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MEMOIRS AND PROCEEDINGS

OF

THE MANCHESTER
LITERARY & PHILOSOPHICAL SOCIETY.

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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

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THE MANCHESTER LITERARY AND PHILOSOPHICAL SOCIETY.

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Ordinary Meeting, October 6th, 1891.

EDWARD SCHUNCK, PH.D., F.R.S., F.C.S., President, in the Chair.

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

The PRESIDENT unveiled and presented to the Society a bronze bust of the late Dr. R. Angus Smith, F.R.S., taken from a bust in white marble by T. Nelson MacLean, and briefly referred to Dr. Smith's services to science, his long connection with the Society, and particularly to his work for it as the author of the *Memoir of Dalton and History of the Atomic Theory*, and of the *Centenary of Science in Manchester*, published by the Society.

A hearty vote of thanks was awarded to Dr. Schunck for his valuable gift.

Mr. FARADAY briefly recapitulated some previous interesting gifts to the Society, including the bust of Dr. William Henry, F.R.S., which Sir Francis Chantrey was commissioned to execute for it in 1836; the bust of Eaton Hodgkinson, by Slater, presented in 1862 by Dr. Joule, Dr. Schunck, Mr. (subsequently Sir) John Hawkshaw, Mr. (subsequently Sir) Joseph Whitworth, Mr. James Heywood, Mr. R. P. Greg, Mr. Thomas Turner, Mr. G. R. Stephenson, and other members; a collection of the MSS. of Sturgeon and Eaton Hodgkinson, and a manuscript volume of lectures on chemistry by Mr. Thomas Henry, one of the founders of the Society, presented in 1863; Dr. Dalton's chemical apparatus, presented by Dr. William Charles Henry, to whom the apparatus was bequeathed by Dalton; a portrait of Dr. Joule by G. Patten, A.R.A., presented by Mr. Binney and others in 1864, and a bust of Dr. Dalton, presented by Mrs. Samuel Fletcher in the same year; the manuscript journals of Mr. George Walker, presented by Mr. B. H. Green in 1871, and a collection of Dalton's MSS., presented by Dr. W. C. Henry in 1863; the manuscript journals and other papers of Mr. Thomas Heelis, F.R.A.S., presented by Dr. Crompton and Mr. John Heelis; a bust of James Wolfenden, of Hollinwood, a noted mathematician (B. 1754, D. 1841), who calculated the first tide-table for Liverpool in 1807, presented by Mr. Binney in 1873; a portrait of Dr. Percival, one of the first Presidents, painted by Crozier, and presented by Mr. Francis Nicholson in 1878; a portrait of Eaton Hodgkinson, painted by Duval, and presented by Sir Thomas Fairbairn in 1878; a portrait of Mr. Binney, painted by W. H. Johnston, and presented by Dr. Joule in 1879; and medallion portraits of Mr. and Mrs. G. Walker (the former one of the founders of the Society), presented by members of the Council in 1883.

Mr. FARADAY stated that he had compiled this list from the records of the Society, and remarked that as it was incomplete, it would be more interesting if other members would supplement it.

The following note "On Summer Lightning" was read by the author, Professor ARTHUR SCHUSTER, F.R.S. :—

"During a recent journey to Switzerland I happened to be, late in the evening, at a considerable height on the glacier which stretches down from the Dent Blanche towards Ferpecle, and there noticed a phenomenon which has probably been described before, although I cannot recollect any definite reference to it. The sky was perfectly clear, but a cloud filled the valley of Evolena, and reached up to a height of about 7,000 feet, while I was at an altitude of about 11,000. About once every two or three minutes there was an electric discharge, of the kind known as sheet lightning, from the cloud upwards. At the time, I was under the impression that the discharge took place between the cloud and the rocks of the Dent Blanche; but, on consideration, it seems to me equally probable that the discharge took place towards the upper parts of the atmosphere. The following reflections are suggested by the phenomenon:—The cloud lay in a deep-cut valley, the mountains on all sides rising high above it. If the cloud was at the same electric potential as the surrounding parts of the earth, there could be no discharge between them, and we should certainly not expect a discharge towards the upper regions of the atmosphere to take place from the inside of a cavity. The cloud therefore must have been at a different potential from the mountains; but unless there was some cause at work which kept up that difference of potential we could not have such a series of flashes lasting certainly for more than an hour. The cloud seemed to rise up in the valley as time went on, but probably the lower boundary kept stationary, while the upper boundary of the cloud extended more and more upwards as the mountain sides grew colder. If the water-drops were charged electrically, and increased in size, this would of course account for a gradual rise in potential. We know too little, however, of what happens when a cloud forms in an electric field, to speculate further."

The following note on "Halos as Prognostics of Bad Weather" was read by the author, Professor ARTHUR SCHUSTER, F.R.S.:—

"The halo I am referring to is the ring of light, generally slightly coloured, which is occasionally seen surrounding the sun at an angle of about 22°. The explanation of the halo is to be found in the refraction of light through small ice crystals. The halo is generally seen in front of a cyclone, and is considered a prognostic of bad weather. The following observations will show, however, that the prognostic is by no means as certain as it is sometimes supposed to be. On Tuesday, the 25th September, about 12 o'clock, the sky above the Zermatt Valley became pretty suddenly covered with a thin film of cirrus clouds, and a halo appeared surrounding the sun. The barometer during that day was rising slightly. The sky cleared in the afternoon, and the two succeeding days were perfectly fine. On one of these days—I am sorry to say I have not kept a record which it was—another halo was seen by others, though not by myself. On Friday, the 28th, the sky clouded over during the morning, and there was a drizzling rain in the afternoon, the barometer keeping high all the time. It cleared about 4 a.m. on Saturday and remained perfectly clear that day. I have not, unfortunately, access to the Swiss weather charts, but I understand that there was much bad weather on the Italian side of the Alps during the days the halos were seen. Cirrus clouds, supposed to be ice-clouds, are often seen without the halo, and there is, *a priori*, no reason why halos should only be seen in that kind of cirrus sky which lies in the front of the track of a cyclone, but observation seems to point in that direction. Halo prognostics are known to break down when a cyclone changes its direction, but it is also possible that in the high regions of the Alps the atmospheric conditions are somewhat different than over plains. At any rate, a more systematic record of all visible halos seems called for, especially in the districts which contain mountains of high altitudes."

The following note "On Dust Figures" was also read by Professor ARTHUR SCHUSTER, F.R.S., the author:—

"In the house which I occupy at present there are two sitting rooms, separated by a wide opening, with a slightly curved top. The opening is closed by a curtain hanging down from a pole about four inches above its highest point. The former tenant used a wooden pole on one side of the opening. That pole was removed, and I substituted a brass pole on the other side of the wall, so that the wall above the opening, where the previous pole was, is now perfectly clear on that side on which the previous pole had been placed. I took possession of the house two years ago. The wall paper in both rooms was carefully removed, the walls cleaned, and a white paper put up, which was subsequently distempered with a uniform tint. About a year ago I noticed, what seems to me to be a very remarkable fact. A black band was seen stretching across the wall above the opening, exactly at the place from which the pole had been removed. This black band, it was ascertained, is due to dust having deposited in greater quantity where the pole had previously been than in other places. Leaving out of account any possible effect of the brass pole on the other side of the wall, we are driven to the conclusion: that a wall which has been stripped of its paper, been washed and then been repapered, shows, by the way the dust deposits on it, the place where, two years ago, a wooden pole had been placed, while the old paper was still on the wall."

