fossilisation resulted in the formation of a mere impression. Such an appearance, however, might be produced by the strand of sclerenchyma, which has been described as running for some distance along the middle line of the leaf, between the vascular bundle and the upper epidermis, as shown in Fig. 7, or by the median ridges shown in Figs. 5 and 6.

The extremely small size of the leaves and the twigs that bore them enable us to form some idea of the delicate and filmy appearance that would be presented by the ultimate ramifications of the type of *Calamites* to which they belonged. This is, in a measure, represented in some of the restorations of *Calamites* that have come under my notice, but none seem to me to have done it full justice. The most likely comparison that occurs to me is that of well-grown Chara plants as seen in our laboratory aquaria.

As regards the structure of the leaves, the details given will show that it has many points of interest, not the least being the presence of the "melasmatic" tissue. In dealing with the primary structure of the stem,* I suggested that this was an important tissue, and this is confirmed by its presence in the leaves. As to its physiological import, there is little to add to what was then stated. The view that it had a conducting function receives additional support from the details given of its position and characters within the leaf, and from the fact that it is continuous from the one to the other. Moreover, it is highly significant, in my opinion, that in the stem it lies at the inner boundary of the Cortex, and appears to correspond in position with the "starch layer" of many recent plants. In the leaf, too, it seems to form a sort of sheath round the stele, and is in intimate relation on the one hand with the delicate vascular bundle, and on the other with the assimilating tissue.

Finally a word may be said as to the type of *Calamites* to which these leaves are to be referred, since it is becoming more and more evident that the plants now included in the genus are not identical in the minuter details of their structure. The type of stem dealt with in my former paper† is the one which appears to predominate in the Lower Coal Measures of Halifax, whence most of the specimens have been obtained, and it is to this that the leaves here described are to be referred. The presence of the peculiar "melasmatic" layer in both stem and leaf would of itself be almost sufficient to justify this reference, but it is placed beyond doubt by the fact that the twigs found in connection with some of the leaves are of the type in question. As in the paper mentioned, reasons were adduced for regarding this type of *Calamites* as the one which had *Calamostachys Binneyana* for its fruit, we may with some confidence look upon this type as one whose organisation is now fairly well known, except so far as there may be special peculiarities in the root.

* *Memoirs and Proceedings of the Manchester Lit. and Phil. Soc.* 4th Series, Vol. VIII., pp. 158-170.

† *Loc. cit.*

In conclusion, I desire to express my great obligations to Messrs. Wm. Cash and James Binns of Halifax, and to Mr. James Lomax of Radcliffe, for the gift and loan of specimens, and to Mr. W. E. Hoyle, Keeper of the Manchester Museum, Owens College, for permission to have photographed three preparations from the Cash Collection.

EXPLANATION OF THE FIGURES.

Plate III. Fig. 1. Longitudinal section of twig and part of a leaf of *Calamites*. From a preparation in the Cash Collection.

- *a*. Outer part of cortex of the twig.
- *b*. Inner part of cortex of the twig.
- *p*. Pith of the twig.
- *n*. Node of the twig.
- *e*. Upper epidermis of the leaf.
- *f*. Assimilating tissue of the leaf.
- *g*. Fragments of the vascular strand.
- *m*. "Melasmatic" tissue of the leaf.

Fig. 2. Longitudinal section of twig and leaves of *Calamites*. From a preparation in my own cabinet.

- *f*. Assimilating tissue of the leaf.
- *m*. "Melasmatic" tissue of the leaf.

Fig. 3. Longitudinal section of a leaf of *Calamites*. From a preparation in the Cash Collection.

- *e*. Epidermis.
- *f*. Assimilating tissue.
- *m*. "Melasmatic" tissue.
- *x*. Fragments of vascular strand.

Fig. 4. Transverse section of a leaf. From a preparation in my own cabinet.

Figs. 5 and 6. Transverse sections of leaves, probably near the base. From a preparation in the Cash Collection.

- *x*. Protoxylem elements, projecting into the fascicular canal (?)

Fig. 7. Transverse sections of a leaf, probably nearer the tip. From a preparation in my own cabinet.

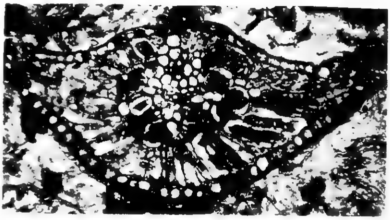
1

4

6

2

7



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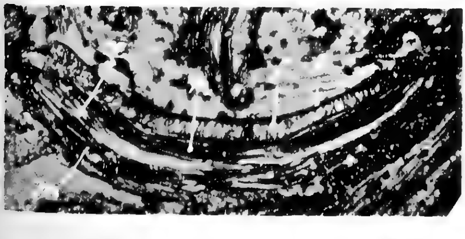

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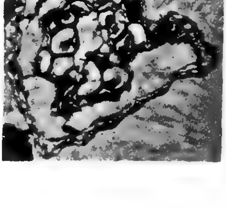

S.B. Bolas & Co. Collotype.

[*Microscopical and Natural History Section.*]

Annual Meeting, April 8th, 1895.

JOHN BOYD, Esq., President of the Section, in the Chair.

The annual report of the Council and the Treasurer's financial statement were submitted and adopted.

The following gentlemen were elected officers and Council for the Session 1895-96:—

President:—JOHN BOYD.

Vice-Presidents:—J. COSMO MELVILL, M.A., F.L.S., P. CUNLIFFE, CHARLES BAILEY, F.L.S.

Treasurer:—MARK STIRRUP, F.G.S.

Secretary:—T. SINGTON.

Council:—G. H. BROADBENT, M.R.C.S., P. CAMERON, ALEX. HODGKINSON, M.B., B.Sc., HENRY HYDE, FRANCIS NICHOLSON, F.Z.S., C. OLDHAM, THOMAS ROGERS, F. E. WEISS, B.Sc.

Mr. J. C. MELVILL, M.A., F.L.S., exhibited specimens of the Edelweiss (*Leontopodium alpinum, Cass*), and its Siberian and Japanese allies. Likewise Himalayan specimens of the same, and three related forms from the New Zealand and Tasmanian Alps, and also one species from the Andes of South America. He read a note on the geographical distribution of the genus, and the altitudes at which it occurs, and likewise exhibited specimens of some of its nearest generic allies.

Mr. THOS. ROGERS exhibited a series of land and fresh-water shells which he had recently received from the Hawaiian Islands, and made some remarks upon the Conchological fauna of those Islands. The number of species, excluding synonyms and mistakes, is about 350, and more than two-thirds belong to the Genus *Achatinella*. The fresh-water shells are very sparse, and for the most part very small in size, numbering altogether about 25 species, belonging to eight genera. The species exhibited by Mr. Rogers were representatives of the genera *Nanina*, *Helix*, *Helicina*, *Succinea*, and *Limnea*.

Mr. J. F. ALLEN read the following communication: "During the long frost of this winter a thin layer of frozen snow lay upon the ground for some weeks. This snow is an excellent medium for obtaining deposits of soot and other impurities out of the atmosphere. During the frost there was a prevalence of easterly winds, from N.E. to S.E. When I thought a thaw was imminent, I carefully collected a sufficient quantity of surface snow to afford a fair sample. Alexandra Park and Whitworth Park lie from Manchester in a similar direction to Ditton Junction and Hale Bank from Widnes—that is, easterly winds bring Manchester smoke over Whitworth and Alexandra Parks, and Widnes smoke over Ditton Junction and Hale Bank. On February 6th, 1895, samples were collected near Widnes:—

1st. At a piece of open land north of the Liver works.

2nd. From a field near Clap Gate, just beyond Ditton Junction, next to Mercer's land.

On February 7th, from Alexandra and Whitworth Parks.

On February 19th, from a drift along a hedge-side opposite Clap Gate, going in a north-westerly direction. The snow in the Manchester parks had disappeared.

The snow was allowed to melt in the glass vessels in which the samples were put, and then filtered. 20,000 grains of snow were measured, and the quantity of dirt deposited ascertained by weighing the residuum left on the filter.

1. Snow taken near Liver works, February 6th, tested neutral, neither acid nor alkaline, and contained, in 20,000 grains, 10·05 grains of black sooty deposit.

2. Snow taken from the field near Clap Gate, neutral, contained 4·3 grains of sooty deposit.

Snow taken from Whitworth Park, February 7th, tested acid, contained 16 grains of sooty deposit, dust, and cotton fibre.

Snow from Alexandra Park, neutral, and contained 6·5 grains of sooty deposit, also cotton fibre. Examining these deposits with the microscope, the sooty dust looked like pieces of coke and coal mixed, also pieces of sand and lime.

The samples taken from the hedge-side drift on the 19th February showed that the longer exposure had considerably increased the quantity of deposit, all tested neutral, and contained as an average 37·31 grains of deposit in 2,000 grains of snow. This deposit on being calcined lost 47·5 of its weight, showing that nearly half of it was carbon; the residuum after burning was a red ash, principally iron and silica, but it also contained copper. The filtrate was evaporated to dryness and this was also found to contain copper; so that copper had been deposited on the snow in an insoluble and soluble condition. The percentage of copper in these samples was:—

Insoluble, found in residuum	·00937
Soluble, found in filtrate	.00046
Total copper	·00983

Very similar results were obtained in January, 1893. Cotton fibre was found in the deposits at Whitworth and Alexandra Parks, and copper in the samples collected at Widnes. The Whitworth Park snow was, as on that occasion, acid; that found at Widnes, alkaline. In January, 1870, Sir Henry Roscoe, Mr. Alfred Fletcher (now chief Alkali Inspector), and Mr. J. Fenwick Allen collected two sets of snow samples in the neighbourhood of St. Helens. The snow had been lying some days, the winds had been easterly (N.E. to S.E.). The smoke from the works in St. Helens had been carried over Eccleston and on to Knowsley Park, from Sutton over Sherdley Park and on to Sutton Heath. Both sets of samples were found to contain sulphuric and muriatic acids. The fixed points to start from were, in St. Helens, the old Ravenhead Copper Works, in Sutton, Newton, Keates & Co.'s Copper Works The St. Helens samples were taken :—

1,320	yards distant	from the	Ravenhead Works,	going West.
1,800	"	"	"	"
2,400	"	"	"	"
4,000	"	"	"	"

The Sutton samples were taken :—

700	yards from	Sutton	Copper Works,	going West.
1,230	"	"	"	"
1,760	"	"	"	"
2,360	"	"	"	"

The samples contained :—

St. Helens.			Sutton.		
	Grains per gallon.			Grains per gallon.	
Distance. Yards.	Sulphuric acid.	Muriatic acid.	Distance. Yards.	Sulphuric acid.	Muriatic acid.
1,320	34·2	10·5	700	10·0	5·2
1,800	22·3	13·8	1,230	5·5	4·5
2,400	7·0	7·3	2,360	3·3	1·6
4,400	4·1	5·1			

There was a deposit of sooty matter on the snow, and, when the samples of snow thawed, the water was discoloured by the deposit, the sample collected nearest St. Helens being quite black, the blackness diminishing in each bottle as the distance increased, the most distant being only slightly discoloured. The number of works and houses in the St. Helens centre was much larger than the number in the Sutton district. It is to be noticed how the heavier acid, the sulphur acid, falls more rapidly than the muriatic acid. Observations made in summer of the vegetation, crops, and trees, bear out these chemical tests, showing how the injury gradually decreases as the distance increases."

LATERAL MORAINE: EASDALE.
(From a Drawing by W. Hull.)

Notes on Glacier Moraines in Cumberland and Westmorland. By W. Brockbank, F.G.S.

(*Received April 23rd, 1895.**)

The *Proceedings* of the Geological Society of London for 1840-1 contain interesting notices on the evidence of glaciers having existed in Great Britain, by Professor Agassiz and others. The subject was then a novel one, having been advanced and widely illustrated by the eminent Swiss professor. His views obtained a ready acceptance and support from Lyell, Buckland, Sedgwick, and the other leaders of geological science, and their researches are given in the London Geological Society's publications which contain a rapid survey of the whole of Great Britain, and describe many moraine-like masses of Drift as illustrating the new theory.

The subject does not appear to have had the careful attention it deserved, bearing, as it does, so particularly upon the origin of our Boulder Drift, or Till, and upon more recent changes of level in the geological history of our Island.

The following notes are offered as a contribution in further elucidation of this subject, being the result of observations made during the last two years (1869-70) in the Lake District.

Dr. Buckland, who accompanied Professor Agassiz in his examinations, describes the glacial evidences in the Lake District, claiming amongst others, as moraines :—(1) The gravel mounds with large boulders, near the junction of the Eden with the Eamont and Lowther near Penrith; (2) the large and lofty insulated piles of gravel in the

* Printed in abstract in the *Proceedings* of the Society for 1870, pp. 19 to 25.

valley of the Kent, near Kendal, and the smaller "moraines" or their detritus which nearly fill the valley thence to Morecambe Bay; (3) similar mounds near Shap, covering about 200 acres, at an elevation of only 500 feet above the sea; and (4) the gravel mounds near Milnthorpe, and thence to Lancaster, even including the hill on which Lancaster Castle stands.

Of these, the finest example of glacier action is that in the Kentmere Valley, near Kendal, which is in all probability a true series of moraines, left directly by glaciers which gathered in the group of mountains about Nan Bield and Harter Fell, at the head of Haweswater. The moraines described at Shap would have the same origin, but they are by no means so remarkable.

In the other instances, the mounds which are described as moraines are situated far down the valleys, and in those near Penrith, even below Ulleswater, and cannot be considered true glacier moraines deposited by ice having its origin in the snow-capped mountains and continuing in the form of glaciers to these localities.

Dr. Buckland proceeds thereafter to generalise further, by describing the west coast of Cumberland—not from personal observation, but from Fryer's map of the district—and he assumes that the "conical hillocks" therein shown in the valley of the Duddon, at the south base of Harter Fell, are moraines; and also that some on the right bank of the Esk, at the east and west extremities of Muncaster Fell, are also moraines, formed by glaciers which descended the west side of Scawfell. These are pure surmises, and are not borne out by the aspect of the valley at the points named.

Dr. Buckland's paper concludes with an account of the manner in which the Shap granite has been distributed by ice—a subject of great interest to Lancashire geologists. Glaciers are again the agents, and he describes the courses they would take so as to drop the granite boulders where they are now found.

This, and the district at the head of Eskdale, are those to which the writer has devoted more particular attention, and which form the subject of the following notes :—

The highest mountain in the Lake District is Scawfell Pike (3,210 feet), and, separated from it only by a narrow valley, is Bowfell (2,960 feet). These two noble hills form the central nucleus of the mountains of Cumberland, from which radiate the valleys of Wastdale, Langdale, Borrowdale, Moasdale, Eskdale, and the Vale of Duddon ; and here, as might be expected, we have the evidences of glacier action in a very marked degree.

The conformation of the upper parts of Scawfell is not such as to fit it for the accumulation of snow and ice, for the formation of glaciers ; on every side it is precipitous, and still bears the marks of plutonic rather than glacial action, in its frowning rents and deep black precipices, and its screes over Wastwater.

Its lordly neighbour, Bowfell, has a very different conformation, its huge shoulders fitting it for a great gathering ground, exactly suited to the aggregation of snow and ice, which would gather on its summits and flow over its shoulders into the deep valleys below.

The flanks of Bowfell are everywhere scored and polished by glacial action, the porphyry and greenstone of which they are composed retaining the markings most clearly, so that one may almost trace the course taken by the ice. The three summits of Bowfell are a piled mass of huge, unworn rocks, angular and weathered, in strong contrast to its worn sides. Between the first and second summits there is a deep rent, and in the deepest part of the hollow there is a strong vein of hematite ore, the ground being of a deep-red colour. Similar veins are visible in several of the neighbouring hills, and especially on the pike of Bliscoe and in the valley behind its summit, where Red Tarn has its shores of hematite ore. The surrounding hills all show red streaks in the brook courses, and the clay soil in the vales below is frequently tinged to a blood-red colour from these sources.

Descending into Langdale we find the finest series of moraines, just below Rossett Gill, at the point whence diverge the bridle roads over Stake Pass into Borrowdale and by Angle Tarn to Wastdale. At this point the valleys from the shoulders of Bowfell and Langdale Pikes converge, and five brook courses meet, so that glaciers would here be abundantly fed from the lofty mountains above.

The moraines at this point form the subjects of the two water-colour drawings exhibited, which have been made for the purpose by Mr. Hull. They are most truthful representations, and give an excellent idea of the scene.

The moraines stretch across the valley in a very perfect series of rounded knolls of huge boulders, rising some 40 or 50 feet above the stream, and forming at least three lines, as if the glaciers had gradually receded at distant intervals of time. The boulders are of hard porphyry and greenstone of the surrounding mountains, intermixed with red clay soil deeply tinged with hematite iron ore, which occurs abundantly on the summit of Bowfell and on Rosset Gill. There are many perched blocks on each side the valleys above the moraines, which may possibly mark out the track of the glaciers—and the rock surfaces, especially in Rosset Gill, are much scored and polished. Altogether, the Langdale moraines, although small, furnish the most perfect example I have yet seen in England, and are, in all probability, the remains of the last glaciers which existed in this country after the valleys around Bowfell had assumed almost their present form. Doubtless at some earlier period the Langdale glaciers extended far down the valley, as the mammilated rocks, perched blocks, and ice markings, which can be clearly traced at many prominent points, abundantly prove; and they appear to have gradually receded, probably as our climate became warmer, until at length they had dwindled down to the comparatively small size indicated by the moraines now in almost perfect condition at the head of the valley, immediately under Bowfell.

Proceeding through Rosset Gill, on the path to Wastdale, over to the head of Borrowdale, we see Angle Tarn, a very remarkable lake, under a lofty range of precipitous rocks, forming one of the huge shoulders of Bowfell.

Professor Ramsay, in his lectures on physical geology, describes some lakes on the Italian side of the Alps, which were formed by the scooping out powers of glaciers, the waters being dammed up by their terminal moraines, and he adds, "there are several among the mountains of Wales, but whether there are any in Cumberland, I do not know," evidently surmising the existence of such. It is interesting, therefore, to find in Angle Tarn a perfect example of this class of lake. The glacier by which it was formed had poured over the lofty precipice above, and deposited the moraine so as to form the lake just as we now find it. The embankment by which the waters are pent in consists of a series of rounded knolls, exactly like the Langdale moraines, the lake gradually shelving in, at first very shallow, until it attains a great depth at the foot of the precipices at its head.

A little further on is another similar example, at the head of Long Strathdale, where another tarn has evidently existed, but the waters have burst through the moraine embankment, and left a swampy marsh behind. The rocks which are thus left bare by the departed waters cover a considerable area, and are very remarkable instances of glacial action, being much striated and polished.

The streams which flow from this point and from Angle Tarn are tributaries to the River Derwent and, with

Stake Pass, form the head of Borrowdale. There are similar moraines, I am informed, on the Borrowdale side of the Stake Pass also, and evidences of glacial action are abundant as you proceed down this remarkable valley.

My friend Mr. Wm. Hull also informs me that the Little Langdale valley, centreing in Bowfell, contains similar moraines, and he has kindly sent me a sketch of an interesting example just below the road over Wrynose Gap. Doubtless they will be found to occur in all the valleys which radiate from this Scawfell and Bowfell group, to the eastwards. Westwards from Bowfell are the vales of the Esk and the Duddon. Eskdale proceeds directly from Bowfell to the sea at Ravenglass, having in its short course of only 12 miles a fall of nearly 3,000 feet, and this chiefly in the first six miles of the valley.

The estuary at Ravenglass has a very remarkable appearance from the numbers of large boulders of granite, greenstone, slate, and porphyry, which lie scattered along the shore and harbour, resembling on a small scale the shores now frequented by drift-ice in the harbours of Newfoundland. A nearer examination at once introduces a Lancashire geologist to the family of boulders found in our Lancashire clays of the Boulder Drift, and the analogy is so striking as at once to indicate their origin.

Proceeding thence up Eskdale, we enter the granite district, within the second mile; the sharply serrated mountain range in the foreground of the landscape, of Muncaster Fells, Harter Fells, and Birker Moor Fells, at once revealing their granitic character. In its lower reach, above Muncaster Castle, and thence for four or five miles, the valley is wide and filled up with diluvium, forming an almost level "strath" through which the Esk winds its course. Standing on the bridge, a mile above Muncaster Castle, the landscape is completely closed in by an amphitheatre of granite hills, and the idea is at once suggested that in former times this

MORAINES: LITTLE LANGDALE.

(From a Drawing by W. Hull.)

MORAINES: LITTLE LANGDALE.

(From a Drawing by W. Hull).

was doubtless an arm of the sea, which would then wash the bases of these granite mountains, from which our boulders have in all likelihood had their origin. This is the part of Eskdale where Dr. Buckland, judging by Fryer's map, supposed moraines to be in existence, but it is quite evident that in the present aspect of the valley none are to be found.

The panorama of mountains which form the head of Eskdale is by far the finest in the Lake district, comprising as it does the whole of the Scawfell and Bowfell range. The flanks of Bowfell on this side are grooved and planed in a very remarkable degree, and in the whole of the upper part of the valley there are evidences of glacial action at almost every turn ; and seen from above, the whole valley has an iceworn, hummocky aspect. The writer did not find any moraines in the upper parts of the Esk or the Duddon valleys, and in this respect there is a marked difference between the east and west sides of Bowfell ; but the glacial evidences are not less marked. To the eastward the vales of Langdale and Borrowdale lie high, and the ice would soon be checked in its flow, as we now find the evidences in the terminal moraines at the heads of the valleys. To the westward the valleys have a continuously rapid fall for five or six miles, throughout which course they have a hummocky aspect, and below this they are comparatively wide and levelled—so that in all probability the glaciers which formerly existed had their termination in an arm of the sea.

This is exactly the sort of glacial condition which would best explain the requirements of a drift theory, according to which the travelled boulders found in Lancashire have been carried thither by ice ; and a careful study of the Eskdale valley, after having previously ascertained the existence of moraines at its head, confirms the writer in this view. It is only needful to suppose a state of things to have existed in England analagous to that which now obtains in similar latitudes on the ice-bound coasts of Labrador and Newfoundland, where floe ice prevails for many months of the year over an area of from 200 to 300 miles wide, whilst the land is covered with glaciers during the same period. The glaciers bear the boulders down to the sea shore during the summer, and these are picked up by the floe ice, during the following winter and borne away at the breaking-up of the ice as warm weather returns, and floated seawards as the wind and waves may direct their course. To complete the picture, we have only to suppose the Lake District an isolated group of mountains, in a frozen sea, and much of Lancashire and the Midland Counties submerged, and under similar conditions to those now prevailing in Labrador and Newfoundland ; and there is every reason to believe that such were the conditions which obtained during the period in which our Boulder Drift was deposited.

The Duddon Valley, in its upper portion, which centres in Bowfell, is in its glacial aspect similar in every way to Eskdale, from which, in fact, it is only separated at its origin by a low water-parting, so that any glacier from Bowfell would flow over into each of those valleys in common. Below Seathwaite Tarn it would, however, receive a very important affluent from the Coniston range, "Coniston Old Man" being immediately above Seathwaite Tarn. At this point of the valley of the Duddon we therefore find, as might be expected, very fine examples of glacial action, and especially in the mammilated and scored rocks and perched blocks, several of which form the subjects of the interesting set of drawings exhibited, for which I am indebted to my friend W. Hull. I have not visited the Duddon recently, but was aware of the existence of these examples of glacial action, and requested my friend to send me a few sketches of them. He does not profess to be a geologist, but his remarks upon the Duddon Valley are of interest. He writes, in reply to my note, "that no one could pass through the Duddon Valley without being struck with the worn and disturbed appearance of its rocks and crags, and the immense amount of debris scattered over the hill sides. About Seathwaite the perched blocks are very conspicuous in all directions—some of them can be called huge in size, but when they come against the sky their position gives them a look which arrests attention and makes them appear larger than they really are. They frequently occur in groups, and seem to lie in one main current—along which the glacier had moved and deposited these blocks as they were arrested by the masses of smoothly worn elevated crags on which they now rest."

Mr. Hull's description will at once explain to a geologist that the groups of perched rocks he describes are probably lateral moraines, and his most interesting sketches are convincing proofs of this—and shew that the glaciers about Seathwaite in the Duddon Valley have been of great size and depth, filling a wide valley to a considerable height up the hill sides. The estuary of the Duddon opens out below Broughton-in-Furness into a wide bay, and supposing, as in the Eskdale valley, that it formerly reached much further inland, and was subject to the action of floe-ice, it would thus receive the moraine debris, and float it away as before described. The granite district of Harter Fells would furnish its contribution of granite boulders, to be mixed with the porphyries and greenstones of Bowfell and the slates of Coniston in the terminal moraines.

Dr. Buckland held the opinion that the granite boulders of the Shap district had been carried southwards by the agency of glaciers, but there are not the same evidences now to be found about the Shap Fells as those which exist in Eskdale. The granite district at Shap is of a very limited area, comprising only some 800 to 1,000 acres around Wastdale Pike, about two miles above the Wells House, near

Shap. Wastdale Pike is not an isolated peak, and would not be recognised as granitic from its contour. It is an outlier of the mountain range at the head of Troutbeck and Haweswater, of which Tarn Crag forms the central summit.

The Shap granite is of a very marked character, having a rich red colour with very large crystals of feldspar. A railway has been recently made up to the quarries, and an extensive plant put down for polishing the granite. It is to be used in our new Town Hall, and cannot fail to come into popular use on account of its great beauty. It can be obtained in very large masses.

The moraines described by Dr. Buckland at Shap are not of a marked character, as the writer failed to find anything to be considered a true moraine. The valley below the granite, and thence over the whole of Shap Fells, has a most remarkable appearance from the large numbers of of immense rounded masses of granite which are everywhere scattered, all the way to Tebay, where Wastdale Beck joins the Lune. These widely dispersed boulders cannot, the writer thinks, be accounted for by the agency of glaciers; besides which the summit of Wastdale Pike is but 1,853 feet above the level of the sea, and the valley below it some 500 feet lower, whilst the junction with the Lune at Tebay is 700 feet above the sea, so that it is almost an impossibility for any glacier to have transported its moraines to any point from which they could be carried and dispersed by drift ice.

Another explanation must be sought, and it will probably be found in the very fact of the occurrence of this solitary granite peak where it is now found. The whole district of Shap abounds in extensive veins of Whinstone and other plutonic rocks, crowned by the huge granitic mass of Wastdale Pike, which has evidently been forced upwards by some volcanic movement through the slates. The changes which would result from this immense movement, possibly followed by denudations on an enormous scale, such as formed the valley of the Lune and washed the deep wild hills into their present form, would carry the granite debris far and wide, and, rolling it into its boulder form, scatter it broadcast over the country, and possibly as far as the sea shore, where ice might thence become the transporting agent.

There is, therefore, a very marked difference from a glacial point of view between the granite districts of Eskdale and Shap. Indeed the glacial evidences in the latter case are of small importance.

General Meeting, May 22nd, 1895.

HENRY WILDE, F.R.S., President, in the Chair.

This was an extraordinary general meeting summoned in accordance with the Articles of Association to confirm a resolution adopted at the Annual General Meeting on April 30. The resolution, as follows, was confirmed *nem. con.* :—

Moved by the PRESIDENT aud seconded by Mr. FRANCIS JONES, F.R.S., Ed. :—

That the following clause be inserted in and be one of the clauses of the Articles of Association of the Society :—

> "82A. All deeds and documents which require the seal "of the Society to be attached shall be signed by the President and one or more Vice-Presidents, or by two or more "Vice-Presidents, and countersigned by one of the Secretaries, "and the power of appointing a substitute, given by Clause "82, shall not apply to this clause."

Annual Report of the Council, April, 1895.

During the session 1894-5 there have been admitted to the Society 21 ordinary members, and 4 ordinary members have resigned. These changes leave the number of ordinary members on the Society's roll 136, as against 119 at the close of the session 1893-4. This is the first time for several years that the Council has been able to report an increase of membership. The Council hopes that this change in the fortunes of the Society may be a permanent feature, and would urge the members not to neglect opportunities of still further increasing the list under the new conditions recently provided. The Society has lost by death the following honorary and corresponding members:—Arthur Cayley, F.R.S., &c., the Rev. Thomas P. Kirkman, F.R.S., the Marquis de Saporta, Hermann Von Helmholtz, A. Kundt, J. C. de Marignac, Lothar Meyer, Wilhelm Roscher, and Sir James Cockle, F.R.S.

The Treasurer's accounts presented with this report give the detailed expenditure and receipts during the financial year ended March, 31st, 1895, and show that the cash in the hands of the Society's bankers at the close of the financial year was £162. 16s. 11d., or £81. 17s. 0d. less than it was at the corresponding period in 1894. In consequence of the Society's late housekeeper, Mr. Charles Hargreaves, having been incapacitated by illness from collecting members' subscriptions, the income from this source shows a falling-off as compared with that of the previous year, but as the charges for printing incurred during the session have not been adjusted in time to be included in these accounts, the balance in the Society's favour would not have been materially altered. The Council reports with regret that

Mr. Hargreaves died on April 7th. He was appointed to the office of housekeeper in November, 1887, and proved himself an obliging and reliable officer.

It will, consequently, be seen that the ordinary income of the Society has not been keeping pace with the current expenditure, while much necessary work in the Library, both as regards book accommodation and binding, has been brought to a standstill. The exigence of the finances has obliged your Council to begin to charge to the Natural History Fund the cost of printing the botanical and zoological papers in the *Memoirs and Proceedings*, which Fund has hitherto not been used for this purpose, but has been devoted to the purchase of natural history works and defraying the cost of plates for the *Memoirs*; and, as will be seen from the summary balance sheet herewith, the expenditure this session has been £70. 8s. 10d., while the income has been £59. 5s. 5d.

No appropriation has been made from the "Joule Memorial Fund," the origin of which was set forth in the last report. A balance of £7. 7s. 9d. lies at the credit of this account.

The Council had the extreme gratification of learning from the President, Mr. Henry Wilde, F.R.S., his intention to endow the Society with the munificent sum of £8,000 in order to put the Society in a sounder financial position. The details of this gift, with the purposes for which it is to be employed, have already been fully stated in the *Memoirs and Proceedings*. The thanks of the members have been accorded to Mr. Wilde for this recognition of the work and aims of the Society, and your Council would express the fervent hope that this noble generosity may not only secure the permanence of the Society itself, but stimulate original investigation in years to come. It may be added that Mr. Wilde's benefactions to the Society now amount to upwards of £10,000, the large extension of the building and its adequate equipment having been mainly due to his impulse in the centenary year of the Society.

The Librarian reports that during the past year upwards of 150 volumes have been bound, and that several works have been presented to the Society by authors or compilers, in addition to the publications received from kindred societies and public institutions throughout the world in exchange for the Society's *Memoirs and Proceedings.* The following books have been presented during the year :—

H. H. Hayter. "Statistical Register of the Colony of Victoria, 1892."

The Radcliffe Trustees. "Radcliffe Catalogue of 6424 Stars for the Epoch 1890."

The Clarendon Press. "The Sacred Books of the East." Vols. XXXV., XXXVI., XLIX. Edited by F. Max Müller.

Oliver Heaviside. "Electrical Papers." Vols. I. and II.
,, "Electro-magnetic Theory." Vol. I.

Scottish Microscopical Society. "Proceedings." 1893-4.

P. Francesco Denza. Cenni Necrologici. 1894.

Ministero di Agricoltura, Industria e Commercio. "Statistica delle Biblioteche." Rome. Vols. I. and II.

The Council is sorry to report to the members that their honorary librarian, Mr. Francis Nicholson, F.Z.S., as will be seen from the subjoined letter to the President, is unable, from the pressure of other duties, to continue to discharge the obligations of the office, and your Council would tender to him the sincere thanks of the Society for his twenty-one years' continuous service.

Oakfield, Ashley Road,
Altrincham, *April 20th, 1895.*

Dear Sir,

At the last meeting of the Council of this Society, as you are aware, I expressed a wish to be relieved from the Hon. Librarianship at the end of the present session. I take, therefore, the earliest opportunity of asking you kindly to intimate to the members at the Annual Meeting, on April 30th, my desire not to be again elected to the vacant post. I need hardly say how much regret I shall feel in ceasing to occupy a position which I have now held for twenty-one years, but increasing engagements elsewhere make it undesirable for me to continue its responsibilities, and, moreover, I consider it most important, at a time when great changes are imminent—from your having so liberally endowed the Society and proposing to elect a paid Assistant, whose principal work will be in the Library—that my successor should commence his duties from the beginning.

Requesting you to thank my colleagues on the Council for the consideration always shown me in the past, and with the kindest regards to yourself,

Believe me,

Yours very truly,

FRANCIS NICHOLSON.