(Added, October 27.)—"Since writing the above, and partly in consequence of the remarks made by some of the speakers at the meeting, I have made further inquiries, and heard from the former tenant that he believes an iron beam is imbedded in the brick wall at the place where the dust line shews. This beam was not visible when the paper was removed, and is therefore completely covered with plaster. Nevertheless it may account for the dust mark by causing

some inequality in the shape or texture of the surface of the wall. No unevenness is visible, which shows what a delicate test we have in the deposit of dust in tracing slight inequalities in the nature of a surface."

The following "Memorandum on Lifeboats, as to the relative values of Stability *versus* Self-righting Power," was read by the author, Mr. JOSEPH CORBETT:—

"Lifeboats have been in use for more than a century, but the self-righting principle was only introduced in 1852 by the Northumberland Prize Committee. This Committee recorded the principle as a contested one, but decided to try it. No methodical competitive trial of the principle has ever been made, and it has been continuously challenged as being so detrimental to the working powers of a lifeboat as to be not worth having. The Southport Lifeboat disaster in December, 1886, when the crews of two self-righting lifeboats were all drowned, except two men, called public attention very urgently to the dangers of these boats; but, unfortunately, the general drift of criticism was that lifeboats should be made more positively self-righting than heretofore. Professor Osborne Reynolds read a paper before this Society, 'On Methods of Investigating the Qualities of Lifeboats,' in which he advocated experiments with models. The Committee of the Royal National Lifeboat Institution appointed a special sub-committee 'to make a searching investigation into the self-righting and other properties of the Institution's boats,' and this committee, after three months of laborious inquiry, and experiments with self-righting boats, made its final report, in April, 1887, recommending the introduction of copper air-cases in place of canvas-covered wooden ones, and 'a careful revision of the weights and materials used in the several parts of the boats, ensuring increased stability, strength, and seaworthiness, at the same time largely increasing their self-righting power,' also recommending the appointment of a consulting Naval Architect, and making other good suggestions, all of which were immediately adopted. The Southport Local Committee, after careful deliberation, obtained, through the Institution, a sailing lifeboat, designed by Mr. G. L. Watson from their sketches, which is the most powerful existing lifeboat, and non-righting. I had corresponded with some of the chief officials of the Institution, and with other good authorities on lifeboat work, in 1867-68, in connection with a paper on lifeboats, read by me before the Manchester Institution of Engineers, in which I ventured to challenge the self-righting boats as compared with the Tubular and the Norfolk boats; and twenty years continued attention to the question had materially strengthened my convictions. Having obtained, with some difficulty, working drawings of all the types of lifeboats used by the Institution, I got working models made to one-twelfth or one-sixteenth scale, ascertained their 'curves of stability' and other chief elements for comparison, prepared a paper on the subject, and was favoured by the Building Committee of the Institution with a long discussion on it, on May 6th, 1889. The Committee then requested their Naval Architect, Mr. G. L. Watson, to embody some of my suggestions in a design for a large Sailing Lifeboat, not self-righting. Having read a *résumé* of my paper before the Institution of Naval Architects on March 28th, 1890, I received most encouraging letters from Mr. R. E. Froude, and from several naval architects, and eventually the Committee of the Lifeboat Institution very liberally offered me £600 to pay for a non-righting Rowing and Sailing Lifeboat on a modified plan, resulting from conferences with Lancashire honorary officers and coxswains of the Institution. But our deputation made the further request, which was kindly granted, that this liberal offer should be set aside and Mr. G. L. Watson commissioned, with 'a perfectly free hand,' to design a lifeboat to compete with a self-righting lifeboat of similar size. These lifeboats, with several others representing various approved types, are to be subjected to exhaustive practical trials early next year; and it is confidently hoped that, as the result of these practical experiments, a very superior type of lifeboat may soon be available. It has been often erroneously stated on behalf of the self-righting boats, that the elements which give the self-righting power also add to the working stability and safety of a boat; but the contrary may be proved point by point—thus:—*1st.* The high end-air-cases are *the essential feature* of all self-righting boats. They seriously hinder progress to windward, either under sails or oars, by enlarging the total end-area. They increase the liability to being capsized by increasing the side area exposed to the waves. They also hinder the access to stem and stern, and unduly restrict the space available for the crew and passengers. On the other hand, it must be conceded that they protect the crew from a head sea. *2nd.* It is requisite that a self-righting lifeboat be only lightly loaded in proportion to its effective buoyancy. This reduces the momentum of the boat in proportion to its end area, rendering it less capable of holding way through the waves, and also causing it to drift more to leeward when across the wind. The reduced weight in proportion to bulk, like reduced specific gravity, renders the boat more liable to capsize from the violent movements of the waves. On the other hand, this increased buoyancy tends to ride over, rather than to dash through, the wave crests; and thereby to keep the crew somewhat less wet. *3rd.* The cross-sectional form of a self-righting boat must be something like that of a barrel, and so restricted in breadth that for all angles the meta-centre shall be above the centre of gravity; resulting in the meta-centric curve not surrounding the centre of gravity when delineated on the body plan. This necessitates a narrow and high form of boat, with small side-air-cases, and therefore with small stability. My experiments indicate that from 50 to 60 per cent of the available stability at all angles up to about 90°, has to be sacrificed in order to obtain the self-righting quality. This serious diminution of stability necessarily increases the liability to capsizing. It also proportionately reduces the sail-carrying power, and thereby the power of beating to windward, and it hinders rowing by so increasing the boats' rolling as to have earned for the self-righting lifeboats the nickname of 'roly poly boats.' *4th.* The heavy keel required for a self-righting boat is claimed as a valuable attribute of the system ; but, in fact, heavy keels are used on all classes of sailing boats, and non-righting boats can advantageously carry heavier keels than the self-righters. Thus, I find no element of the self-righting power which is, on the whole, beneficial to the ordinary use of a lifeboat ; and, therefore, I venture to hope that the forthcoming practical competition between different types of lifeboats will result in the success of some more stable type. The Northumberland Prize Committee, who first introduced self-righting, only valued this quality at 6 points out of 100 points apportioned to the various desirable qualities in lifeboats ; yet, for nearly forty years past, 50 or 60 per cent of stability and sailing power, and 30 per cent of momentum, have been sacrificed for this one object. Now that methodical competitive examinations are at last to be extended to lifeboats, we may hope for increased safety and greatly increased efficiency in the lifeboat service, which has for a century past been one of our noblest and most honoured institutions."

[*Microscopical and Natural History Section.*]

Ordinary Meeting, October 12th, 1891.

ALEXANDER HODGKINSON, M.B., B.Sc., President of the Section, in the Chair.

Mr. HYDE showed a number of natural history specimens mounted in glass-topped boxes to illustrate the method he has adopted for preparing such objects for class-teaching purposes. They are packed up to the glass top with cotton wool, so that they will stand any ordinary handling. Mr. T. ROGERS exhibited a number of dried specimens of *Gentiana pneumonanthe* collected by him during the past summer near Moelfre Bay, Anglesea.

A general conversation followed on rooks collecting acorns, edible fungi, variation in the common star-fish, the parasites found on the common dung-beetle, etc.

Ordinary Meeting, October 20th, 1891.

EDWARD SCHUNCK, PH.D., F.R.S., F.C.S., President, in the Chair.

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

Mr. R. F. GWYTHER, M.A., called attention to a peculiar shrivelling of the leaves of trees, which occurred during the gales immediately following the hot weather early in

September. The shrivelling appeared to be sudden, partial, and quite distinct from the ordinary withering process.