To HENRY WILDE, F.R.S.,
President of the
Manchester Literary and Philosophical Society.

The Council recommends the continuance of the system of electing Associates of Sections, and the usual resolution authorising the same will be submitted at the annual meeting.

LE MARQUIS GASTON DE SAPORTA was a distinguished Palæo-Botanical honorary member. Born at St. Zacharie (Var, France), July 28, 1823, and educated in the Jesuit College at Fribourg in Switzerland, he commenced his scientific studies when 30 years old, and when a widower for the first time. His first work was undertaken along with M. Philippe Matheron, of Marseilles (who was chosen a correspondent of the Academy but a few days before Count Saporta's death), and was entitled "Examen analytique des flores tertiaires de Provence précédé d'une notice géologique, et paléontologique sur cette région." (Zurich, 1861.) In 1863, he is again writing, "Sur le rôle des végétaux a feuilles caduques, dans les flores tertiaires" *(Bibl. Universelle et Revue Suisse)*, and, during the same year, he sent a note "Sur la flore fossile de Koumi" to the *Bull. Soc. Géol.* In 1864 he sent one to the same journal on a Cycad from the middle Tertiaries of Provence. In 1866 the same journal published another "Notice sur les plantes fossiles des calcaires concrétionnés de Brognon," and the same year we find him spreading his wings yet more widely in his "Genres de végétaux actuels constatés à l'état fossile," which appeared in the *Bull. Soc. Botanique.* We also find him contributing on similar subjects, though enlarging their range as he advances, to the Congresses of Lyons and Stockholm. At the same time the Tertiary strata continue to be the favoured fields to which he mainly limits most of his earlier as well as later researches. We now reach a time when he personally crossed my path and made my acquaintance. At a very much earlier date I had worked out, as far as was then possible, one of the most remarkable fossils of the Yorkshire coast, and prepared a well-illustrated memoir on the subject of the *Zamia gigas*, assuming that to be the fossil of which my father and I had gathered some remarkably fine examples from the Yorkshire coast, between Runswick Bay and Skinningrave. After many strange adventures this memoir ultimately disappeared from the hands of my old friend Edward Forbes, no one knowing either how or whither. Somewhat similar specimens had now attracted notice on the Continent, and especially fixed the attention of M. Saporta, who arrived at a different conclusion from that to which I had been led; a conclusion still *sub judice.*

Near that time I had commenced my explorations amongst the fossil plants of the Coal-measures, and especially arrived at some important conclusions at variance with those taught by Brongniart, and, it followed, held by every man who had been a student under Brongniart, who had arrived at the determination that they were nearly all phanerogams. This opinion was also held by Saporta, Grand-Eury, and by Renault. This controversy brought the first of these three observers and myself very near to each other, being carried on in the most friendly manner.

This was also done in a second case. Numerous objects were gathered, some in a fossil state, and some, which I was able to demonstrate (*Memoirs of the Literary and Philosophical Society of Manchester*, Vol. X., 3rd Series, Plate 2), were mere casts of the sandy surface left by the retiring waves of the sea. Though such well understood differences existed between us, no break of friendly feeling ever manifested itself. He continued his labours, uninfluenced by the conclusions of most of his opponents; but at length the man of all others, M. Grand-Eury, abandoned his old conclusions about the coal-plants, and boldly announced to the Academy of Paris his conversion to my views. To do this, required no small measure of courage. His change led Saporta, though very unwillingly, in the same direction. He was the only one of my opponents who expressed himself rather angrily at being misled by Brongniart. A Science Academy having been formed at Aix, where Saporta had a princely home, I need scarcely add that he soon became the head, not only of it but of other institutions in the town. The Aix Academy is not only a scientific one; it exists also for the encouragement of literature, agriculture, and so forth; it was not recently founded, but has been established for many years. Only three days before his death in February, 1895, Saporta delivered an address at the Academy, the eloquence of which arrested most forcibly the attention of everyone who heard it, but which gave no note of what was to follow three days later. He was an earnest Romanist.

He had for many years had an estate at Fonscolombe, at which place he was interred. He was elected an honorary member of the Society in 1892. W. C. W.

AUGUST KUNDT was born at Schwerin, in Mecklenburg, on the 18th of November, 1839, and was educated until his twentieth year at the Gymnasium of his native town. In 1859 he entered the University of Leipsic, at which he studied mathematics and natural philosophy under Hankel till 1861, when he went to Berlin, and continued his studies under Encke, Dove, and Magnus. At that time the apparatus available for physical experiments was of a comparatively crude order, and there can be little doubt that Kundt's extraordinary power of devising and adapting apparatus for experimental purposes was developed and fostered in Magnus's laboratory. His first papers, that on "double refraction in vibrating rods" amongst others, appeared in 1863-4, and in 1866 he published an extremely important paper, "On a new kind of acoustical dust figures," in which he described and applied the now well-known "Kundt's method" of finding the velocity of sound in a gas, or in a solid. He married in 1866, became lecturer of Berlin University in 1867, succeeded Clausius as professor of physics at the Polytechnic at Zurich in 1868, and after a stay of two years at Zurich, was called to Würzburg, again as successor to Clausius. During these years he appears to have been directing his attention more to optical questions, publishing as a result several papers on anomalous dispersion and allied subjects, and displaying again his great ingenuity by the invention of the "crossed prisms" method of experimenting in this field. After another interval of two years, Kundt was called to Strassburg to take part in re-establishing there a German University. Under his direction the Physical Institute was built, and it has since served as the model for many institutes intended for the teaching of physics and the prosecution of research. He remained at Strassburg till 1888, acting as Rector of the University in 1877-8. During this interval, either alone or in conjunction with his students, he published papers dealing with the viscosity, thermal conductivity, absorption and dispersion, of gases; the electrical properties of crystals; the rotation of the plane of polarisation of light by magnetic substances; and the indices of refraction of metals. In 1888 he was called to Berlin to succeed Helmholtz, and his successful career there was terminated all too soon by his death, which took place at Israelsdorf near Lübeck, on the 21st May, 1894. During his stay at Strassburg his well-known skill as a teacher and experimenter attracted to that University a great number of students of physics, who have since made names for themselves, and it is not too much to say that there are very few of the more distinguished younger German physicists who do not owe a deep debt of gratitude to Kundt, and who do not look back with pleasure to the time they spent working in his laboratory at Strassburg or at Berlin. He was elected an honorary member of the Society in 1892. C. H. L.

JEAN CHARLES GILLISARD DE MARIGNAC, a descendant of a Huguenot family settled in Geneva since the end of the 17th century, was born in that town April 28th, 1817. After finishing the general educational course in his native town he went to Paris, in 1835, to study science at the Ecole Polytechnique, where he distinguished himself to such a degree, that (as head of his class) he was promoted two years later to the Ecole des Mines. He was then attracted to Liebig's laboratory, in Giessen, where he performed his only organic investigation on "Phthalic Acid." In his twenty-third year, the position of chemist to the Sèvres Porcelain Works was offered to him on account of his career in the Parisian Schools, but a call of the Geneva Academy, to the Professorship of Chemistry and Mineralogy, proved more attractive. For thirty-seven years Marignac taught and worked in this position and won the love and gratitude of his numerous students, especially through the clearness of his lectures, illustrated by well chosen and carefully arranged experiments. When, in 1878, the Academy was re-organised as a University, he retired, and continued his work in a laboratory arranged in his house, until a painful heart disease compelled him, in 1887, to cease practical work. After several years' sickness and suffering he died on April 15th, 1894. Marignac's experimental work in inorganic chemistry began in 1840, with an analysis of "Cobalt Minerals." Soon stereo-chemical studies followed, comprising the determination of the combining weights of eighteen elements, which remain his most appreciated researches. His first publications on the atomic weight of silver, potassium, chlorine, bromine, iodine and nitrogen, in 1842 and 1843, induced Berzelius to express the wish that the revision of the atomic weights, already approximately determined by himself with insufficient means, might be carried out by chemists who, like Marignac, "combined exactness and patience in the repetition of experiments with conscientiousness in the statements of the results." Isomorphism was then the leading guide for deducing the atomic weight from the combining weight, and Marignac, as familiar with mineralogy and crystallography as with chemistry, naturally took in this discovery of Mitscherlich's the greatest interest, which led to his numerous masterly crystallographic-chemical investigations. The studies on the rare elements also absorbed much of his time and energy, and those on fluorides, ozone, diffusion, specific heat and expansion of salt solution yielded material for numerous publications, appearing mostly in the *Bibliothèque Universelle de Genève.* These investigations, besides the teaching, represent an astounding amount of activity even for a long life, and prove the indefatigable nature of the man. Personally, Marignac was of a retiring disposition, and only appeared in public when performing academical duties. Nevertheless, his merits were well recognised. He was elected a member of many Academies and Societies, and was the recipient of the Davy-Medal and the Prussian Order Pour-le-Merite. His election as an honorary member of this Society took place in 1892. M. J. L.

In the death of Sir JAMES COCKLE we have lost one of the most distinguished of our corresponding members, a man eminent as a lawyer and a judge, and no less eminent as a mathematician. Of the work which he did, and of the distinctions which he won at the Bar and on the Bench something may be said here ; though he was known to us chiefly by his writings on subjects far removed from his professional life. The first paper contributed by him to our Memoirs bears the title, "Researches in the Higher Algebra ;" it was read before the Society on the 5th October, 1858, that is, more than six-and-thirty years ago. He was then a Barrister on the Midland Circuit, where he gained the good opinion and esteem of all with whom he came in contact, being especially admired for his justness of thought, clearness of view, refinement of mind, and elevation of character. These characteristics, combined with a sound knowledge of law and unwearied industry, eminently fitted him for the high position which, a few years later, he was called to fill as first Chief Justice of Queensland. This advancement he owed to Sir William Erle, then Chief Justice of the Court of Common Pleas, who had formed a very favourable opinion of his capacity and character. Erle, on being applied to by the Colonial Office, "named" Cockle for the position "on account of the estimation and regard in which he was held by the good men on his circuit."

Cockle commenced his judicial labours amid difficulties not of his own creating—for they had arisen before his arrival in the Colony, and were in no way connected with any action of his—but by courtesy, tact, and decision he was enabled speedily to overcome them, and his subsequent course was comparatively smooth.

For more than fifteen years he presided over the Supreme Court of Queensland, and throughout the whole period he enjoyed the respect and confidence alike of his colleagues on the Bench, the members of the Bar, and the community in general.

Chief Justice Erle, who watched his Australian career from the beginning to the end with interest and satisfaction, often testified to the excellence of his judicial administration. "With regard to the duties of his office," he wrote to the Duke of Buckingham and Chandos when Cockle had been for some years at work in Queensland, "I am confident that he has done 'what to justice appertains according to law' with zeal and ability, setting a good example of the dignity and motives which become the office. But, besides the work included in his judicial contract, he has been indefatigable as a legislator, systematising the law there, and bringing it up to the best improvements here." (Erle enumerates in his letter some thirty Statutes consolidated mainly by Sir James Cockle). "He has endeavoured to diffuse the culture which, as a Fellow of Trinity, Cambridge, strong in mathematics, he imported with him, and has imparted in lectures and publications." (Cockle was a Cambridge man and a wrangler, but not a Fellow of Trinity). "He set out in troubled waters—from the clash of legislative and judicial powers—which were soon calmed by his discretion. I have had much knowledge of judicial men, and I am sure the Queen has never had a servant who more thoroughly earned every farthing of the wages he hoped to receive."

Equally emphatic testimony was given by men on the spot and those who had been long and intimately associated with Cockle in his judicial administration. When he was about to return to England, and before it was known that he was also about to resign his official connection with the Colony, the journalists of Queensland testified in warm terms to the universal appreciation of his public services and private worth, and expressed the hope that his absence would be but of brief duration. We cite a few passages from one article which may be taken as a fair specimen of others that appeared at the time :—

"In the early days of a new country, it is of the utmost importance that the foundations of her chief corner stones should be well and truly laid: it is of the last importance that her fountain of justice should be a fountain pure and undefiled. If laborious investigation, patient research, sterling integrity, and untiring industry, together with a long acquaintance with and a good knowledge of law, are recommendations in a Judge, we may indeed congratulate ourselves that, all these excellencies being found in Sir James Cockle, we have had in him the benefit of them all." "If all have not been satisfied with the judgments given all have been satisfied with the perfect integrity of the Judge." "While the professional character of a Judge stands high, it is greatly to be desired that his private character should rank equally high, and happily indeed for Queensland we know, from observing the career of Sir James Cockle for fifteen years, that his private character stands so high that no breath of scandal—in which all small communities are so prolific—has ever sullied his fair fame." "To say that we wish Sir James Cockle a pleasant passage to England sounds a very poor wish. We wish him—in the best interests of the colony, whose law courts he has presided over so ably and so long—we wish him a speedy return. As an able lawyer, a humane and earnest judge, a distinguished man of science, a brilliant scholar, and a warm-hearted, genial, hospitable friend, we are sorry to lose him even for a time. However short the time may be during which he will be absent, we know we shall miss him. We can only assure him that all classes of our community are sorry for the departure, even for a little time, of the excellent Chief Justice who has so faithfully administered the law of the land as largely to make Queensland what it is to-day—the land of the law." (*Brisbane Courier*, Wednesday, June 26th, 1878.)

Nearly seventeen years have elapsed since these words were written, and Queensland still remembers with grateful feeling her first Chief Justice. When the news of Sir

James Cockle's death was cabled out to the colony a few weeks ago, the journalists there lost no time in expressing the public sense of loss. The occasion served to revive old memories :—the Judge, his dignified and courteous bearing, his unwearied labours, the fidelity with which he dispensed justice according to law, his varied services to Queensland, the profundity of his learning and his mathematical distinctions. Only one who had an intimate knowledge of the late Judge and his work could have penned the following lines :—

"In his judicial duties Sir James Cockle was patient and painstaking, courteous to the Bar, and cautious and accurate in his judgments. In the preparation of Acts and rules, regulating the practice of the Courts, his collaboration was much valued by his brother judges. His work in the consolidation and simplification of the Statutes dealing with the duties of Justices rendered the work of drafting our effective Justices Act of 1886 much lighter." "No community could desire to build up their series of Chief Justices upon a more upright and steadier foundation stone than the late Sir James Cockle." (*Brisbane Telegraph*, Jan. 30th, 1895).

But it was as a mathematician that Sir James Cockle was best known to us. All his papers in the *Memoirs* and *Proceedings* of this Society, and most of his writings in scientific journals and the transactions of other societies, relate to questions in pure mathematics. Here and there we find an exception. He wrote in one journal two learned essays, entitled respectively, "On the Indian Astronomical Literature," and "On the Indian Cycles and Lunar Calendar ; on the date of the Vedas and Jyotish Sastra ; and on the Ages of Garga and Parasara ;" in another, some notes "On Light under the action of Magnetism ;" and in a third, four elaborate memoirs "On the Motion of Fluids ;" but in general he confined himself to problems in pure mathematics. His papers may be grouped for the most part under two heads, viz., Common Algebra and the Theory of Differential Equations. In Algebra he worked mainly among the higher equations; and for many years his labours in this department were inspired and directed by the hope of "solving the quintic," or to be more exact, expressing a root of the general equation of the fifth degree by a finite combination of radicals and rational functions. The problem had long engaged the attention of mathematicians, and was attacked by the most celebrated analysts of the last century with great skill and vigour, but without success. In the early part of the present century, Abel, the young and gifted Norwegian mathematician, attempted to show that a finite solution of the problem was impossible. To prove a negative, however, is proverbially difficult; and despite Abel's "demonstration," and the non-success of preceding investigators, Cockle clung to the conviction that what had been done for the lower equations might be done also for equations of the fifth degree. He laboured long and hard at the problem; and although he failed, like others before him, to effect a general solution, yet his labour was not lost. He found not what he sought for, but other things which amply repaid the toil of effort, and he opened up new methods of working and new lines of research which are of acknowledged value in themselves. His first communication to this Society contained a result which attracted much attention on account of its remarkable simplicity. By an indirect but ingenious process he succeeded in determining the explicit form of a certain sextic equation on the solution of which that of the general quintic may be shown to depend. The accuracy of this sextic or "auxiliary" equation (whose co-efficients are all monomials save one, which is a binomial) was soon afterwards confirmed by an independent calculation. The writer of this notice was led to consider the problem in connection with some researches on the finite solution of algebraic equations, in the course of which he calculated the sextic by a direct process. He published his researches with the details of his calculation in the Society's *Memoirs;* and followed up the subject in two papers on the theory of quintics in the *Quarterly Journal of Mathematics*, and also in an elaborate exposition of Cockle's "method of symmetric products" in the *Philosophical Transactions.* The study of these papers led the illustrious Cayley to investigate the subject, and his results were embodied in a memoir entitled "On a New Auxiliary Equation in the Theory of Equations of the Fifth Order," which appeared in the *Philosophical Transactions* for 1861. Cockle had calculated the auxiliary equation for one of the trinomial forms to which the quintic may be reduced without any loss of generality; hence the simplicity of his result. Cayley, employing an invariantive process, calculated the same equation for the complete quintic, that is, the quintic not deprived of any of its terms and not modified in any of its co-efficients. The result is, of course, less simple than that for the trinomial form, but it has the advantage of being absolutely complete. Thus, Cockle's labours on the quintic invested the theory with a new interest, and the methods he devised, and the results he obtained largely directed the course of subsequent speculation on the subject.

His mode of dealing with the theory of differential equations was equally marked by originality and independence of mind. Not confining himself to the beaten track, he pushed his way into unexplored regions, and succeeded in bringing to light important relations and analogies between algebraic and differential equations. He found, for instance, that from any rational and entire algebraic equation of the degree n, whereof the coefficients are functions of a single parameter, we can derive a linear differential equation of the order $n-1$, which is satisfied by any one of the roots of the algebraic equation. Out of this germ has grown the theory of differential resolvents, a subject treated of by many writers both in the Society's *Memoirs* and other publications, but which it must be confessed is still far from being complete.

To Cockle also belongs the honour of being the first to discover and develop the properties of those functions of the coefficients of linear differential equations called Criticoids or Differential Invariants,—so called because they remain unaltered when the differential equation is transformed by a change of one of the variables, and are analogous in this respect to the critical functions or semivariants of common algebra. Criticoids seem destined to play an important part in the theory of linear differential equations. It would be impossible to discuss in detail Cockle's various discoveries in algebra and the calculus without covering page after page with mathematical symbols, which would be quite out of place in a brief obituary notice. Enough to say here that his work was eminently initiatory. He started theories, but left others to elaborate and perfect them. Of his eighty or ninety papers given to the mathematical world, many are no doubt slight and fragmentary; but there are few, even among the shortest and least complete, which do not contain original and valuable suggestions. Ideas struck out by him have taken root in other minds and borne fruit.

The leading events in the life of Sir James Cockle are soon told. He was born at Great Oakley, near Harwich, in Kent, on the 14th January, 1819. Of his early days little is known. From 1825 to 1829 he was educated at Stormond House, Kensington; thence he was sent to Charterhouse, where he showed considerable power in making Latin verses. At the end of his second year he was removed and placed under the tuition of the Rev. Christian Lenny, D.D., of St.

John's College, Cambridge, who was the first to discover his mathematical talent. When he had nearly completed his seventeenth year he went abroad (Nov. 1835), and was absent from England about twelve months, visiting the West Indies and the United States of America; at Cuba he learned the Spanish language. On his return home he entered Trinity College, Cambridge, October 1837, and graduated as 33rd Wrangler in 1841. His position in the Tripos gave no indication of his future eminence as a mathematician, nor do we wonder at this when we consider the character of his preparatory training and the long break in his studies before he went up to the University. He proceeded to the degree of B.A. in 1842, and of M.A. in 1845.

Mr. Cockle was entered as a student at the Middle Temple in 1838. He practised as a special pleader from 1845 to 1849, was called to the Bar at the Middle Temple in 1846, and joined the Midland Circuit at the Nottingham Spring Assizes in 1848. On the 22nd August, 1855, he married Adelaide Catherine, eldest surviving daughter of the late Henry Wilkin, formerly of Walton, Suffolk. In 1862 he drafted the "Jurisdiction in Homicides Act" (Imperial); and in 1863 he was appointed by the English Government first Chief Justice of Queensland. The position at the outset was very trying. Mr. Justice Lutwyche, who during the previous year or two had come into collision on several occasions with the Governor, and also with the Government of the Colony, and whose claims to the supreme place on the bench were in consequence passed over by the Home authorities in favour of the English barrister, naturally felt himself aggrieved at the appointment of a younger man who had had no judicial experience. The story as told in the Brisbane papers when the old Judge died in 1880 reflects equal credit on both men; we cite a passage:—

"The late Judge made no secret of his mortification at the appointment of Mr. Cockle. A few years of association, however, entirely obliterated any feelings of hostility to the Chief Justice that this event may have originally engendered, and the two Judges became sincere and attached friends. Sir James always paid a very marked deference to the opinion of his learned brother, and the amiable disposition of the Chief Justice so wrought upon the sterner nature of his colleague that, when Sir James left for Europe two years ago, the parting was a severe trial to Mr. Lutwyche, who was extremely affected at bidding goodbye to a friend whom he rightly divined he was never to see again."

The Chief Justice was Senior Commissioner for the consolidation (effected in 1867) of the statute law of Queensland. He was knighted by patent in 1869. In 1874 the Legislative Assembly of Queensland showed their appreciation of his services by passing an Act giving him a substantial increase of salary.

Sir James Cockle's professional occupations at this period were numerous and exacting; yet he did not neglect his favourite science. He turned to mathematics as a relaxation, and devoted the intervals of official labour to researches in algebra and differential equations, embodying his results in papers which appeared from time to time in our *Memoirs*, the *Quarterly Journal of Mathematics*, the *Philosophical Magazine*, and other periodicals in England, and in the *Proceedings* of the Royal Societies of New South Wales and Victoria in Australia. He also wrote and published a number of presidential addresses delivered before the Queensland Philosophical Society (now incorporated into the Royal Society of Queensland) in which he dealt with questions in philosophy, logic and mathematics.

In 1879 he resigned his position as Chief Justice of Queensland, having a few months before returned to England with Lady Cockle and his family of eight children. The remainder of his days were given to mathematical writing, the business of several learned bodies, and the society of his friends; but he was never really strong after his return home, his health suffering perhaps from the change of climate.

He was elected a Fellow of the Royal Astronomical Society in 1854, and served on the Council from 1888 to 1892. He was elected a Fellow of the Royal Society in 1865, a Corresponding Member of this Society, and a Member of the London Mathematical Society in 1870; he filled the Presidential Chair of the last named Society from 1886 to 1888. He was President of the Queensland Philosophical Society from 1863 to 1879, and was elected an Honorary Member of the Royal Society of New South Wales in 1876. He was a Commissioner for the Queensland Section of the Colonial and Indian Exhibition held in London in 1886; and was nominated to represent the Australian Colonies at the Washington Prime Meridian Conference in 1884, but was unable to accept the position.

Of his personal and social qualities the writer may be permitted to speak from personal knowledge. Our acquaintance began forty-eight years ago, and soon ripened into a friendship which lasted to the end of his life, and was never clouded even for a moment by the slightest misunderstanding. We had similar scientific tastes, but otherwise little in common. In our political and ecclesiastical opinions we differed fundamentally, and had it not been for Cockle's imperturbable temper and graciously tolerant spirit, these differences would often have disturbed our cordial relations. Controversy, however, was distasteful to him; and he avoided the conflict of argument. When it was suggested on one occasion that he should offer himself for a seat in Parliament, he said playfully: "My address to the electors shall run thus—Gentlemen, I am in favour of making things agreeable all round—all round!" That was the spirit of the man. He desired to live peaceably with all men, and so far as we know, he had not a single enemy. His modesty was remarkable; rarely speaking of his own work, he was ever ready to recognise and do full justice to the work of others. There were in him none of the petty jealousies which haunt meaner minds. The writer remembers with gratitude that when he entered fields which Cockle might be said to have made his own, he was not treated as an intruder or a rival, but welcomed as a friend and fellow-worker, and received from his elder an amount of encouragement and help which he can never sufficiently acknowledge.

Cockle was an excellent correspondent, and when writing on congenial themes would often wax truly eloquent. He had a positive enthusiasm for mathematics, and the discovery of a new theorem always gave him intense delight. The writer has preserved most of the letters he received from him, and placed them, bound in several goodly volumes, among the choicest of his literary treasures.

Something of a recluse, Sir James Cockle astonished many of his friends, both in England and Australia, by the zest with which, during the last ten or twelve years, he threw himself into the Club life of the great Metropolis. He became a member of the Garrick, the Saville, and the Savage, and an *habitué* of all three, being particularly attached to the last. Queenslanders visiting London could hardly look on gravely when they saw how their old Chief Justice adapted himself to what one of them called, his "Bohemian and brilliant environment." But, truth to tell, he was not a typical club man. "In the Savage Club (London), of which he was Treasurer 1884-89," writes one in the Monthly Notices of the R. A. S. for Feb. last, p. 192, "it was a familiar sight to see him quietly working at some algebraical research on the back of an envelope or some odd scrap of paper, though always ready to break off and offer a genial welcome to one of his friends." The "ruling passion" was strong even there, but it was not a passion we look for in "Savages."

Sir James Cockle was a man of upright character and simple tastes, amiable in his disposition and courteous in his bearing, constant in his friendships and faithful in all the relations of life; absolutely devoid of ostentation, vanity or pretence, his whole life was a beautiful illustration of the motto on his crest—*Esse quam videri.*

Not demonstrative or effusive in the expression of his feelings, few even of his intimate friends knew the depth and tenderness of his nature. When he lost his son, his then only son (another was born to him afterwards), he wrote to his most intimate mathematical friend, the following brief, simple, touching note, under date 26th April, 1860:—"My dear Sir,—Thanks I send for letting me see the paper—but my son, my Harold, died yesterday.

"Ever yours,

"JAMES COCKLE."

Sir James passed away peacefully at his Bayswater residence on Sunday, the 27th January, 1895 (the day after the lamented Cayley, and on the following Saturday (the day before the lamented Kirkman died), we stood beside the open grave in Paddington Cemetery, and mourned as his body was laid to rest beside that of his son, his Harold, whose untimely death nearly thirty-five years before was one of the great trials of his life. He had nine children, of whom eight survive; Lady Cockle also survives him.

The following is a list of Sir James Cockle's papers published in the *Proceedings and Memoirs* of this Society:

1858. Researches in the Higher Algebra.
(*Proc.*, Vol. I., pp. 62-63; *Mem.*, Ser. 2, Vol. XV. (1860), pp. 131-142).

1859. Supplementary Researches in the Higher Algebra.
(*Proc.*, Vol. I., pp. 173-175; *Mem.*, Ser. 3, Vol. I. (1862), pp. 108-114).

1862. On Transcendental and Algebraic Solution.
(*Proc.*, Vol. II., pp. 202-203).

1862. On certain Linear Differential Equations.
(*Proc.*, Vol. III. (1864), pp. 16-17).

1863. On the Theory of Equations.
(*Proc.*, Vol. III. (1864), pp. 171-173).

1864. On Differential Equations.
(*Proc.*, Vol IV. (1865), pp. 38-40).

1865. On Coresolvents.
(*Proc.*, Vol. V. (1866), pp. 13-15).

1867. Memoramdum on the Evaluation of Integrals.
(*Proc.*, Vol. VII. (1888), pp. 67-68).

1868-70. On Convertent Functions.
(*Proc.*, Vol. VIII. (1869), pp. 2-3; Vol. IX. (1870), pp. 86-87 Vol. X. (1871), pp. 1-5).

1875. Notes bearing on Mathematical History.
(*Proc.*, Vol. XV. (1876), pp. 6-10; *Mem.*, Ser. 3, Vol. VI. (1879), pp. 10-15).

1876. On Ternary Differential Equations.
(*Proc.*, Vol. XVI. (1877), pp. 66-68).

1877-84. Notes on Envelopes and Singular Solutions.
(*Proc.*, Vol. XVII. (1878), pp. 13-15; Vol. XXI. (1882), pp. 98-100; Vol. XXIV. (1885), pp. 10-12, and 23-25).

1879. On the 'Differential Calculus' of Du Bourguet.
(*Proc.*, Vol. XIX. (1880), pp. 9-10).

1880. On a Proposition of Du Bourguet.
(*Proc.*, Vol. XIX. (1880), pp. 181-182).

1881. On Du Bourguet's 'Calcul' and on Ternaries.
(*Proc.*, Vol. XX. (1881), pp. 119-121).

R. H.

JULIUS LOTHAR MEYER was born on August 19th, 1830, at Varel on the Jahde, in the Grand Duchy of Oldenburg. After leaving school he studied medicine in Zurich, and in 1854 he took his M.D. at the University of Würzburg with a dissertation on the gases of the blood. He then decided to devote himself to physical science, and became a pupil of Bunsen at Heidelberg, where he and his friend Quincke helped their master in the construction of the famous burner. In 1856 he went to Königsberg to work under F. Neumann, and in July, 1858, he took the degree of Ph.D. at Breslau.

Six months later he became a Privat-docent in the same University, presenting as his "Habilitations-Schrift" an essay "on the chemical theories of Berthollet and Berzelius." He became in 1866 Professor at the Forest School at Eberswald, in 1868 Professor at the Karlsruhe *Polytechnicum*, and finally was elected to the Chair of Chemistry at Tübingen, which he occupied until his death on the 11th of April, 1895. Lothar Meyer will be chiefly remembered for two things, his book on "The Modern Theories of Chemistry," and his share in the development of the Periodic Law, for which, in 1882, he was awarded a Davy medal by the Royal Society, the perhaps more important work of Mendeléeff on the same subject being recognised by a similar and simultaneous distinction. Nothing is more interesting than to note the way in which Lothar Meyer's thin pamphlet of 1864 grew to its bulky fifth edition*: an increase not disproportionate to the increase in our knowledge of the more general aspects of chemistry, towards the study of which the book itself and its author's original work had contributed so powerfully. It should be remembered that Ostwald's "Allgemeine Chemie" is dedicated, and fitly dedicated, to Lothar Meyer, who continued the tradition of the great critical chemists, Lavoisier, Berthollet, and (in his younger days) Berzelius. Between the years 1830 and 1870 the great structure of organic chemistry had grown so rapidly and wonderfully, that there was some temptation for the younger men to turn their eyes away from the study of other portions of the subject, and to develop chemistry in a one-sided way. Doubtless in time the task might have been accomplished by someone else; but, as it is, the new school of physical chemists, which has averted the danger, owes its immediate origin to the labours of Lothar Meyer. Meyer's critical power is, perhaps, nowhere better illustrated than in a short essay, which

* Translated into English by Professors Bedson and Williams.

he published a few years ago, on Chemical Affinity: a term discussed with precision for the first time by Berthollet, for whom, indeed, Meyer had the profoundest admiration. The osmotic pressure and ion solution theory of his disciples Meyer felt some difficulty in accepting. Among his experimental researches must be mentioned those on the blood, in which he proved that oxygen is not dissolved in but combined with the blood, and that it is displaced directly from it in molecular proportions by carbon monoxide; investigations on spectrophotometry, rates of reaction, etc. In devising new modes of preparation of known substances, and in the construction of apparatus Meyer was particularly happy. Nor must we forget the unselfish labour which led to the publication, in conjunction with his friend and colleague Seubert, of a recalculation of all the atomic weights at that time determined. Lothar Meyer will be well remembered personally by those who saw his stately figure at the Manchester Meeting of the British Association, in 1887. Since that time several of our University students have gone to work with him in the little town in the Würtemberg hills. They have all brought back the warmest gratitude and respect for a man who was as genial as he was learned. He was elected an honorary member of the Society in 1889. P. J. H.

HERMANN LUDWIG FERDINAND VON HELMHOLTZ was born August 31st, 1821, at Potsdam, where his father was Professor at the Gymnasium. His mother, whose maiden name was Penn, was of Scotch descent. He was educated as a medical student, and started his career as a military surgeon, a position he held till the year 1848, when he was appointed assistant of the Anatomical Museum of Berlin and teacher of Anatomy at the Academy of Arts. Only a year later he was made Professor of Physiology at Königsberg where he remained till 1856. He occupied in succession the chair of Physiology at Heidelberg (1859—1871) and Physics at Berlin (1871—1888). The last years of his life were spent in organising the work of the Physikalisch-technische Reichsanstalt at Charlottenburg. It is impossible to give within the space of a short obituary notice an adequate idea of the work accomplished by one who must for ever be recognised as one of the foremost thinkers of the century, and I can only briefly indicate the most important of his contributions to science.