Professor OSBORNE REYNOLDS, F.R.S., described a phenomenon which often occurs in the breaking of glass water-gauges in the Engineering Laboratory of Owens College. The peculiarity of which Professor REYNOLDS wished to have an explanation is that the fracture is indicated by a slight sharp crack, which, after a pause, is followed by a serious loud explosion, and the whole gauge disappears almost in dust. The explosion occurs after the tube is broken. Professor H. B. DIXON, F.R.S., suggested that the fracture happens at the bottom, where the water is in contact with the tube, and that when the fracture reaches the top the more serious explosion of steam takes place.

Professor H. B. DIXON, F.R.S., read a paper, by himself and Mr. J. A. HARKER, entitled "On the Decomposition, by shock, of Endothermic Compounds."

A paper, entitled "Experiments on the Transmission of Explosions across Air-gaps," by BEVAN LEAN, B.Sc., Dalton Chemical Scholar, and Professor H. B. DIXON, F.R.S., was also read by the latter.

The Rev. T. P. KIRKMAN, F.R.S., communicated a paper on "The 143 Six-letter Functions given by the First Transitive Maximum Group of Six Letters, with full Exhibition of the Values of the Function."

On the Decomposition by shock of Endothermic Compounds. By J. A. Harker, Dalton Chemical Scholar, and H. B. Dixon, F.R.S., Professor of Chemistry in the Owens College.

(*Received October 20th, 1891.*)

In his work "Sur la Force des Matières Explosives," published in 1883, M. Berthelot described some experiments on the decomposition by shock of certain bodies formed with absorption of heat. Most of his experiments were made on gases. He exploded a charge of 0·1 grm. of fulminate of mercury in a strong glass tube holding about 25 cc. of the gas. With acetylene the experiment always succeeded, only about ·01 cc. gas remaining undecomposed, and a deposit of very finely divided amorphous carbon being left on the walls of the vessel. Cyanogen was sometimes wholly decomposed, sometimes not at all. The other gases he succeeded in breaking up were nitric oxide and arseniuretted hydrogen. The decomposition, started by the fulminate, is, according to Berthelot, a detonation propagated from layer to layer with extreme rapidity, and is of the same nature as the 'explosion-wave.'

In the *Journal of the Chemical Society* for 1889, Prof. Thorpe stated that he had discovered accidentally that carbon bisulphide could be detonated with a bright flame in the same way, yielding a mixture of carbon and sulphur. No explosive, he says, would cause the decomposition except fulminate of mercury, and the brown powder, obtained by the action of a fluid alloy of potassium and sodium on carbon bisulphide. The explosion of one-twentieth of a gram of mercury fulminate will decompose the carbon bisulphide vapour filling a tube 600 mm. long and 15 mm. diameter. Thorpe accepts Berthelot's explanation, which he gives as follows:—"The shock of the explosion communicates to the layer of gaseous molecules in immediate proximity to the fulminate an enormous active force, whereby the 'molecular edifice' is shaken to pieces, and the initial active force is augmented to a degree corresponding to the heat evolved in the decomposition of the gas. A new shock is thereby produced in the next layer, and the action is repeated, and so propagated."

According to this view, it would seem that the explosion, once initiated in cyanogen, acetylene or carbon bisulphide, should travel as far as the gas extends, and that the rate of explosion should conform to the laws governing the propagation of the explosion-wave in gaseous mixtures. It appeared, therefore, of interest to determine whether the explosion, set up by the shock of the fulminate, was propagated along a tube filled with one of the gases; and, if so, to measure the rate at which the flame was propagated.

The experiments described below were carried out by one of us—Mr. J. A. Harker.

The first gas tried was acetylene. To produce the shock, a mixture of acetylene and oxygen (2 vols. to 3), one of the most violently explosive gaseous mixtures, was fired in contact with the acetylene. A coiled leaden pipe, 13 mm. in diameter and 20 metres long, was provided with a glass firing-piece and tap at one end, and, at the other, a detachable tube of strong glass and a second tap. The whole was first filled with acetylene, and then a mixture of acetylene and oxygen was driven in at the firing end so as to form a column of about a metre in length. The taps were then closed, and the mixture fired by a spark. The explosion made the "ping" on the walls characteristic of extreme violence, but the flame did not appear at the further end of the tube. On examination it was found that the great bulk of the acetylene was undecomposed. The experiment was repeated with the same result.

An apparatus was then fitted up, to test the action of fulminate of mercury. It consisted of a steel cylinder or 'bomb,' holding about 400 cc., provided with a screw top, through which passed insulated copper wires, and having a tap for admission of gas. This was connected by a union joint with a lead tube similar to that used in the last experiment, having at its other end a strong glass tube and steel tap. The bore through the joint was not less than that of the tube itself. The fulminate used was procured from the Roburite Explosives Company, in the form of detonators containing one gram each. After each explosion the bomb was immediately detached, and the end of the leaden tube stopped by a cork till its contents could be examined. In no case was there any flame in the glass tube at the other end, and on testing the contents of the tube, it was found that the gas was never decomposed down the tube for more than about 15 cm. The acetylene in the bomb itself was decomposed, and the sides of the bomb were covered with a deposit of fine carbon.

A second series of experiments was then made, in which carbon bisulphide vapour was used instead of acetylene. This gave a different result. On attaching to the bomb described a strong glass tube 1¼ metres long, instead of the lead one, and filling the whole, by exhaustion, with vapour of CS_2, one of the same detonators produced complete decomposition of the gas, and a deposit of carbon on the whole of the inner surface of the glass. A repetition of the experiment gave a similar result. An attempt was then made to measure the rate of transmission of this explosion. The passage of the flame down the tube was timed by making it break in turn two silver 'bridges' stretched across the tube, each bridge being connected with a magneto-electric style tracing a mark on a moving plate.

In order to fire the fulminate at a given moment, the detonator was fastened by a caoutchouc ring in the end of a firing tube filled with electrolytic gas. This firing tube was screwed into the bomb, so that the detonator on one side was in contact with the electrolytic mixture, and on the other with the carbon bisulphide vapour in the bomb. The electrolytic gas was fired by the moving plate of the chronograph, and the explosion was transmitted to the fulminate, and so to the carbon bisulphide. The bomb, with the detonator in position, was connected with a long glass tube, having a silver bridge about one metre from the bomb, and a delicate arrangement, capable of being adjusted to be broken by a shock of greater or less violence at the other. The other end of the tube was closed by a tap, and the distance between the breaks was five metres. On repeating the experiment with this apparatus the decomposition was in no case propagated more than about 2·5 metres; the density of the deposit decreasing with increasing distance from the bomb. On repeating the experiment with a lead tube coiled up in a water-bath at 100°, the second bridge circuit was unbroken. The decomposition in the bomb itself is extremely violent, and a flash of intense yellow colour can be seen in the glass tube as far as the explosion proceeds.

It appears, therefore, from these experiments, that the decomposition by shock of acetylene and carbon bisulphide is not propagated like the explosion-wave at a constant velocity as far as the gas extends, but that the decomposition set up by the fulminate dies out at a distance from the detonator, depending on the nature of the gas and, probably, also on the intensity of the initial shock and the cooling power of the walls.

Experiments on the Transmission of Explosions across Air gaps. By Bevan Lean, B.Sc., Dalton Chemical Scholar, and Harold B. Dixon, F.R.S., Professor of Chemistry in the Owens College.