Helmholtz is one of the founders of the modern theory of the "Conservation of Energy." The first treatment of the subject is contained in a pamphlet, "Ueber die Erhaltung der Kraft" (1852). Maxwell (*Nature*, Vol. XV.) thus refers to this paper :—

"To appreciate the full scientific value of Helmholtz's little essay on this subject, we should have to ask those to whom we owe the greatest discoveries in thermodynamics and other branches of modern physics how many times they have read it over, and how often during their researches, they felt the weighty statements of Helmholtz acting on their minds like an irresistible driving-power."

Helmholtz's physiological work includes the invention of the ophthalmoscope, the measurement of the rate of propagation of sensational impulse along the nerves, and those researches on the sense of hearing which are contained in the celebrated volume on the "Ton-Empfindungen."

His mathematical powers are shown in a series of researches on hydrodynamics, the best known of which is the one on vortex motion, "in which," to quote Maxwell once more, "he establishes principles in pure hydrodynamics which had escaped the penetrative power of all the mathematicians who preceded him, including Lagrange himself." The results of the paper are perhaps best known by the application and further developments they have received at the hands of Lord Kelvin, who founded on them his celebrated "vortex atoms." A further series of papers on the application of hydrodynamics to meteorology have not, as yet, perhaps, received all the attention they deserve.

Amongst his electrical contributions we may draw attention to his theory of the "double layer," which explains the so-called electro-capillary actions, and to the important questions treated in his "Faraday Lecture" before the Chemical Society. From this lecture I may quote the following passage, which has already served as text to several theoretical deductions, and which will probably receive increased attention in the immediate future:—

"If we accept the hypothesis that the elementary substances are composed of atoms, we cannot avoid concluding that electricity, also positive as well as negative, is divided into definite elementary portions, which behave like atoms of electricity."

Helmholtz was not a good lecturer, but he exercised a powerful influence on the students in his laboratory. The quiet and thoughtful attention he always gave to the often crude ideas of his pupils, the deep and sympathetic manner in which he discussed their difficulties, must have left a lasting impression on all with whom he came into contact. He was elected an honorary member of the Society in 1886, and died in September, 1894. A. S.

Wilhelm Roscher, who has been rightly described by a German biographer as the founder of the historical school of political economy, to which Emile de Laveleye and Cliffe Leslie also belonged, was born in Hanover in 1817, and was educated in the Lyceum of that town. He subsequently studied, from 1835 to 1839, at the Universities of Göttingen and Berlin. At the Lyceum he came under the influence of the divinity teacher Petri, subsequently one of the most famous Protestant preachers in Germany, and at the Universities he sat at the feet of Leopold Ranke, Gervinus, Ottfried Müller (the philologist and archæologist), and Albrecht. During his University career he gave special attention to philosophy, history, and political economy. From 1843 to 1848 he occupied a chair at Göttingen, and in 1849 he was appointed to the Professorship of Political Economy in the Leipsic University, where he remained until his death in June, 1894, successively declining invitations from the Universities of Zurich, Vienna, Munich, and Berlin. He received the honorary degree of Doctor of Laws from Königsberg, Bologna, and Edinburgh, and distinctions were conferred upon him by other German and by Russian seats of learning, as well as by many learned societies in Europe, including the Institute of France. He was elected an honorary member of our own Society in 1889. The publication in 1843 of a small treatise on the historical method of economic inquiry practically inaugurated a new departure in the science to which his life was devoted, and in his subsequent writings he developed the principles then laid down. Whereas Adam Smith introduced his great work as an inquiry into the annual labour of nations as the basis of economics, and J. B. Say took the production of wealth, and Ricardo the theory of value as the fundamental ideas of the science, Roscher characteristically begins his greatest work, the "System der Volkswirthschaft," with the sentence "Ausgangspunkt, wie Zielpunkt unserer Wissenschaft ist der Mensch"—the starting point and the goal of our science is humanity. In the introduction to the first volume of this work, designed as "a manual and text-book for business men and students," Roscher sketched his plan and intimated that he proposed, if his life were spared, to complete it in four volumes. He lived to achieve the task. The first volume appeared in 1854, and was devoted to the general principles of national economy. It was translated into French by Wolowski, the bimetallist, into English by Lalor, and into Russian by

Javanovich. The second volume, devoted to agriculture and its allied industries, appeared in 1859, and was also translated into French by Wolowski, into Italian by Luzzatti, and into Russian by Schtschepkin and Zimmermann. The third volume, which deals with trade, monetary systems, the exchanges, and manufacturing industry, did not appear until after an interval of twelve years, in 1881, and the fourth volume, on financial science, was published in 1886. All these volumes, except the last, have gone through many editions. In the third volume Roscher fully justifies Wolowski's monetary theory, but throughout the whole work the tone adopted is eminently judicial, while the industry and scholarship displayed in the collection and quotation of authorities on every statement in the text is nothing less than marvellous. No other work on the subject can be compared with it as a treasury of economic facts and deductions. Other works may deal with particular points in more elaborate detail; but Roscher has presented a comprehensive and analytical survey of all experience and knowledge on the subject, distinguished by absolute freedom from the doctrinaire spirit. His method of investigation is eminently that of the unbiassed experimentalist in physical science; he seeks the truth rather than the confirmation of a theory. He defined political economy as the facts of the development of the social life as well as of the economic life of the people, and as embracing, like all social science, the consideration not only of the individual man, but of the human race. The speech, the religion, the art, the science, the laws, the economic condition, the constitution of the State, the family life, are all factors in Roscher's science, and the line of investigation in any particular case must, in his opinion, be "not only historical but physiological." It will be seen that Roscher was no teacher of abstract dogmas by which the actions of men may be foretold, or with which legislation must be squared. The universality and the thoroughness of his historic method were illustrated by his special liking for inquiries into the economic and social developments of classical antiquity, and their relation to the economic phenomena of modern times. He was an industrious and voluminous publicist, and the list of his works embraces, in addition to the monumental work already referred, such subjects as "The Life, Work, and Period of Thucydides," "The Economic Opinions of Herodotus and Thucydides," "Colonies, Colonial Policy, and Emigration," "Luxury," "The Relations between Economics and Jurisprudence," "German Agriculture in Ancient Times," "The Economic Significance of Machinery," "The Position of the Jews in the Middle Ages considered from the Mercantile Point of View," "The Currency Question and the German Monetary Reform," "The Monarchical, Aristocratic, and Democratic Principles Historically Considered," "The History of German National Economics," "Socialism and Collectivism," "English Economics in the 16th and 17th Centuries," "The Economic Opinions of Frederick the Great," and "The Romantic School of Political Economists," a list which is very far from exhausting the catalogue of his writings, but is sufficiently suggestive of the breadth and scientific thoroughness of his researches.

F. J. F.

ARTHUR CAYLEY, by whose death the world has lost one of the mathematicians whose fame is secure for all time, was the son of Henry Cayley, a Russian merchant living at St. Petersburg, but was born at Richmond, in Surrey, on August 16, 1821, during a visit of his parents to England. When Arthur Cayley was eight years of age, his father retired from business, and returned to England. Cayley left King's College School at the age of 17, and went into residence at Trinity College, Cambridge, and was Senior Wrangler and First Smith's Prizeman in 1842. For a long series of years, Cambridge had suffered from the too devoted adherence to Newton's methods, and had fully demonstrated that it was given to as few to use them usefully as to bend Ulysses' bow. Mainly by the exertions of Peacock, the use of other methods had been admitted, and the result was shewn by an extraordinary succession of illustrious mathematicians, who have made up all the leeway which Cambridge had lost. Sylvester and Green, Leslie Ellis, Stokes, Cayley, Adams, and Lord Kelvin, in almost successive years, form a group of which any school may be proud. Cayley began his original work while an undergraduate, and continued it nearly up to his death. His teaching connection with his College was very slight, and before his fellowship lapsed he left Cambridge. He entered at Lincoln's Inn in 1846, and became a pupil of Mr. Christie, the conveyancer. For fourteen years he remained at the bar, taking no work except conveyancing for Mr. Christie, a work for which he gained a reputation by his remarkable skill. This period was the most prolific of his more substantial mathematical papers, covering an enormous range, and including discoveries of the greatest brilliancy. In 1863 the Sadlerian Professorship of Pure Mathematics was founded, by the amalgamation of nine lectureships on Algebra, endowed in 1706 by Lady Mary Sadleir, and Cayley was appointed to the chair, which he held for the rest of his life. Besides the lectures which he gave as Professor, and which were attended chiefly by the mathematical teachers of the University, he served the University well, not only as a draftsman, but also as a general adviser in both business and legal matters. It is beyond the scope of this short note to discuss his principal memoirs or his position among mathematicians of his age. His papers are in course of republication by the Cambridge University Press, and seven large quarto volumes, edited by himself, had been issued at the time of his death. By the kindness of Professor Cayley, these volumes are in the Society's Library.

In one of his researches we may claim a special interest. The number of hydro-carbons in different groups was naturally a matter of interest to Professor Schorlemmer, and, having failed to interest a distinguished German mathematician in the subject, he was advised to suggest the problem to Cayley. Schorlemmer expressed the greatest admiration for a statement of the question, asking whether it was exact, which he received by return of post, and the answer was returned within a fortnight. The paper was published in 1875 (*Brit. Ass. Report*, pp. 257-305). This is an illustration of the wide interest which Cayley took in all scientific matters.

In manner Cayley was modest and retiring; his relaxations were travelling, walking, and climbing, water-colour painting, and the study of architecture. To this we must add novel reading. He was famed for his novel reading as an undergraduate, and continued the practice through his life. For some years Cayley suffered from a painful internal malady, and for three years it had undermined his health, and gave him few intervals of relief from pain. On the 26th of January, 1895, he got relief by death. In time, a proper estimate of his work will no doubt be arrived at; at present, to his contemporaries, it seems gigantic. He was elected an honorary member of the Society in 1859. The following is a list of his contributions to our publications :—

1860. On the Δ faced Polyacrons, in reference to the Problem of the Enumeration of Polyedra.
(*Proc.*, Vol. II. (1862), pp. 3-4; *Mem.*, Ser. 3, Vol. I. (1862), pp. 248-256).

1862. Note on a Differential Equation.
(*Proc.*, Vol. II. (1862), p. 193, *Mem.*, Ser. 3, Vol. II. (1865), pp. 111-114).

1877. On Compound Combinations.
(*Proc.*, Vol. XVI. (1877), pp. 113-114; *Mem.*, Ser. 3, Vol. VI., (1879), pp. 99-100).

R. F. G.

Thomas Penyngton Kirkman, son of John Kirkman, a cotton dealer in Bolton, Lancashire, was born on the 31st March, 1806. The only education he received at other hands than his own was that which the Bolton Grammar School could give, after leaving which he earned, by tuition, the cost of graduating at Dublin University, and, afterwards, accepted a private tutorship in the family of an Irish Baronet. Taking orders on his return to England, he served curacies, first, at Bury, under the Rev. Geoffrey Hornby, and, later, at Lymm, after which, in 1840 (to use his own version), he was enticed by fair words, by the then rector of Winwick, to bury himself for life as rector of the newly-formed Parish of Southworth with Croft, where he remained for 52 years. Here, by perseverance and his gift of teaching, he formed, out of the roughest material, a parish choir of boys and girls who could sing, at sight, any four-part song set before them. Here also, with an expenditure of mental labour that only the finest of physical constitutions could have sustained, he devoted, practically, the whole of his time (for the parochial work was small) to the study of pure mathematics, the higher criticism of the Old Testament, and questions of first principles.

His mathematical papers include original work on Combinations, Partitions, the Theory of the Polyedra and the Theory of Groups, and are to be found in the *Philosophical Transactions of the Royal Society* and the *Proceedings of the Literary and Philosophical Society of Liverpool* (of which he was an honorary member) and the publications of this Society, of which he had been an honorary member since 1852. In 1857 Mr. Kirkman was elected a fellow of the Royal Society, and later became a foreign member of the Dutch Society of Sciences at Haarlem. His researches pierced the highest region of pure mathematics along paths severe and difficult traversed by few of his contemporaries, and he used to sigh at the gulf of time which separated his own day from that of the possible use of his work in applied science. In one instance, however, Professor Tait of Edinburgh, whilst studying the properties of knots in an attempt to develop in one special direction Lord Kelvin's idea of vortex-atoms, received important aid (of which he made fitting acknowledgment in his papers on the subject) from Mr. Kirkman's already developed results in his Theory of the Polyedra. Mr. Kirkman was the author of the problem of "The Fifteen Young Ladies," a trifle inserted in the *Lady's and Gentleman's Diary* for 1850, his solution of which attracted much attention at the time, and since gained for him some reputation.

Mathematical training, assisted, possibly, by reaction from his early experience of the Methodists, among whom he was brought up, produced, in Mr. Kirkman a habit of thought that demanded strict proof of a proposition before admitting the right in another to assert its truth; and the right to impose this test was not affected in Mr. Kirkman's mind by the character of the subject under discussion. He became, at an early period of his life, a broad Churchman, and we find him, about 1863, coming forward in defence of Bishop Colenso, and, later, contributing to the series of pamphlets published in aid of the cause of "Free Enquiry and Free Expression," by Thomas Scott of Ramsgate. Holding the broadest views on the questions of the inspiration of Holy Writ and the relaxation of Church of England exclusiveness, his sermons for years principally fell under three heads: 1, Exaltation of St. Paul; 2 and 3, crusades against priest-craft and atheism. The latter years of his life developed increasing vigour in his handling of the last of these three. In fact, he lived and existed to smash the atheists and (which meant much the same thing in his mind) the materialists. Under this head Mr. Kirkman classed those who, in the place of a belief (which he, as a man of science, most firmly held and asserted to the last) in a living Creator and Upholder of the Universe conscious of what he is doing, profess to look for a first and final cause in matter and motion and their so-called inherent laws and qualities, and in his view such persons included a large proportion of then living leaders in scientific inquiry. His weapons in this attack were the rules of strict logic, rigidly applied to every phrase and every term, and his fashion was to strike at the earliest possible point. Thus to a speculation upon the nature and origin of the Universe, founded upon the conceptions of the speculator, Mr. Kirkman opposes the initial demur that, one man's conceptions not being given to any other finite thinker, the argument rests on the sophism of *non datum pro dato.* (See Paper No. 13 in the appended list). Again, whilst confessing his confirmed belief in what is commonly known as the first law of motion, and accepting the axiom, as a mathematician, within the limits of all human observation and computation, he denies the right to treat the proposition as scientifically demonstrated; and he vouches, in support of his own elaborate argument, the utterances of Newton, Laplace, Thomson and Tait, and De Morgan. (See Paper No. 14 in list.)

The aim in Mr. Kirkman's papers of this class seems to have been to meet the claim of materialism to foundation upon physical laws, known or unknown, by an inquiry how far the reputation of such of those laws as are supposed to be known will stand examination, upon a claim to absolute constancy, for all time, for all space, and independent of conditions. His "Philosophy without Assumptions," published in 1876, was written mainly with the object of steadying the minds of philosophically inclined young men, who might be hesitating on the materialistic rail. This is a powerfully-written treatise upon such questions as "I am," "Thou art," the will, matter, ether, atoms, force, causation, and law, in which the utterances, on those subjects, of Boscovitch, Berkeley, Kant, Hume, Mill, Huxley, Tyndall, H. Spencer, and others, are critically examined and their authors commended, or mercilessly lashed, according to their agreement or otherwise with the writer's views. Mr. Kirkman spoke and wrote in good and forcible English, never failing to define his terms, and he was a great hater of the clouding of ideas, by the use of vague, undefined, and misleading Latin and Greek words. He often expressed the regret rather than the boast that he never had a halfpenny spent on his education. The Bolton Grammar School, it is presumed, was free. Yet he made himself a good Latin and Greek scholar, able to read and speak French and German. In his earlier days he knew all the plants, grasses, mosses, and fungi to be found within reach of his limited opportunities for travel, and he could turn a very neat English verse.

It is perhaps to be regretted that Mr. Kirkman's polemical writings were deeply tinged with satire, of which, possibly, the result was to afford excuse for silence on the part of those attacked instead of evoking the replies he so ardently wished for. However that may be, it is, we believe, a fact that, to his outspoken attacks upon the published utterances of some of the leading men of his day, no attempt at answer was ever made. Mr. Kirkman died on the 3rd February, 1895, within two months of attaining the age of 89, and he was, at his death, contributing difficult mathematical problems to the *Educational Times.*

The following (along with others purely mathematical) are among Mr. Kirkman's papers:—

1. On a so-called Theory of Causation. 1862.
2. Truth against Tradition. (A Lecture.) 1865.
3. Where is the Firmament that God created on the second day? (A Lecture.) 1865.