(*Received October 20th, 1891.*)

How far the shock produced by the explosion of a gaseous mixture can be transmitted through a column of air so as to ignite a gaseous mixture beyond—is a question often asked in the discussions raised as to the nature of colliery explosions. Some practical men have expressed the opinion that the shock can be transmitted through air along great lengths of straight gallery, so as to cause the explosion of accumulations of fire damp at the further end ; others hold that a few score yards of gallery free from firedamp and dust, will effectually prevent the propagation of an explosion in a mine. To obtain some data by which to decide the question, the following experiments were tried on the small scale.

Apparatus.—The apparatus consisted of two lead tubes, 880 mm. in length, and 17½ mm. internal diam., which could be connected together by glass tubes of varying dimensions by means of brass junctions.

Explosive Mixture. The explosive mixture employed was one of two vols. of hydrogen mixed with slightly more than 1 vol of oxygen. The mixture was kept over water in a stale gas-holder. The hydrogen was made from zinc and sulphuric acid, without special purification, and the oxygen was prepared from potassium chlorate.

Fig. 1.

A and B are two lead tubes 880 mm. in length, and 17½ mm. internal diam.

EC is a glass firing piece, fixed to A by Faraday's cement.

L is a steel tap fixed to the firing piece by Faraday's cement.

DF is a strong glass tube fixed in between B and a steel tap by Faraday's cement.

X is a glass tube fixed to the two brass junctions by means of Faraday's cement.

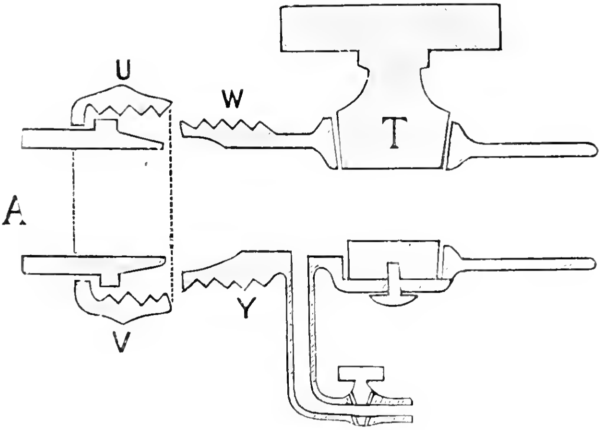

Fig. 2.

The means for connecting either brass junctions up to A or B is shown in fig. (2).

UV is a circular ring which when screwed up over WY makes an air tight connection between the brass piece and the lead tube A.

G and H (fig. 1) are small brass tubes, provided with taps by means of which A may be placed in communication with B, without making use of X.

T and S are large taps in the brass junctions, connecting X with A or B. The passage in each tap is 11 mm. in diameter.

Method of Experiment. After passing a current of air through the apparatus, air was enclosed in the tube X by turning off the taps T and S. The tube G was then connected with H by means of an indiarubber tube, and the explosive gas passed in at L, and through the apparatus, until a sample taken at F was found to explode violently. The taps at E, F, G, and H were then all turned off, and the platinum wires in the firing piece connected up with a Ruhmkorff coil. One observer then stationed himself opposite the tube X, and immediately before giving the command to fire, quickly turned on the taps T and S. A second observer, placed opposite DF, thereupon broke the primary circuit of the coil, producing a spark in EC, and at the same time closely watched DF for any flash indicating that the mixture in B had been fired across the air gap by the explosion in A.

Though the glass tube DF was very strong, it was found necessary to wrap wire gauze around it, inasmuch as it was several times shivered to pieces by the violence of the explosion-wave. Though the glass tubes employed between A and B were frequently comparatively weak, experience showed that the pressure produced by the explosion against the wall of the tube X was so small, that the tube was in no case burst.

FIRST SERIES OF EXPERIMENTS.—A number of experiments were made with glass tubing of 20 mm. internal diameter of various lengths. After fixing the glass tube by means of Faraday's cement to the two brass junctions, the distance from the centre of the tap T to the centre of the tap S was measured. Only these experiments in which this distance TS is exactly the same, are made under the same conditions: it is not sufficient to make experiments with a particular tube of say 200 mm. length at one time, and again at a subsequent period, without making sure that the tube is fixed on to the brass pieces in the same manner. Differences in the length of TS with the same glass tube to the extent of 10-15 mm. may easily occur, which subsequent experiments will show to be very important. We shall therefore class experiments according to the length of TS. The volume of the air-gap was determined in each case by titration with water.

(1) TS = 283 mm. Vol. of air-gap 73 cc.

The flash produced by the explosion in A traversed the whole length of X, but the mixture in B was not fired.

6 experiments made, with the same results.

(2) TS = 215 mm. Vol. of air-gap 53·6 cc.
B not fired by explosion in A.
6 concordant experiments made. (May 6).
On May 9 the experiment was repeated, employing the same glass tube, the same mixture of hydrogen and oxygen, TS being 215 mm., as before. In 4 successive experiments B was fired by the explosion in A, but in two of these the glass tube DF exploded wlth great violence, and in the other two the cement at one or other junction was cracked. Thus, in these four experiments, in which B was fired, the pressure in the apparatus was relieved; since, therefore, it seemed conceivable that in cases in which the limit had been nearly reached, such relief of the pressure might enable A to fire B across the air-gap, it appeared advisable in future experiments only to accept as conclusive those in which every junction had stood intact the shock of the explosion.
4 more experiments were made, in which the apparatus successfully stood the explosion, and in each case B was not fired.

(3) TS = 175 mm. Vol. of air-gap, 38·2 cc.
B fired by explosion in A.
3 experiments made, May 9.
5 experiments made, May 12.
Thus the desired limit is to be found when TS lies between 215 and 175 mm.

(4) TS = 205 mm. Vol. of air-gap, 48·5 cc.
B not fired by explosions in A.
2 experiments made—cement intact.

(5) TS = 184 mm. Air-gap = 40 cc.
B fired. 2 experiments.

(6) TS = 192 mm. Air-gap = 43 cc.
B fired. 2 experiments.

(7) TS = 196 mm. Air-gap = 44·7 cc.
B not fired. 3 experiments.

Thus the limit is to be found between (6) and (7.)

SECOND SERIES OF EXPERIMENTS.—A number of experiments were next made employing much narrower tubing to enclose the air-gap, viz., 8-8½ mm. internal diameter, instead of 20 mm., as in the former experiments.

(1) TS = 275 mm. Air-gap 17·5 cc. Internal diam. 8·5 mm.
B fired. 3 experiments.
(2) TS = 389 mm. Air-gap 27 cc. Bore 8·5 mm.
B fired. 4 experiments.
(3) TS = 532 mm. Air-gap 32¼ cc. Bore 8·5 mm.
B fired. 4 experiments.
(4) TS = 588 mm. Air-gap 31¼ cc. Bore 8·0 mm.
B fired. 4 experiments.
(5) TS = 665 mm. Air-gap 38·2 cc. Bore 8·0 mm.
B not fired. 3 experiments.
(6) TS = 656 mm. Air-gap 37·6 cc. Bore 8·0 mm.
B fired. 2 experiments.
(7) TS = 663 mm. Air-gap 38·1 cc. Bore 8·0 mm.
B not fired. 2 experiments.

Thus the limit is found between (6) and (7).

We can now advantageously compare the main results of these two series of experiments.

In series (1).
If TS = 196 mm., and air gap = 44·7 cc., B is not fired.
If TS = 192 mm., and air gap = 43·0 cc., B is fired.

In series (2).
If TS = 663 mm., and air gap = 38·1 cc., B is not fired.
If TS = 656 mm., and air gap = 37·6 cc., B is fired.

It would appear, therefore, that the question as to whether B shall be fired by A through a given air gap, depends upon the volume of air interposed, rather than upon the length of the column of air.

To test this conclusion a bulb was blown upon a portion of the glass tubing (bore 8·0 mm.) used in series No. 2, and this was substituted for a plane glass tube between the two brass junctions.

(1) TS = 198 mm. Vol. of air gap 83·5 cc.
B was not fired.
(2) TS = 144 mm. Vol. of air gap 78·8 cc.
B was not fired, though the bulb was filled with flame.

The two experiments last mentioned bear out the conclusion that for a given mass of a gaseous explosive minture, there is a certain minimum mass of air which will, if interposed between it and another explosive mixture, guard this last in the manner of a protective shield or plug, and that it is practically immaterial whether this air be enclosed as a short and broad, or a long and narrow column.

The 143 six-letter functions given by the first transitive maximum groups of six letters, with full exhibition of the values of the functions. By the Rev. Thos. P. Kirkman, M.A., F.R.S.

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The groups to be treated are the elementary but highly important ones of my §6, p. 301, *Manchester Memoirs*, 1862. They are easily formed for every number n of letters, are all of the order $2n$, and all of the form G+RG, where G is a transitive group of n powers $1, \theta, \theta^2, \theta^3 ..$, whose derived derangement RG is composed of n square roots of unity. It happens in the cases of $n=6$ and $n=4$ that they are also maximum groups, (F.G. 4).

To form such a group of order $2n$, we complete under 1, in unity $=123 \ldots n$, any vertical permutation C of the n elements, and then complete the same circle C under every element. This gives G.

For RG, we write the same C again under 1 by itself, and complete C vertically $n-1$ times more under the other elements by this rule—In the horizontal line beginning with e, plant your 1 at the e^{th} place.

For comparison of two given series of Q columns or rectangles, each containing a function of n letters and its $\text{Q}-1$ values, *i.e.*, for comparison of

$$\mathfrak{G}_a^+ \cdot\cdot \text{ and } \mathfrak{G}_b^+ \cdot\cdot,$$

it is necessary that $\mathfrak{G}_a$ and $\mathfrak{G}_b$ should both exhibit unity under exactly the same line Σ of n arbitrary Greek exponents, all different or not all. Then the two series are one and the same algebraically, when and only when every value of $\mathfrak{G}_a^+ \cdot\cdot$ is the same sum of L products of powers, as is some value of $\mathfrak{G}_b^+ \cdot\cdot$.

The title of our 60 equivalent groups of order 6·2 is

$$6{\cdot}2 = 1 + 2_6 + 2_{33} + 4_{222} + 3_{2211} \qquad Q = 60.$$

That they are maximum groups appears from $QL = n!$, *i.e.*, $60{\cdot}12 = 6!$, L being the order, and Q the number of the equivalents: (F.G. 4).

I shall refer by (F.G. a, b) to article a and equation b, in my paper "Functions given by groups," in the *Proceedings and Memoirs* of this Society, 1890-1.

The index system Σ may be any of the nine (F.G. 5, 2) $\alpha\beta\gamma\delta\epsilon\varepsilon$, $\alpha\beta\gamma\delta\delta\delta$, $\alpha\beta\gamma\gamma\delta\delta$, $\alpha\beta\gamma\gamma\gamma\gamma$, $\alpha\beta\beta\gamma\gamma\gamma$, $\alpha\alpha\beta\beta\gamma\gamma$, $\alpha\alpha\alpha\beta\beta\beta$, $\alpha\alpha\beta\beta\beta\beta$, $\alpha\beta\beta\beta\beta\beta$.

We choose the first,

$$\underline{\Sigma = \alpha\beta\gamma\delta\varepsilon\varepsilon.}$$

2. The index group determined by Σ is (F.G. 6),

$$I_{t+1} = I_2 = 123456 \qquad = 1 + \theta,$$
$$123465 = \theta$$

of which the title is $2 = 1 + 1_{21111}$.

Since our title (art. 1) has no subscript 21111, shewing four elements undisturbed, none of our 60 equivalent groups under Σ has any Θ in common with I_{t+1}, (F.G. 12, 15).

Denoting by (234561), a principal substitution of it, the cyclical group G + RG, we take this (234561) for G_d, and we form (F.G. 10, 12) by θ in I_{t+1} the equivalent of G_d,

$$\theta G_d \theta^{-1} = G_e = (234615),$$

which determines G_e by one of its two principal substitutions. This G_e is (F.G. 8) to be marked out of our table (A_n) of 60 equivalents.

We take any third group $(235164) = G_{dd}$, or, better, G_{2d}, for our second standard, which marks out

$$\theta G_{2d} \theta^{1-} = (236145) = G_{2e}$$

from the table (A_n).

We thus employ 30 standards,

$$G_d,\ G_{2d},\ G_{3d}.\ .\ .\ .\ G_{30d},$$

of which each marks out a different group, in the order

$$G_e,\ G_{2e},\ G_{3e}\ \ldots\ G_{30e},$$

where $G_{ie}=\theta G_{id}\theta^{-1}$, got by θ in I_{t+1}.

The 30 standards are written in vertical order in sixes thus, which are to be read as $\mathfrak{G}_d$, $\mathfrak{G}_{2d}$, $\mathfrak{G}_{3d}$, $\mathfrak{G}_{4d}$, $\mathfrak{G}_{5d}$, $\mathfrak{G}_{6d}$, &c., all under $\alpha\beta\gamma\delta\epsilon\epsilon$.

	$\alpha\beta\gamma\delta\epsilon\epsilon$	$\alpha\beta\gamma\delta\epsilon\epsilon$	$\alpha\beta\gamma\delta\epsilon\epsilon$	$\alpha\beta\gamma\delta\epsilon\epsilon$	$\alpha\beta\gamma\delta\epsilon\epsilon$	
$G_d=$	234561	251643	342561	356142	452613	G_{25d}
$G_{2d}=$	235164	251364	345162	356214	456312	
$G_{3d}=$	235641	254163	345621	362514	465213	
$G_{4d}=$	241563	254631	352164	435261	534621	
$G_{5d}=$	246315	256341	354261	435612	536241	
$G_{6d}=$	245613	265143	354612	452361	564231	G_{30d}

$$\mathfrak{G}^{+\cdot\cdot}_{id}\ \text{and}\ \mathfrak{G}^{+\cdot\cdot}_{(i+k)d}$$

are two different sets of 60 values, each value of 12 products. And

$$\mathfrak{G}^{+\cdot\cdot}_{id}=\mathfrak{G}^{+\cdot\cdot}_{ie}$$

are two sets of 60 values, each on the left algebraically identical with one on the right; but the values on the left are found in a different order from their equals on the right.

The 30 groups G_{ie} are thus written in the order of the standards G_{id} which mark them out:

$G_e=$	234615	261534	342615	365124	462531	G_{25e}
$G_{2e}=$	236145	261345	346125	365241	465321	
$G_{3e}=$	236514	264135	346512	352641	456231	
$G_4=$	241635	264513	362145	436215	634512	
$G_{5e}=$	245361	265314	364215	436521	635214	
$G_{6e}=$	246531	256134	364521	462315	654213	G_{30e}

But is this all quite proved? How do we know, first, that no one of the 30 standards under Σ has fewer than 60 values? And, secondly, how do we know that

$$\mathfrak{G}^{+\cdot\cdot}_{d}=\mathfrak{G}^{+\cdot\cdot}_{2d},\quad \mathfrak{G}^{+\cdot\cdot}_{2d}=\mathfrak{G}^{+\cdot\cdot}_{3d},\ \text{\&c.}$$

are none of them true under this Σ?