4. On the rest and refreshment of God on the seventh day. (A Lecture.) 1866.

5. The Ordeal of Jealousy. (A Lecture.) 1866.

The following were published in Thomas Scott's series :—

6. Church Cursing and Atheism. 1869.

7. The XXXIX. Articles and the Creeds. Parts I., II., III. 1870.

8. Is death the end of all things for man? 1870.

9. On the Infidelity of Orthodoxy. 1870.

10. On Church Pedigrees. Parts I. and II. 1872.

11. On Clerical Dishonesty. (Published by John Heywood.) 1871.

12. Philosophy without Assumptions. (Longmans.) 1876.

13. I. On Mr. Herbert Spencer's Conquest of the problem of the Universe.

    II. On the three zeros—Necessary, *A priori*, and Transcendental; or, An enquiry into the philosophical value of the word necessity used without an *if* implied or expressed. (Read before the Literary and Philosophical Society of Liverpool, 1887-8).

14. On the Simplest Possible Experiment in Physical Science, an Elementary Study in Philosophy without Assumptions. (Read before the Literary and Philosophical Society of Liverpool, 1879).

The following is a list of Mr. Kirkman's contributions to the publications of our own Society :—

1848. On Mnemonic Aids in the Study of Analysis.
(*Mem.*, Ser. 2, Vol. IX. (1851), pp. 29-45).

1851. On Linear Construction.
(*Mem.*, Ser. 2, Vol. IX. (1851), pp. 279-296).

1853. On the Representation and Enumeration of Polyedra.
(*Mem.*, Ser. 2, Vol. XII. (1855), pp. 47-70).

1854. On the k-partitions of N.
(*Mem.*, Ser. 2, Vol. XII. (1855), pp. 129-145).

1857. On the 7-partitions of X.
(*Mem.*, Ser. 2, Vol. XIV. (1857), pp. 137-149).

1857. On the triedral partitions of the X-ace, and the triangular partitions of the X-gon.
(*Proc.*, Vol. I. (1857), p. 11; *Mem.*, Ser. 2, Vol. XV. (1860), pp. 43-74).

1858. General Solution of the Problem of the Polyedra.
(*Proc.*, Vol. I. (1858), pp. 25-28, *Mem.*, Ser. 2, Vol. XV. (1860), pp. 92-103).

1858. On the absurdity of Ontology, and the vanity of Metaphysical Demonstrations; illustrated by reference to Professor Ferrier's Institutes of Metaphysic.
(*Proc.*, Vol. I. (1858), pp. 38-40).

1858. New Formula in Polyedra.
(*Proc.*, Vol. I. (1858), p. 41).

1859. On the j-nodal k-partitions of the R-gon.
(*Proc.*, Vol. I. (1859), pp. 113-117).

1859. On the Partitions and Reticulations of the R-gon.
(*Mem.*, Ser. 2, Vol. XV. (1860), pp. 220-237).

1861. On the Theory of Groups and many-valued Functions.
(*Mem.*, Ser. 3, Vol. I. (1862), pp. 274-398).

1861. Theorems on Groups.
(*Proc.*, Vol. II. (1862), pp. 73-97).

1862. On Non-Modular Groups.
(*Proc.*, Vol. II. (1862), pp. 245-253; *Mem.*, Ser. 3, Vol. II. (1865), pp. 204-227).

1863. On Maximum Groups.
(*Proc.*, Vol. III. (1864), pp. 59-65).

1863. The Complete Theory of Groups, being the Solution of the Mathematical Prize Question of the French Academy for 1860.
(*Proc.*, Vol. III. (1864), pp. 133-152, and 161-162; Vol. IV. (1865), pp. 171-172).

1864. On the Relation of Force to Matter and Mind.
(*Proc.*, Vol. IV. (1865), pp. 14-18, and 28).

1868. Note on "An Essay on the Resolution of Algebraic Equations, by the late Judge Hargreave."
(*Proc.*, Vol. VII. (1868), pp. 133-137).

1868. On the Solution of Algebraic Equations.
(*Proc.*, Vol. VII. (1868), pp. 141-148).

1868. Note on the Correction of an Algebraic Solution.
(*Proc.*, Vol. VII. (1868), pp. 221-223).

1872. Once again——the Beginning of Philosophy. [Title only.]
(*Proc.*, Vol. XI. (1872), p. 76.

1891. On the number and formation of many-valued Functions of $x_1 x_2 x_3 - - x_n$, which of any degree can be constructed upon any Group of those elements, with exhibition of all the values of the Functions.
(*Mem.* and *Proc.*, Ser. 4, Vol. IV. (1891), pp. 315-337).

1891. The 143 six-letter Functions given by the first transitive maximum group of six letters, with full exhibition of the values of the Functions.
(*Mem.* and *Proc.*, Ser. 4, Vol. V. (1892), pp. 23-53).

1893. On the k-partitions of R and of the R-gon.
(*Mem.* and *Proc.*, Ser. 4, Vol. VII. (1893), pp. 211-213).

1893. On the k-partitions of the R-gon.
(*Mem.* and *Proc.*, Ser. 4, Vol. VIII. (1894), pp. 109-129).

W. W. K.

MANCHESTER LITERARY AND

Charles Bailey, Treasurer, in Account with the Society

Dr. *Statement of the Accounts*

	1894-95. £ s. d.	1894-95. £ s. d.	1893-94. £ s. d.	1893-94. £ s. d.
1895.—March 30th:—				
To Cash in hand, 1st April, 1894		244 13 11		136 8 4
To Members' Contributions:—				
Admission Fees:—1893-94, 1 at £2. 2s. 0d...	2 2 0			
„ 1894-95, 4 „	8 8 0			
Subscriptions:— 1891-92, 2 „	4 4 0			
„ 1892-93, 4 „	8 8 0			
„ 1893-94, 12 „	25 4 0			
„ 1894-95, 71 „	149 2 0			
„ 1895-96, 3 „	6 6 0			
Half Subscriptions, 1894-95, 2 at £1. 1s. 0d.	2 2 0			
		205 16 0		265 13 0
Compounder's Fee, one..		0 0 0		26 5 0
To Members' Donations:—				
For cost of Electric Light Installation:		0 0 0		76 0 0
For repainting the Society's rooms, repairs, &c. (cost incurred, £89. 5s. 3d.)		0 0 0		61 10 0
To Balance of Members' Donations towards the cost of oil portrait of the late Mr. Joseph Baxendell, F.R.A.S. ..		0 0 0		0 10 6
To Library Subscriptions:—				
One Natural History Associate, 1893-94, at 10s.		0 0 0		0 10 0
To Contributions from Sections:—				
Microscopical and Natural History Section	0 0 0		5 5 0	
Physical and Mathematical Section, 1893-94..	2 2 0		2 2 0	
		2 2 0		7 7 0
To Use of the Society's Rooms:—				
Mr. G. Bridgford, 24th—25th January, 1895..	2 2 0		2 2 0	
Manchester Architects' Society to 31st Dec., 1894	37 7 0		37 7 0	
Manchester Geological Society to 31st March, 1894 ..	30 0 0		0 0 0	
Manchester Medical Society to 30th September, 1893 ..	0 0 0		25 0 0	
Manchester Photographic Society to 30th Sept., 1894 ..	25 0 0	94 9 0	25 0 0	
				89 9 0
To Sale of the Society's Publications, 1894-95		9 5 0		11 8 10
To Natural History Fund, 1894-5:—				
Dividends on £1225, Great Western Railway Co.'s Stock..		59 5 5		59 10 6
To Joule Memorial Fund:—				
Balance of Subscriptions: presented by the subscribers to fund for the erection of a marble statute in the Manchester Town Hall to the memory of the late Dr. Joule		0 0 0		257 11 0
Dividends on £258 Loan to Manchester Corporation ..		7 16 9		0 0 0
To Bank Interest, 1894-95		1 6 6		1 17 6
		£624 14 7		£994 0 8

1895.—April 1. To Cash in Williams, Deacon, Manchester and Salford Bank, Limited £162 16 11

PHILOSOPHICAL SOCIETY.

from 1st April, 1894, to 30th March, 1895, with a Comparative for the Session, 1893-1894.

Cr.

	1894-95. £ s. d.	£ s. d.	1893-94. £ s. d.	£ s. d.
1895.—March 30th:—				
By Charges on Property:—				
Chief Rent (Income Tax deducted)	12 10 0		12 11 5	
Income Tax on Chief Rent	0 8 7		0 7 6	
Insurance against Fire	13 17 6		13 17 6	
Repairs to Building, Gas, and Furniture, Ord. Expenditure	10 6 5		3 7 1	
„ „ „ „ .. Special „	0 0 0		89 5 3	
Electric Light Installation	0 0 0		76 0 0	
		37 2 6		195 8 9
By House Expenditure:—				
Coal, Gas, Electric Light, Water, Wood, &c.	46 8 10		32 3 2	
Tea, Coffee, &c., at Meetings	11 19 5		11 12 10	
Cleaning, Cleaning Windows, Sweeping Chimneys, &c. ..	5 1 5		6 19 6	
		63 9 8		50 15 6
By Administrative Charges:—				
Clerk and Housekeeper	62 8 0		62 8 0	
Postages and Carriage of Parcels, and of Memoirs.. ..	34 15 2		24 6 11	
Stationery, Cheques, Receipts, and Engrossing	5 19 5		7 3 4	
Printing Circulars, Reports, and List of Members	7 13 0		0 0 0	
		110 15 7		93 18 3
By Publishing:—				
Honorarium for editing the Society's publications, 1894-95.	50 0 0		50 0 0	
Printing 'Memoirs and Proceedings'	45 12 6		0 0 0	
Binding 'Memoirs' Joule volume	6 9 0		0 0 0	
Wood Engraving and Lithography	35 8 0		0 0 0	
		137 9 6		50 0 0
By Library:—				
Binding Books in Library	0 0 0		0 0 0	
Books and Periodicals	26 17 7		23 13 9	
Assistant in Library, &c...	9 10 0		8 0 0	
Palæontographical Society for the years 1894 and 1895 ..	2 2 0		0 0 0	
Ray Society for the years 1894 and 1895	2 2 0		0 0 0	
Zoological Record, Vols. 30 and 31	2 0 0		1 0 0	
		42 11 7		32 13 9
By Natural History Fund:—				
Natural History Books and Periodicals	23 1 10		18 10 6	
Grant to Microscopical and Natural History Section, for Books and Binding	0 0 0		50 0 0	
Plates for Natural History Papers in 'Memoirs'	16 15 6		0 0 0	
Printing Natural History Papers in 'Memoirs'	30 11 6		0 0 0	
		70 8 10		68 10 6
By Joule Memorial Fund:—				
Loan to the Manchester Corporation, redeemable on the 25th March, 1914. Mortgage No. 1564. Public Health Act, 1875		0 0 0		258 0 0
By Balance 30th March, 1895..		162 16 11		244 13 11
		£624 14 7		£994 0 8

NOTE.—The Accounts (of which the above is a summary) have been audited and found correct, April 29th, 1895, by Mr. R. E. Cunliffe and Mr. William Thomson, F.R.S.E.

Summary Balance Sheet, Session 1894-95.

	£	s.	d.	£	s.	d.
General Account:—						
Balance against this Account, 1st April, 1894				56	9	1
Expenditure during the Session, 1894-95:—						
Charges on Property	37	2	6			
House Expenditure	63	9	8			
Administrative Charges	110	15	7			
Publishing	137	9	6			
Library	42	11	7			
				391	8	10
				447	17	11
Receipts during the Session, 1894-95:—						
Subscriptions, Admission Fees, Sections, &c.	207	18	0			
Use of the Society's rooms	94	9	0			
Sale of the Society's publications	9	5	0			
Bank Interest	1	6	6			
				312	18	6
Balance against this Account, 30th March, 1895				£134	19	5
Compounders' Fund:—						
Balance in favour of this Account, 1st April, 1894				203	15	0
Compounders' Fees received during the Session 1894-95				0	0	0
Balance in favour of this Account, 30th March, 1895				£203	15	0
Natural History Fund:—						
Balance in favour of this Account, 1st April, 1894	97	17	0			
Dividends on Great Western Railway Co.'s Stock, £1225, during the Session, 1894-95	59	5	5			
				157	2	5
Expenditure during the Session, 1894-5:—						
Natural History Books and Periodicals	23	1	10			
Grant to Natural History and Microscopical Section for Books and Binding	0	0	0			
Printing papers on Natural History	30	11	6			
Plates for papers on Natural History	16	15	6			
				70	8	10
Balance in favour of this Account, 30th March, 1895				£86	13	7
Joule Memorial Fund:—						
Dividends on £258 Loan to the Manchester Corporation, redeemable 25th March, 1914. (No. 1564)	7	16	9			
Balance against this Account, 1st April, 1894	0	9	0			
Balance in favour of this Account, 30th March, 1895				£7	7	9
Credit Balances:—						
Compounders' Fund, as above	203	15	0			
Natural History Fund, as above	86	13	7			
Joule Memorial Fund, as above	7	7	9			
				297	16	4
Debit Balances:—						
General Account, as above				134	19	5
Cash in Williams, Deacon, and Manchester and Salford Bank, Limited, 30th March, 1895 ..				£162	16	11

Annual Report of the Council of the Microscopical and Natural History Section.

The Council in presenting their Annual Report are able to state that the Section has had a satisfactory session, and that the various communications and papers contributed by members and associates have maintained the average interest and importance of former years.

During the session one new associate has been elected and three have resigned (two of whom have left the neighbourhood). The Section now consists of 16 members and 15 associates:

Members:—J. J. Ashworth, C. Bailey, F.L.S., John Boyd, G. H. Broadbent, M.R.C.S., Henry Brogden, A. Brown, M.A., M.D., S. Cottam, E. Coward, R. E. Cunliffe, Hastings C. Dent, A. Hodgkinson, M.B., B.Sc., C. J. Heywood, J. Cosmo Melvill, M.A.. F.L.S., F. Nicholson, F.Z.S., C. H. Schill, Mark Stirrup, F.G.S.

Associates:—J. F. Allen, Wm. Blackburn, P. Cameron, T. A. Coward, P. Cunliffe, T. Hick, B.A., B.Sc., H. Hyde, Leslie Jones, M.D., C. Oldham, T. Rogers, W. R. Scowcroft, T. Sington, G. Nash Skipp, J. Watson, F. E. Weiss, B.Sc.

The Microscopical and Natural History Section of the Manchester Literary and Philosophical Society in account with the Parent Society for Grant for Books from Natural History Fund.

Dr. *Session 1894-95.* **Cr.**

		£	s.	d.			£	s.	d.
1894.					1894.				
April.	To Balance of Grant unexpended	22	17	1	May 23.	By Jour. de Conchyliologie, (2 years' subs.)	1	9	3
	To Balance due to Section	19	12	8	June 15.	,, Printing Catalogue of Nat. Hist. Books	31	14	6
					Oct. 2.	,, Fauna and Flora, von Neapel, Monograph XXI.	3	0	0
					Nov. 2.	,, Index Kewensis, Part 3	2	2	0
					1895.				
					Feb. 2.	,, Preparing Nat. Hist. Catalogue for Printers	4	4	0
		£42	9	9			£42	9	9
						By Balance due to Section	£19	12	8

Mark Stirrup, Treasurer, in account with the Microscopical and Natural History Section of the Manchester Literary and Philosophical Society.