These questions ought to have been put and answered in (F.G. 12). We here consider them in turn.

3. First, if G_f under Σ has fewer than 60 values there must be in $G_f^{+\cdot\cdot}$ under Σ, *i.e.*, in $\mathfrak{G}_f^{+\cdot\cdot}$, a repetition of the value $\mathfrak{G}_f$, and we must have

$$K\mathfrak{G}_f=\mathfrak{G}_f, \tag{a}$$

where KG is a derivate of $G_f^{!}$, made by a substitution K; for the values of $\mathfrak{G}_f$ are obtainable only by substitutions among the variables under barred or immovable indices: that is, there is somewhere in the derivate KG_f a substitution C, which under Σ is $\mathfrak{C}$, algebraically identical with unity under Σ in $\mathfrak{G}_f$, thus making (a) true. This C must therefore be somewhere in the index group, and is no θ common to I_{t+1} and G_f; for no derivant C of G_f is in G_f; and not only has every substitution of I_{t+1} the value under Σ which unity under Σ has, but no C having that property is missing from I_{t+1}. Wherefore when (a) is true there is a substitution $\theta_i=C$ in I_{t+1}, which makes it true, making $C\mathfrak{G}_f=K\mathfrak{G}_f=\mathfrak{G}^f$, although

$$CG_f=G_f$$

is always false, if C be not in G_f; and $\mathfrak{G}_f$ *i.e.* G_f under Σ, must be symmetrical in the variables transposed by $\theta_i=C$. Examples will occur. It is clear that none of our 60 maximum groups is, under $\Sigma=\alpha\beta\gamma\delta\epsilon\epsilon$, symmetrical in 5 and 6 disturbed by θ in I_{t+1} in art. 2; for 5 and 6 carry different indices all through every $\mathfrak{G}$, except in two products.

Thus we know that no one of our 30 standards under Σ has fewer than 60 values.

Secondly, if

$$(a') \qquad \mathfrak{G}_{2d}=\mathfrak{G}_{d}, \quad \text{or} \quad \mathfrak{G}_{\;i+1)d}=\mathfrak{G}_{d} \qquad (a'')$$

there must, if a′ is true, be a derivate KG_{2d}, which under Σ has in it a product $\mathfrak{C}$ algebraically identical with unity in G_d under Σ; so that KG_{2d} is CG_{2d}, which, by what precedes in this article, must be $\theta_i G_{2d}$, where $\theta_i = C$ is in I_{t+1}, and is no Θ of G_{2d}; and thus, if a′ is true,

$$\mathfrak{G}_d = \theta_i \mathfrak{G}_{2d}$$

algebraically. This makes G_{2d} one of the G_e marked out by G_d (F.G. 8, 5).

But this is impossible, because no new standard G_{nd} was ever selected (F.G. 12) from the groups marked out by preceding standards.

Wherefore neither a′ nor a″ is ever true of any two of our retained standards.

We have demonstrated that there are thirty and no more different functions of 12 terms that have, under $\Sigma = \alpha\beta\gamma\delta\epsilon\epsilon$, 60 values. They are formed by writing this Σ over the rectangles of the maximum groups above given, each given by a principal substitution, viz., G_d, G_{2d}, . . G_{30d}; which thus become 60-valued functions.

4. We shall next show how all these 30 functions, with all their values, can be easily dictated more rapidly than they can be written down.

Here follows the complete paradigm of the cyclical maximum group (234561), or $G^{+}_{234\dot{5}\dot{6}1} = G^{+\cdot\cdot}_{d}$ above handled.

THE PARADIGM OF $\underline{(234561)}^{+\cdot\cdot} = \underline{G^{+\cdot\cdot}_{d}}$

1	2	3	4	5	6
123456	124536	125346	123546	125436	124356
234561	245361	253461	235461	254361	243561
345612	453612	534612	354612	543612	435612
456123	536124	346125	546123	436125	356124
561234	361245	461253	461235	361254	561243
612345	612453	612534	612354	612543	612345
165432	163542	164352	164532	163452	165342
654321	635421	643521	645321	634521	653421
543216	354216	435216	453216	345216	534216
432165	542163	352164	532164	452163	342165
321654	421635	521643	321645	521634	421653
216543	216354	216435	216453	216345	216534

7	8	9	10	11	12
123465	124635	126345	123645	126435	124365
234651	246351	263451	236451	264351	243651
346512	463512	634512	364512	643512	436512
465123	635124	345126	645123	435126	365124
651234	351246	451263	451236	351264	651243
512346	512463	512634	512364	512643	512436
156432	153642	154362	154632	153462	156342
564321	536421	543621	546321	534621	563421
643215	364215	436215	463215	346215	634215
432156	642153	362154	632154	462153	342156
321564	421536	621543	321546	621534	421563
215643	215364	215436	215463	215346	215634

13	14	15	16	17	18
123564	125634	126354	123654	126534	125364
235641	256341	263541	236541	265341	253641
356412	563412	635412	365412	653412	536412
564123	634125	354126	654123	534126	364125
641235	341256	541263	541236	341265	641253
412356	412563	412635	412365	412653	412536
146532	143652	145362	145632	143562	146352
465321	436521	453621	456321	435621	463521
653214	365214	536214	563214	356214	635214
532146	652143	362145	632145	562143	352146
321465	521436	621453	321456	621435	521463
214653	214365	214536	214563	214356	214635

19	20	21	22	23	24
124563	125643	126453	124653	126543	125463
245631	256431	264531	246531	265431	254631
456312	564312	645312	465312	654312	546312
563124	643125	453126	653124	543126	463125
631245	431256	531264	531246	431265	631254
312456	312564	312645	312465	312654	312546
136542	134652	135462	135642	134562	136452
365421	346521	354621	356421	345621	364521
654213	465213	546213	564213	456213	645213
542136	652134	462135	642135	562134	452136
421365	521346	621354	421356	621345	521364
213654	213465	213546	213564	213456	213645

25	26	27	28	29	30
132564	135624	136254	132654	136524	135264
325641	356241	362541	326541	365241	352641
256413	562413	625413	265413	652413	526413
564132	624135	254136	654132	524136	264135
641325	241356	541362	541326	241365	641352
413256	413562	413625	413265	413652	413526
146523	142653	145263	145623	142563	146253
465231	426531	452631	456231	425631	462531
652314	265314	526314	562314	256314	625314
523146	653142	263145	623145	563142	253146
231465	531426	631452	231456	631425	531462
314652	314265	314526	314562	314256	314625

31	32	33	34	35	36
132465	134625	136245	132645	136425	134265
324651	346251	362451	326451	364251	342651
246513	462513	624513	264513	642513	426513
465132	625134	245136	645132	425136	265134
651324	251346	451362	451326	251364	651342
513246	513462	513624	513264	513642	513426
156423	152643	154263	154623	152463	156243
564231	526431	542631	546231	524631	562431
642315	264315	426315	462315	246315	624315
423156	643152	263154	623154	463152	243156
231564	431526	631542	231546	631524	431562
315642	315264	315426	315462	315246	315624

37	38	39	40	41	42
132456	134526	135246	132546	135426	134256
324561	345261	352461	325461	354261	342561
245613	452613	524613	254613	542613	425613
456132	526134	246135	546132	426135	256134
561324	261345	461352	461325	261354	561342
613245	613452	613524	613254	613542	613425
165423	162543	164253	164523	162453	165243
654231	625431	642531	645231	624531	652431
542316	254316	425316	452316	245316	524316
423165	543162	253164	523164	453162	243165
231654	431625	531642	231645	531624	431652
316542	316254	316425	316452	316245	316524

43	44	45	46	47	48
142365	143625	146235	142635	146325	143265
423651	436251	462351	426351	463251	432651
236514	362514	623514	263514	632514	326514
365142	625143	235146	635142	325146	265143
651423	251436	351462	351426	251463	651432
514236	514362	514623	514263	514632	514326
156324	152634	153264	153624	152364	156234
563241	526341	532641	536241	523641	562341
632415	263415	326415	362415	236415	623415
324156	634152	264153	624153	364152	234156
241563	341526	641532	241536	641523	341562
415632	415263	415326	415362	415236	415623

49	50	51	52	53	54
142356	143526	145236	142536	145326	143256
423561	435261	452361	425361	453261	432561
235614	352614	523614	253614	532614	325614
356142	526143	236145	536142	326145	256143
561423	261435	361452	361425	261453	561432
614235	614352	614523	614253	614532	614325
165324	162534	163254	163524	162354	165234
653241	625341	632541	635241	623541	652341
532416	253416	325416	352416	235416	523416
324165	534162	254163	524163	354162	234165
241653	341625	541632	241635	541623	341652
416532	416253	416325	416352	416235	416523

55	56	57	58	59	60
152346	153426	154236	152436	154326	153246
523461	534261	542361	524361	543261	532461
234615	342615	423615	243615	432615	324615
346152	426153	236154	436152	326154	246153
461523	261534	361542	361524	261543	461532
615234	615342	615423	615243	615432	615324
164325	162435	163245	163425	162345	164235
643251	624351	632451	634251	623451	642351
432516	243516	324516	342516	234516	423516
325164	435162	245163	425163	345162	235164
251643	351624	451632	251634	451623	351642
516432	516243	516324	516342	516234	516423

If $\alpha\beta\gamma\delta\varepsilon\epsilon$ be written in the paradigm over each of the 60 rectangles of 12 substitutions, and if they be then read as 60 sums of 12 products of powers $x_1^{\alpha}x_2^{\beta}\,..\,x_6^{\epsilon}+x_2^{\alpha}x_3^{\beta}\,..\,x_1^{\epsilon}$, &c.,

$$\begin{array}{rcr}
\overset{\alpha\beta\gamma\delta\epsilon\varepsilon}{123456} & \text{and} & \overset{\alpha\beta\gamma\delta\epsilon\varepsilon}{124536} \\
+\overset{\alpha\beta\gamma\delta\epsilon\epsilon}{234561} & & +\overset{\alpha\beta\gamma\delta\varepsilon\varepsilon}{245361} \\
\vdots & & \vdots \\
+\overset{\alpha\beta\gamma\delta\epsilon\epsilon}{321654} & & +\overset{\alpha\beta\gamma\delta\varepsilon\varepsilon}{421635} \\
+\overset{\alpha\beta\gamma\delta\epsilon\epsilon}{216543} & & +\overset{\alpha\beta\gamma\delta\epsilon\epsilon}{216354}
\end{array}$$

being the two first of the 60 sums, the function on $G_d^{+}\cdot\cdot$ is correctly dictated with its 60 values under $\Sigma=\alpha\beta\gamma\delta\varepsilon\epsilon$.

If we wish to dictate $G_{25d}^{+}\dot{}$, page 25, under Σ, which is $(452613)^{+}\cdot\cdot$ under Σ, given by its principal substitution, whose vertical circle, read under 1 in the group of its six powers, is 146325, we have to turn our $G_d^{+}\cdot\cdot$ into $G_{25d}^{+}\cdot\cdot$.

We look for this vertical circle and find it in the 47th rectangle of $G_d^{+}\cdot\cdot$, the derivate $146325G_d=\phi G_d$.

We want

$$G_{25d}=\phi G_d\phi^{-1}=146325G_d146325^{-1}=146325G_d154263\,.$$

The dexter operation of $\phi^{-1}=154263$ on this 47th rectangle so permutes its entire and unaltered vertical rows, that they become exactly G_{25d} headed by 123456; and, by writing over this deranged rectangle our selected Σ, we make it $\mathfrak{G}_{25d}$. We have only thus to derange by ϕ^{-1} the other 59 rectangles, and to impose over them the same Σ, and we have plainly before us $\mathfrak{G}_{25d}^{+}$, with the function $\mathfrak{G}_{25d}$ under $\alpha\beta\gamma\delta\varepsilon\varepsilon$ in the 47th rectangle.

For one of the 59 is G_d, which so deranged has become $G_d\phi^{-1}$, $=\phi^{-1}G_{25d}$, and is now a derivate of G_{25d}. Another is BG_d, which has become

$$BG_d\phi^{-1}=B\phi^{-1}(\phi G_d\phi^{-1})=B\phi^{-1}G_{25d},=CG_{25d},$$

another derivate of G_{25d}. And thus G_d and the 59 different derivates of G_d have become G_{25d} and the 59 different derivates of G_{25d}. We write our Σ over the 60 rectangles, and $\mathfrak{G}_{25d}^{+\cdot\cdot}$ is complete before our eyes, with $\mathfrak{G}_{25d}$ not first but 47th.

The reader easily sees that in dictating to his own or to another ear for penning, he could, without displacing rows, so pronounce the first substitution of every rectangle of our paradigm, that after completion, under the so deranged elements of these penned first substitutions of the vertical rows headed by them in the paradigm, and after writing our Σ unpermuted over all, $\mathfrak{G}_{25d}^{+\cdot\cdot}$ would be correctly written down, with $\mathfrak{G}_{25d}$ as 47th rectangle. The 60 deranged first substitutions have secured the position of every vertical row of all the values under the proper index in Σ, and every product of each value is correct.

Or, simpler still, for dictation by a little girl. The reader, instead of disturbing the vertical rows of the values, in order to place each under the right index in Σ, could over all the rectangles by one rule, so permute the indices as to place the right one over every fixed vertical row. No product in $\mathfrak{G}_{25d}^{+\cdot\cdot}$ would be altered by thus deranging indices instead of vertical rows.

In fact, this ϕ^{-1} names aloud, by place, the vertical rows of every rectangle of the paradigm, over which you are to write the first, second, third, &c., indices of the Σ that makes $G_d^{+\cdot\cdot}$ into $\mathfrak{G}_d^{+\cdot\cdot}$, in order to turn that rectangle, as it stands, into a value of $\mathfrak{G}_{25d}$ under that unaltered Σ. Was ever the reader's faith so tried before? I hope they won't burn me for a witch!

I have the right, and I beg permission here, to say, as a very old clergyman under solemn ordination-vows, that the real conjuring, which I am here doing, beats into fits that ancient altar-conjuring which the clever craftsmen of my cloth are now so triumphantly restoring. This conjuring of mine will be both sacred and celebrated, when their celebrations are all again historical rubbish.

As soon as the reader is familiar with these few considerations, all easily verifiable on the paradigm, and has proceeded a little way into this paper, he will find that he has broken every bone in the body of the champion problem of many-valued functions of n variables. For what has just been stated about dictation, by a little girl from one paradigm, of all the values of every function given by the first maximum groups of $n=6$ elements, is equally true and practicable from one paradigm for $n=600$ elements, if only the girl can pronounce in order correctly the figures or letters of a line so long.