Dr. *Session 1894-5.* **Cr.**

		£	s.	d.			£	s.	d.
1894.					1894.				
April	To Balance in Manchester and Salford Bank (St. Ann Street Branch)	101	5	3	May 21.	By Eason and Son, "Irish Naturalist," 1894	0	5	0
Dec. 20.	,, Bank Interest	0	12	7	23.	,, H. Crosse, "Jour. de Conchyliologie," 2 years, 1893 and 1894	1	9	3
	,, Subscriptions and Arrears from April 4th, 1894, to April 5th, 1895	21	0	0	,,	,, W. E. Collinge, "Jour. of Malacology," 1894	0	4	4
					June 15.	,, T. Sowler and Co., Printing Nat. History Catalogue	31	14	6
					Oct. 2.	,, Williams and Norgate, "Fauna and Flora von Neapel," Monograph XXI.	3	0	0
					Nov. 2.	,, H. Frowde, "Index Kewensis, Part 3"	2	2	0
					,,	,, West, Newman and Co., "Jour. of Botany, 1894"	0	12	0
					5.	,, J. E. Cornish, "Naturalist," Oct. 1893—Oct. 1894	0	6	0
					Dec. 18.	,, H. P. Aylward, Case for Microscope	2	5	0
					27.	,, Gurney and Jackson, "Ibis," 1895	1	1	0
					1895.				
					Jan. 8.	,, Eason and Son, "Irish Naturalist," 1895	0	5	0
					,,	,, W. Douglas, "Annals of Scot. Nat. Hist.," 1895	0	7	6
					Feb. 2.	,, Charles Hargreaves, jun., Preparing Nat. History Catalogue for Printers	4	4	0
					April 5.	,, Chas. Hargreaves, Teas, Postages, &c.	3	15	11
					,,	,, Parent Society, Sectional Subscription	5	5	0
					8.	,, B. O'Connor, Circulars and Cards	2	17	0
					,,	,, Cash in the hands of the Treasurer	1	3	7
					,,	,, Balance in Manchester and Salford Bank	62	0	9
		£122	17	10			£122	17	10
	To Balance to Credit of Section	£63	4	4					

Examined and found correct,
April 8th, 1895,

G. H. BROADBENT.
CHAS. OLDHAM.

THE COUNCIL AND MEMBERS.

President.

HENRY WILDE, F.R.S.

Vice-Presidents.

ARTHUR SCHUSTER, PH.D., F.R.S., F.R.A.S.
EDWARD SCHUNCK, PH.D., F.R.S., F.C.S.
OSBORNE REYNOLDS, M.A., LL.D., F.R.S.
FRANCIS NICHOLSON, F.Z.S.

Secretaries.

FREDERICK JAMES FARADAY, F.L.S., F.S.S.
REGINALD F. GWYTHER, M.A.

Treasurer.

CHARLES BAILEY, F.L.S.

Librarian.

W. E. HOYLE, M.A., M.Sc., M.R.C.S.

Of the Council.

J. C. MELVILL, M.A., F.L.S.
HAROLD B. DIXON, M.A., F.R.S.
ALEXANDER HODGKINSON, M.B., B.Sc.
JOSEPH THOMPSON.
FRANCIS JONES, F.C.S.
JAMES BOTTOMLEY, B.A., D.Sc., F.C.S.

Ordinary Members.

Date of Election.

1870, Dec. 13. Angell, John, F.C.S., F.I.C. 6, *Beaconsfield, Derby Road, Fallowfield, Manchester.*

1861, Jan. 22. Anson, Rev. George Henry Greville, M.A. *Birch Rectory, Rusholme.*

1837, Aug. 11. Ashton, Thomas. 36, *Charlotte Street.*

1887, Nov. 16. Ashworth, J. Jackson. 39, *Spring Gardens, Manchester.*

1895, Jan. 8. Armstrong, Geo. B. *Clarendon, Sale, Cheshire.*

1865, Nov. 15. Bailey, Charles, F.L.S. *Ashfield, College Road, Whalley Range, Manchester.*

1888, Nov. 13. Bailey, G. H., D.Sc., Ph.D. *Owens College.*

1888, Feb. 7. Bailey, Alderman Sir W. H. *Sale Hall, Sale.*

1895, Jan. 8. Barnes, Charles L., M.A. 10, *Nelson Street, Chorlton-on-Medlock.*

1894, Jan. 9. Beckett, J. Hampden. *Corbar Hill House, Buxton.*

1895, Mar. 5. Behrens, Gustav. *Holly Royde, Withington.*

1868, Dec. 15. Bickham, Spencer H. *Underdown, Ledbury.*

1861, Jan. 22. Bottomley, James, D.Sc., B.A., F.C.S. 220, *Lower Broughton Road.*

1875, Nov. 16. Boyd, John. *Barton House, Didsbury Park, Didsbury.*

1889, Oct. 15. Bradley, Nathaniel. *Sunnyside, Whalley Range.*

1894, Mar. 6. Broadbent, G. H., M.R.C.S. 8, *Ardwick Green.*

1855, April 17. Brockbank, William, F.G.S., F.L.S. *Chapel Walks.*

1861, April 2. Brogden, Henry, F.G.S. *Hale Lodge, Altrincham.*

1889, April 16. Brooks, Herbert S. *Slade House, Levenshulme.*

1844, Jan. 22. Brooks, Sir William Cunliffe, Bart., M.A. *Bank,* 92, *King Street.*

1860, Jan. 23. Brothers, Alfred, F.R.A.S. 14, *St. Ann's Square, Manchester.*

1886, April 6. Brown, Alfred, M.A., M.D. *Claremont, Higher Broughton.*

1893, April 18. Brown, F. E., B.A. *Hulme Grammar School, Manchester.*

1846, Jan. 27. Browne, Henry, M.A. (Glas.), M.R.C.S. (Lond.), M.D. (Lond.) *The Gables, Victoria Park.*

1889, Jan. 8. Brownell, T. W. 68, *Robert Street, Upper Brook Street.*

1880, Oct. 15. Budenburg, C. F., M.Sc. *Bowdon Lane, Marple, Cheshire.*

1872, Nov. 12. Burghardt, Charles Anthony, Ph.D. 35, *Fountain Street.*

1894, Nov. 13. Burton, Wm., F.C.S. *The Hollies, Clifton Junction, Nr. Manchester.*

1893, Jan. 10. Chadwick, W. I. 2, *St. Mary's Street.*

1854, April 18. Christie, Richard Copley, M.A. *Ribsden, Bagshot, Surrey.*

1895, April 9. Claus, Wm. H. 31, *Mauldeth Road, Fallowfield.*

1884, Nov. 4. Corbett, Joseph. *Town Hall, Salford.*

1853, Jan. 25. Cottam, Samuel, F.R.A.S., F.R. Hist. S., F.C.A. 49, *Spring Gardens.*

Date of Election.

1859, Jan. 25. Coward, Edward. *Heaton Mersey, near Manchester.*
1876, April 18. Cunliffe, Robert Ellis. *Halton Bank, Pendleton.*

1871, Nov. 8. Dale, Richard Samuel, B.A., 1, *Chester Terrace, Chester Road.*
1853, April 19. Darbishire, Robert Dukinfield, B.A., F.S.A. *St. James' Square.*
1895, April 9. Dawkins, Wm. Boyd, M.A., F.R.S., Professor of Geology. *Owens College, Manchester.*
1894, Mar. 6. Delépine, Sheridan, M.D., Professor of Pathology. *Owens College.*
1879, Mar. 18. Dent, Hastings Charles, F.L.S., F.R.G.S. 20, *Thurloe Square, London, S.W.*
1887, Feb. 8. Dixon, Harold Bailey, M.A., F.R.S., Professor of Chemistry. *Owens College.*
1895, Jan. 8. Dreyfus, Charles. *The Clayton Aniline Co., Ltd., Clayton.*

1895, April 9. Erskine, Henry Adeane. *Branch Bank of England, Newcastle-on-Tyne.*

1883, Oct. 2. Faraday, Frederick James, F.L.S., F.S.S. *Ramsay Lodge, Slade Lane, Levenshulme.*
1895, April 30. Flux, A. W., M.A., Lecturer in Political Economy. 10, *Amherst Street, Fallowfield.*

1885, Feb. 9. Gee, W. W. Haldane, B.Sc. *Technical School, Princess Street, Manchester.*
1895, April 9. Green, Arthur G. 18, *King's Drive, Heaton Moor, Stockport.*
1881, Nov. 1. Greg, Arthur. *Eagley, near Bolton.*
1874, Nov. 3. Grimshaw, Harry, F.C.S. *Thornton View, Clayton.*
1888, Feb. 7. Grimshaw, William. *Stoneleigh, Sale, and* 75, *Princess Street, Manchester.*
1892, Nov. 15. Groves, W. G. *The Larches, Alderley Edge.*
1875, Feb. 9. Gwyther, Reginald F., M.A., Fielden Lecturer in Mathematics. *Owens College.*

1890, Feb. 18. Harker, Thomas. *Brook House, Fallowfield.*
1862, Nov. 4. Hart, Peter. *Messrs. Tennants & Co., Mill Street, Clayton, Nr. Manchester.*
1873, Dec. 16. Heelis, James. 71, *Princess Street.*
1890, Nov. 4. Heenan, H., M.I.C.E., M.I.M.E. *Manor House, Wilmslow Park, Wilmslow.*
1890, Mar. 4. Henderson, H. A. *Eastbourne House, Chorlton Road.*
1889, Jan. 8. Heywood, Charles J. *Chaseley, Pendleton.*
1833, April 26. Heywood, James, F.R.S., F.G.S., F.S.A. 26, *Kensington Palace Gardens, London, W.*
1895, April 5. Hickson, S. J., M.A., D.Sc., Professor of Zoology. *Owens College.*

Date of Election.	
1884, Jan. 8.	Hodgkinson, Alexander, M.B., B.Sc. 18, *St. John Street.*
1889, Oct. 15.	Hoyle, William Evans, M.A., Keeper of the Manchester Museum. *Owens College.*
1870, Nov. 1.	Johnson, William H., B.Sc. 26, *Lever Street.*
1878, Nov. 26.	Jones, Francis, F.R.S.E., F.C.S. *Manchester Grammar School.*
1890, Jan. 7.	Joseland, H. L., B.A. *Manchester Grammar School.*
1891, Nov. 17.	Joyce, Samuel, Electrical Engineer. *Technical School, Princess Street, City.*
1886, Jan. 12.	Kay, Thomas, J.P. *Moorfield, Stockport.*
1852, Jan. 27.	Kennedy, John Lawson. 47, *Mosley Street.*
1891, Dec. 1.	King, John Edward, M.A., High Master. *Manchester Grammar School.*
1893, Nov. 14.	Lamb, Horace, M.A., F.R.S., &c., Professor of Mathematics, *Medindee, Burton Road, Didsbury.*
1890, Nov. 4.	Langdon, Maurice Julius, Ph.D. 3, *Cooper Street.*
1884, April 15.	Leech, Daniel John, M.D., Professor of Materia Medica. *Owens College.*
1895, Mar. 5.	Levinstein, Ivan, *Wilbraham Road, Fallowfield.*
1857, Jan. 27.	Longridge, Robert Bewick. *Yew Tree House, Tabley, Knutsford.*
1870, April 19.	Lowe, Charles, F.C.S. *Summerfield House, Reddish, Stockport.*
1866, Nov. 13.	McDougall, Arthur, B.Sc. *Fallowfield House, Fallowfield.*
1859, Jan. 25.	Maclure, John William, M.P., F.R.G.S. *Whalley Range.*
1875, Jan. 26.	Mann, John Dixon, Professor of Medical Jurisprudence, M.D., F.R.C.P., Lond. 16, *St. John Street.*
1864, Nov. 1.	Mather, William. *Iron Works, Salford.*
1873, Mar. 18.	Melvill, James Cosmo, M.A., F.L.S. *Brook House, Sedgeley Park, Prestwich.*
1879, Dec. 30.	Millar, John Bell, M.E., Lecturer in Engineering, *Owens College.*
1881, Oct. 18.	Mond, Ludwig, Ph.D., F.R.S., &c. *Winnington Hall, Northwich.*
1894, Feb. 6.	Mond, Robt., M.A. *Winnington Hall, Northwich.*
1873, Mar. 4.	Nicholson, Francis, F.Z.S. 111, *Portland Street.*
1889, April 16.	Norbury, George. *Hillside, Prestwich Park, Prestwich.*
1862, Dec. 30.	Ogden, Samuel. 10, *Mosley Street West.*
1884, April 15.	Okell, Samuel, F.R.A.S. *Overley, Langham Road, Bowdon.*
1844, April 30.	Ormerod, Henry Mere, F.G.S. 5, *Clarence Street.*

Date of Election.

1892, Feb. 23. Pankhurst, Richard Marsden, LL.D. (Lond.), Barrister-at-Law. *St. James' Square, Manchester.*

1861, April 30. Parlane, James, *Rusholme.*

1876, Nov. 28. Parry, Thomas, F.S.S. *Grafton House, Ashton-under-Lyne.*

1892, Nov. 15. Perkin, W. H., jun., Ph.D., F.R.S., Professor of Organic Chemistry. *Owens College.*

1885, Nov. 17. Phillips, Henry Harcourt, F.C.S. 183, *Moss Lane East, Manchester.*

1854, Jan. 24. Pochin, Henry Davies, F.C.S. *Bodnant Hall, Conway.*

1854, Feb. 7. Ramsbottom, John, M. Inst. C.E. *Fernhill, Alderley Edge.*

1888, Feb. 21. Rée, Alfred, Ph.D., F.C.S. 1, *Brighton Grove, Rusholme.*

1869, Nov. 16. Reynolds, Osborne, LL.D., M.A., F.R.S., M. Inst. C.E., Professor of Engineering, Owens College. *Ladybarn Road, Fallowfield.*

1884, April 3. Rhodes, James, F.R.C.S. *Glossop.*

1880, Mar. 23. Roberts, D. Lloyd, M.D., F.R.S.Ed., F.R.C.P. (London). *Ravenswood, Broughton Park.*

1864, Dec. 27. Robinson, John, M. Inst. C.E. *Westwood Hall, Leek.*

1858, Jan. 26. Roscoe, Sir Henry Enfield, B.A., LL.D., D.C.L., F.R.S., F.C.S. 10, *Bramham Gardens, Wetherby Road, London, S.W.*

1893, Mar. 21. Schill, C. H. 117, *Portland Street, Manchester.*

1842, Jan. 25. Schunck, Edward, Ph.D., F.R.S., F.C.S. *Kersal.*

1873, Nov. 18. Schuster, Arthur, Ph.D., F.R.S., F.R.A.S., Professor of Physics. *Owens College.*

1890, Nov. 4. Sidebotham, Edward. *Earlesdene, Bowdon.*

1890, Jan. 21. Sidebotham, James Nasmyth. *Parkfield, Groby Place, Altrincham.*

1886, April 6. Simon, Henry, M.I.C.E. *Lawnhurst, Didsbury.*

1894, Jan. 9. Stevens, Marshall, F.S.S. *Bolton Lodge, Eccles.*

1894, Nov. 13. Stirrup, Mark, F.G.S. *High Thorn, Stamford Road, Bowdon.*

1892, Nov. 29. Swindells, Rupert, M.I.C.E. *Wilton Villa, The Firs, Bowdon.*

1895, April 9. Tatton, Reginald A., Engineer to the Mersey and Irwell Joint Committee. *Mosley Street, Manchester.*

1893, Nov. 14. Taylor, R. L., Science Master. *Central School, Mosley Street, City.*

1884, Mar. 18. Thompson, Alderman Joseph. *Riversdale, Wilmslow.*

1873, April 15. Thomson, William, F.R.S.E., F.C.S., F.I.C. *Royal Institution, Manchester.*

1889, April 30. Thornber, Harry. *Rookfield Avenue, Sale.*

1860, April 17. Trapp, Samuel Clement. *Mosley Street.*

Date of Election.

1895, Mar. 5. Ward, Adolphus William, LL.D., Litt.D. Principal of the Owens College, Manchester. *The Hollies, Fallowfield.*

1879, Dec. 30. Ward, Thomas. *Wadebrook House, Northwich.*

1873, Nov. 18. Waters, Arthur William, F.G.S. *Sunny Lea, Davos Dörfli, Switzerland.*

1892, Nov. 15. Weiss, F. Ernest, B.Sc., Professor of Botany, Owens College. 4, *Clifton Avenue, Fallowfield.*

1895, April 9. Whitehead, James. *Lindfield, Fulshaw Park, Wilmslow.*

1859, Jan. 25. Wilde, Henry, F.R.S. *The Hurst, Alderley Edge.*

1859, April 19. Wilkinson, Thomas Read. *Manchester and Salford Bank, Mosley Street.*

1888, April 17. Williams, Sir E. Leader, M. Inst. C.E. *Spring Gardens, Manchester.*

1889, April 16. Wilson, Thomas B. 37, *Arcade Chambers, St. Mary's Gate.*

1860, April 17. Woolley, George Stephen. *Victoria Bridge, Salford.*

1863, Nov. 17. Worthington, Samuel Barton, M. Inst. C.E. *Mill Bank. Bowdon, and* 37, *Princess Street, Manchester.*

1865, Feb. 21. Worthington, Thomas, F.R.I.B.A. 46, *Brown Street.*

1894, Nov. 13. Worthington, Wm. Barton, B.Sc., M.I.C.E. 2, *Wiltons Polygon, Cheetham Hill.*

N.B.—Of the above list the following have compounded for their subscriptions, and are therefore life members :

Brogden, Henry.
Johnson, William H., B.Sc.
Bradley, N.
Lowe, Charles, F.C.S.
Bailey, Charles, F.L.S.
Worthington, Wm. Barton, B.Sc., &c.

Honorary Members.

1892, April 26. Abney, Capt. W. De Wyversley, C.B., R.E., F.R.S. *S. Kensington, London.*

1892, April 26. Amagat, E. H. Honorary Professor, Faculty of Sciences. *Lyons.* 34, *Rue St. Lambert, Paris.*

1894, April 17. Appell, Paul, Membre de l'Institut, Professor at the Faculty of Sciences. *Paris.*

1887, April 19. Armstrong, Wm. George, Lord, C.B., D.C.L., LL.D., F.R.S. *Newcastle-on-Tyne.*

1892, April 26. Ascherson, Paul F. Aug., Professor of Botany. *Berlin.*

1892, April 26. Baeyer, Adolf von, Professor of Chemistry. For. Mem. R.S. 1, *Arcisstrasse, Munich.*

1886, Feb. 9. Baker, Sir Benjamin, LL.D., M. Inst.C.E., F.R.S. 2, *Queen's Square Place, Westminster, S.W.*

Date of Election.	
1886, Feb. 9.	Baker, John Gilbert, F.R.S. *Kew.*
1886, Feb. 9.	Berthelot, Prof. Marcellin, For. Mem. R.S., Membre de l'Institut. *Paris.*
1895, April 30.	Beilstein, F., Professor of Chemistry, Technological Institute. *St. Petersburg.*
1892, April 26.	Boltzmann, Ludwig, Professor of Physics. *Vienna.*
1892, April 26.	Brioschi, Francesco. Pres. R. Accad. dei Lincei. 4, *Place Cavour, Milan.*
1886, Feb. 9.	Buchan, Alexander, F.R.S.E. 72, *Northumberland Street, Edinburgh.*
1860, April 17.	Bunsen, Robert Wilhelm, Ph.D., For. Mem. R.S., Prof. of Chemistry. *Heidelberg.*
1888, April 17.	Cannizzaro, S., For. Mem. R.S., Prof. of Chemistry. *University of Rome.*
1889, April 30.	Carruthers, William, F.L.S., F.R.S., Late Keeper of Botanical Dept., British Museum. *Central House, Central-hill, London, S.E.*
1866, Oct. 30.	Clifton, Robert Bellamy, M.A., F.R.S., F.R.A.S. Prof. of Natural Philosophy, Oxford. *New Museum, Oxford.*
1889, April 30.	Cohn, Ferdinand, Professor of Botany. 26, *Schweidnitzer Stadtgraben, Breslau.*
1887, April 19.	Cornu, Professor Alfred, For. Mem. R.S., Membre de l'Institut. *École Polytechnique, Paris.*
1892, April 26.	Curtius, Theodor, Professor of Chemistry. *Kiel.*
1892, April 26.	Darboux, Gaston, Membre de l'Institut, Professor at the Faculty of Sciences. 36, *Rue Gay Lussac, Paris.*
1886, Feb. 9.	Dawson, Sir John William, C.M.G., M.A., LL.D., F.R.S., F.G.S. *McGill College, Montreal.*
1894, April 17.	Debus, H., Ph.D., F.R.S. 1, *Obere Sophienstrasse, Cassel, Hessen, Germany.*
1888, April 17.	Dewalque, Gustave, Professor of Geology. *University of Liège.*
1892, April 26.	Dohrn, Dr. Anton. *Zoological Station, Naples.*
1892, April 26.	Du Bois-Reymond, Emil, Professor of Physiology. For. Mem. R.S. 15, *Neue Wilhelm Strasse, Berlin.*
1892, April 26.	Dyer, W. T. Thiselton, C.B., F.R.S., Director, Royal Botanic Gardens. *Kew.*
1892, April 26.	Edison, Thomas Alva. *Orange, N.J., U.S.A.*
1895, April 30.	Elster, J., Ph.D., 6, *Lessing Strasse, Wolfenbüttel.*
1886, April 30.	Farlow, W. G., Professor of Botany. *Harvard College, Cambridge, Mass., U.S.A.*
1889, April 30.	Flower, Sir William Henry, K.C.B., LL.D., F.R.S. Director of Nat. Hist. Dept., British Museum.

Date of Election.	
1889, April 30.	Foster, Michael, M.A., M.D., LL.D., Sec. R.S., Professor of Physiology. *Trinity College, Cambridge.*
1860, Mar. 9.	Frankland, Edward, Ph.D., M.D., LL.D., D.C.L., V.P.C.S., F.R.S., Cor. Mem. Inst. Fr. (Acad. Sci.), &c. *The Yews, Reigate Hill, Reigate.*
1892, April 26.	Friedel, Ch., D.C.L., Membre de l'Institut, Professor at the Faculty of Sciences. 9, *Rue Michelet, Paris.*
1892, April 26.	Fürbringer, Max, Professor of Anatomy. *Jena.*
1892, April 26.	Gegenbaur, Carl, For. Mem. R.S., Professor of Anatomy. *Heidelberg.*
1895, April 30.	Geitel, H., 6, *Lessing Strasse, Wolfenbüttel.*
1892, April 26.	Gibbs, J. Willard, Professor of Mathematical Physics, Yale University, *Newhaven, Connecticut, U.S.A.*
1894, April 17.	Glaisher, J. W. L., D.Sc., F.R.S. *Trinity College, Cambridge.*
1894, April 17.	Gouy, A., Professor at the Faculty of Sciences. *Lyons.*
1894, April 17.	Guldberg, Cato. M., Professor of Applied Mathematics. *Christiania, Norway.*
1894, April 17.	Harcourt, A. G. Vernon, F.R.S. Lee's Reader in Chemistry, Christ Church. *Cowley Grange, Oxford.*
1894, April 17.	Heaviside, Oliver, F.R.S. *Paignton, Devon.*
1892, April 26.	Hermite, Ch., For. Mem. R.S., Membre de l'Institut, 2, *Rue de la Sorbonne, Paris.*
1892, April 26.	Hill, G. W. *West Nyack, N.Y., U.S.A.*
1848, Jan. 25.	Hind, John Russell, LL.D., F.R.S., F.R.A.S., Cor. Mem. Inst. Fr. (Acad. Sci.). 3, *Cambridge Park Gardens, Twickenham.*
1881, April 17.	Hittorf, Johann Wilhelm, Professor of Physics. *Polytechnicum, Münster.*
1892, April 26.	Hoff, J. Van't, Professor of Chemistry. *Amsterdam.*
1892, April 26.	Hooker, Sir Joseph Dalton, F.R.S. *Sunningdale. Berks.*
1869, Jan. 12.	Huggins, William, LL.D., D.C.L., F.R.S., F.R.A.S., Cor. Mem. Inst. Fr. (Acad. Sci.). 90, *Upper Tulse Hill, Brixton, London, S.W.*
1851, April 22.	Kelvin, William Thomson, Lord, M.A., D.C.L., LL.D., Pres. R.S., F.R.S.E., Prof. of Nat. Phil. in Univ. of Glasgow. For. Assoc. Inst. Fr. (Acad. Sci.). 2, *College, Glasgow.*
1892, April 26.	Klein, Felix, Professor of Mathematics, For. Mem. R.S. 3, *Wilhelm Weber Strasse, Göttingen.*
1894, April 17.	Könisberger, L., Professor of Mathematics. *Heidelberg.*
1895, April 30.	Lacaze-Duthiers, Henri de, Membre de l'Institut, Prof. à la Sorbonne. 7, *Rue de l'Estrapade, Paris.*
1892, April 26.	Ladenburg, A., Professor of Chemistry. 3, *Kaiser Wilhelm Strasse, Breslau.*

Date of Election.

1887, April 19.	Langley, S. P. *Smithsonian Institution, Washington, U.S.A.*
1894, April 17.	Lie, M. Sophus, Professor of Mathematics. *Leipsic.*
1892, April 26.	Liebermann, C., Professor of Chemistry. 29, *Matthäi-Kirch Strasse, Berlin.*
1887, April 19.	Lockyer, J. Norman, C.B., F.R.S., Corr. Mem. Inst. Fr. (Acad. Sci.) *Science School, Kensington.*
1889, April 30.	Lubbock, Sir John, Bart., M.P., D.C.L., LL.D. F.R.S., 15, *Lombard Street, London, E.C.*
1892, April 26.	Marshall, Alfred, Professor of Political Economy. *Balliol Croft, Madingley Road, Cambridge.*
1892, April 26.	Mascart, E., For. Mem. R.S., Membre de l'Institut, Professor at the Collége de France. 176, *Rue de l'Université, Paris.*
1889, April 30.	Mendeléeff, D., For. Mem. R.S. *St. Petersburg.*
1892, April 26.	Meyer, Victor, Professor of Chemistry. 55, *Plöck Strasse, Heidelberg.*
1895, April 30.	Mittæg-Leffler, Gösta, Professor of Mathematics. *Djursholm, Stockholm.*
1892, April 26.	Moissan, H., Membre de l'Institut, Professor at the École Supérieure de Pharmacie. 7, *Rue Vauquelin, Paris.*
1894, April 17.	Murray, John, LL.D., D.Sc. *Challenger Office,* 45, *Frederick Street, Edinburgh.*
1894, April 17.	Neumayer, Professor G., Director of the Seewarte. *Hamburg.*
1887, April 19.	Newcomb, Simon, For. Mem. R.S., Professor of Mathematics and Astronomy. *Johns Hopkins University, Baltimore, U.S.A.*
1894, April 17.	Ostwald, W., Professor of Chemistry. 34, *Bürderstrasse, Leipsic.*
1886, Feb. 9.	Pasteur, Louis, For. Mem. R.S., Membre de l'Institut. *Paris.*
1892, April 26.	Perkin, W. H., F.R.S. *The Chestnuts, Sudbury, Harrow.*
1894, April 17.	Pfeffer, W., Professor of Botany. *Botanisches Institut, Leipsic.*
1851, April 29.	Playfair, Lyon, Lord, K.C.B., LL.D., Ph.D., F.R.S., F.G.S., V.P.C.S., &c. 68, *Onslow Gardens, London, S.W.*
1892, April 26.	Poincaré, H., Membre de l'Institut, Professor at the Faculty of Sciences. 63, *Rue Claude Bernard, Paris.*
1866, Jan. 23.	Prestwich, Joseph, F.R.S., F.G.S., Corr. Mem. Inst. Fr. (Acad. Sci.) *Shoreham, near Sevenoaks.*
1892, April 26.	Quincke, G. H., Professor of Physics. For. Mem. R.S. 60, *Haupt Strasse, Heidelberg.*

Date of Election.

1892, April 26. Raoult, F., Dean of the Faculty of Sciences. 2, *Rue des Alpes, Grenoble.*

1849, Jan. 23. Rawson, Robert, F.R.A.S., *Havant, Hants.*

1866, Feb. 9. Rayleigh, John William Strutt, Lord, M.A., D.C.L., (Oxon,), LL.D. (Univ. McGill), Sec. R.S., F.R.A.S. *Tirling Place, Witham, Essex.*

1889, April 30. Résal, Henri, Membre de l'Institut, Professor of Mechanics. *École Polytechnique, Paris.*

1889, April 30. Routh, Edward John, Sc.D., F.R.S., *Newnham Cottage, Cambridge.*

1894, April 17. Rowland, Henry A., For. Mem. R.S., Professor of Physics. *Johns Hopkins University, Baltimore, U.S.A.*

1872, April 30. Sachs, Julius von, Ph.D., For. Mem. R.S., Professor of Botany. *Würzburg.*

1889, April 30. Salmon, Rev. George, D.D., D.C.L., LL.D., F.R.S., Regius Professor of Divinity. *Provost's House, Trinity College, Dublin.*

1892, April 26. Salvin, Osbert, F.R.S. *Haslemere.*

1894, April 17. Sanderson, J. S. Burdon, F.R.S., Regius Professor of Medicine. *Oxford.*

1892, April 26. Sharpe, R. Bowdler, LL.D. *British Museum, Cromwell Road, London, S.W.*

1892, April 26. Solms, H. Graf zu, Professor of Botany. *Strassburg.*

1869, Dec. 15. Sorby, Henry Clifton, LL.D., F.R.S., F.G.S., &c. *Broomfield, Sheffield.*

1851, April 29. Stokes, Sir George Gabriel, Bart., M.A., LL.D., D.C.L., F.R.S., Lucasian Professor of Mathem. Univ. Cambridge, F.C.P.S., Cor. Mem. Inst. Fr. (Acad. Sci.), &c. *Lensfield Cottage, Cambridge.*

1894, April 17. Stone, Professor E. J., F.R.S. *Radcliffe Observatory, Oxford.*

1886, Feb. 9. Strasburger, Eduard, D.C.L., Professor of Botany. *Bonn.*

1895, April 30. Suess, Eduard, For. Mem. R.S., Professor of Geology. 9, *Africanergasse, Vienna.*

1861, Jan. 22. Sylvester, James Joseph, M.A., D.C.L., LL.D., F.R.S., Savilian Prof. of Geom. in the Univ. of Oxford, Cor. Mem. Inst. Fr. (Acad. Sci.), &c. *New College, Oxford.*

1868, April 28. Tait, Peter Guthrie, M.A., F.R.S.E., &c., Professor of Natural Philosophy, Edinburgh. 38, *George Square, Edinburgh.*

1895, April 30. Thompson, Joseph John, Sc.D., F.R.S., Professor of Experimental Physics. 6, *Scrope Terrace, Cambridge.*

1894, April 17. Thorpe, T. E., Ph.D., F.R.S. *Laboratory, Somerset House, London, W.C.*

1872, April 30. Trécul, A., Membre de l'Institut. *Paris.*

Date of Election.

1894, April 17. Turner, Sir William, F.R.S., Professor of Anatomy. *Edinburgh.*

1886, Feb. 9. Tylor, Edward Burnett, F.R.S., D.C.L. (Oxon.), LL.D. (St. And. and McGill Colls.), Keeper of University Museum. *Oxford.*

1894, April 17. Vines, Sidney Howard, F.R.S., Sherardian Professor of Botany. *Headington Hill, Oxford.*

1894, April 17. Waage, P., Professor of Chemistry. *Christiania, Norway.*

1892, April 26. Walker, General Francis A., Professor of Political Economy. 237, *Beacon Street, Boston, U.S.A.*

1894, April 17. Warburg, Professor E. *Physikalisches Institut, Neue Wilhelmstrasse, Berlin.*

1894, April 17. Ward, H. Marshall, Sc.D., F.R.S., Professor of Botany. *Cooper's Hill, Englefield Green, Surrey.*

1894, April 17. Weismann, August, Professor of Zoology. *Freiburg-i.-B.*

1892, April 26. Wiedemann, G. Prof. of Physics, For. Mem. R.S. 35, *Thalstrasse, Leipsic.*

1889, April 30. Williamson, Alexander William, Ph.D., LL.D., F.R.S., Corr. Mem. Inst. Fr. (Acad. Sci.). *High Pitfold, Shottermill, Haslemere.*

1886, Feb. 9. Young, Charles Augustus, Professor of Astronomy. *Princeton College, N.J., U.S.A.*

1888, April 17. Zirkel, Ferdinand, Professor of Mineralogy. *University of Leipsic.*

1895, April 20. Zittel, Carl Alfred von, Professor of Palæontology and Geology. *University of Munich.*

CORRESPONDING MEMBERS.

Date of Election.

1866, Jan. 23. De Caligny, Anatole, Marquis, Corres. Mem. Acadd. Sc. Turin and Caen. Socc. Agr. Lyons, Sci. Cherbourg, Liège.

1850, April 30. Harley, Rev. Robert, Hon. M.A., Oxford, F.R.S., F.R.A.S., Hon. M.R.S., Queensland. *Rosslyn, Westbourne Road, Forest Hill, London, S.E.*; and *The Athenæum Club, London, S. W.*

1882, Nov. 14. Herford, Rev. Brooke, 91, Fitzjohn's Avenue, Hampstead, London, N.W.

1859, Jan. 25. Le Jolis, Auguste-François, Ph.D. Archiviste-perpétuel and late President of the Soc. Nat. Sc., Cherbourg, &c. *Cherbourg.*

1857, Jan. 27. Lowe, Edward Joseph, F.R.S., F.R.A.S., F.G.S., Mem. Brit. Met. Soc., &c. *Shirenewton Hall, near Chepstow.*

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