And the one paradigm needs not be the cyclical. That of any equivalent will serve equally well; but the cyclical is most easily surveyed, because every substitution of it is, backwards or forwards, in clear order $2n$ times cyclically read. That is the only eminence or precedence which the cyclical has over any other of the Q equivalents. It has been deservedly preferred; but has been very much overvalued by writers who have rarely condescended to glance at the equivalents.

$$\underline{\Sigma = \alpha\beta\gamma\overset{\frown}{\delta}\overset{\frown}{\delta}\overset{\frown}{\delta}.}$$

5. As our title (art. 1) has no subscript containing 111, showing three circles of order one under unrepeated exponents, none of our 60 equivalents has a substitution θ of the index group determined by Σ. This group is, $m=0$,

$$I_{t+1} = I_6 = 123456 \qquad \text{(F.G. 12, 15)}$$
$$123564 = \theta_1$$
$$123645 = \theta_2$$
$$123465 = \theta_3$$
$$123654 = \theta_4$$
$$123546 = \theta_5$$

Taking (234561) for G_d, we form

$$\theta_1 234561 \theta_1^{-1} = 235164 = G_{e1}\,; \quad \theta_2 G_d \theta_2^{-1} = 236514 = G_{e2}\,;$$
$$\theta_3 G_d \theta_3^{-1} = 234615 = G_{e3}\,; \quad \theta_4 G_d \theta_4^{-1} = 236145 = G_{e4}\,;$$
$$\theta_5 G_d \theta_5^{-1} = 235641 = G_{e5}\,;$$

and we mark out the five G_e's as giving all the same $\mathfrak{G}_d^{+}\cdot\cdot$, which contains 60 values, because $\mathfrak{G}_d$ is not symmetrical in 456 nor in any pair of them (art. 2). $\mathfrak{G}_d$ is one of our sought functions.

We next take any seventh unmarked equivalent, 241563, for G_{2d}, and by the same five θ's we obtain five groups more, G_{2e} $G_{2e1} \ldots G_{2e5}$, to be marked out as all giving the function and values $\mathfrak{G}^{+}_{2d}{\cdot}{\cdot}$. $\mathfrak{G}_{2d}$ is another of our sought functions.

Thus we go on till we have ten standards selected from groups unmarked, each heading, as follows, a line of five groups G_{ie} marked out by it.

$$\Sigma = \alpha\beta\gamma\hat{\delta}\hat{\delta}\hat{\delta}.$$

$G_d = (234561)$: 235164; 236514; 234615; 236145; 235641.
$G_{2d} = (241563)$: 251364; 241653; 261345; 261534; 251643.
$G_{3d} = (246315)$: 254631; 265143; 245361; 264513; 256134.
$G_{4d} = (245613)$: 256341; 264135; 246531; 265314; 245163.
$G_{5d} = (342561)$: 352164; 362514; 342615; 362145; 352641.
$G_{6d} = (345162)$: 356214; 364521; 346125; 365241; 354612.
$G_{7d} = (345621)$: 356142; 346512, 365124; 354261; 364215.
$G_{8d} = (435261)$: 536124; 634512; 436215; 635142; 534621.
$G_{9d} = (435612)$: 536241; 634125; 436521; 635214; 534162.
$G_{10d} = (456312)$: 564231; 645123; 465321; 654213; 546132.

Of these standards the last only is so symmetrical under Σ that a substitution C of I_{t+1} gives

$$C\mathfrak{G}_{10d} = \mathfrak{G}_{10d}. \qquad \text{(art. 3).}$$

And every substitution of I_{t+1} is such a C.

This $G_{10d} = (456312)$ gives under Σ the function, $\delta \overline{\overline{>}} 0$,

$$\begin{array}{rl} & \alpha\beta\gamma\hat{\delta}\hat{\delta}\hat{\delta} \quad \alpha\beta\gamma\hat{\delta}\hat{\delta}\hat{\delta} \\ \mathfrak{G}_{10d} = & 123456 + 456123 \\ & + 231456 + 564123 \\ & + 312456 + 645123 \\ & + 132456 + 465123 \\ & + 321456 + 654123 \\ & + 213456 + 546123 \end{array}$$

which is six times repeated in $\mathfrak{G}^{+}_{10d}{\cdot}{\cdot}$ and has therefore twelve terms and ten values. There are but ten ways of making out of six letters a triplet containing 1; and every such triplet under $\alpha\beta\gamma$ determines a value of the function.

$$\Sigma=\alpha\beta\gamma\overset{\frown}{\delta}\overset{\frown}{\delta}\overset{\frown}{\delta}.$$

It is thus demonstrated that under Σ there are nine distinct functions, $\mathfrak{G}_d$, $\mathfrak{G}_{2d}\ldots\mathfrak{G}_{9d}$, each of 60 values and of 12 terms, and one function, $\mathfrak{G}_{10d}$ of 10 values and of 12 terms. All of them are easily dictated, with all their values, from our cyclical paradigm of $G^{+\,\cdot\,\cdot}_{234561}$.

$$\underline{\Sigma=\alpha\beta\gamma\gamma\overset{\frown}{c}\overset{\frown}{\delta}.}$$

6. Our title, art. 1, has three subscripts 2211. That of the entire group of order 6! has 45 of them. By

$$60\cdot3_{2211}=4\cdot45_{2211}$$

we see that four, and only four, of our 60 equivalent maximum groups have the same one of the 45. Of the four containing 124365 two are

$$\begin{array}{rl}
G_d=123456 & 123456=G_{2d}\\
356142 & 542631\\
642315 & 364125\\
215634 & 216543\\
534261 & 451362\\
461523 & 635214\\
\\
\Theta=124365 & 124365=\Theta\\
465132 & 632541\\
532416 & 453126\\
216543 & 215634\\
643251 & 361452\\
351624 & 546213
\end{array}$$

Both have Θ of the index-group, which group of 4 is broken up into up into the product of two groups, thus

$$\begin{array}{llll}
I_{t+1}=I_4=123456 & =123456\times123456 & & =J_2\times H_2.\\
\quad 124365=\Theta & \Theta=124365 & 124356=\lambda & \\
\quad 123465=\theta & & & \\
\quad 124356=\lambda. & & &
\end{array}$$

We here require a theorem.

Theorem T. If I_{t+1} be any group of order $t+1$, of n elements, which is the product of two groups J_{m+1} and

H_{h+1} of orders $m+1$ and $h+1$, that have no common substitution; and if G_d be any maximum group of the n elements, which has, in common with

$$\begin{aligned} I_{t+1} = 1 &+ \Theta + \Theta + \cdots + \Theta_m \\ &+ \lambda_1 + \lambda_2 + \cdots + \lambda_h \\ &+ \theta_1 + \theta_2 + \cdots + \theta_{t-m-h}, \end{aligned} \qquad (d)$$

the subgroup

$$J_{m+1} = 1 + \Theta_1 + \Theta_2 + \cdots + \Theta_m,$$

and no other substitution of I_{t+1}; then if

$$H_{h+1} = 1 + \lambda_1 + \lambda_2 + \cdots + \lambda_h,$$

the h groups

$$\lambda_1 G_d \lambda_1^{-1},\ \lambda_2 G_d \lambda_2^{-1} \ldots \lambda_h G_d \lambda_h^{-1},$$

are h different maximum groups, equivalents of

For, be it supposed that two are equal, as

$$\lambda_a G_d \lambda_a^{-1} = \lambda_b G_d \lambda_b^{-1};$$

it follows that

$$\lambda_b^{-1} \lambda_a G_d = G_d \lambda_b^{-1} \lambda_a, \qquad i.e.,$$
$$\lambda_c G_d = G_d \lambda_c.$$

This is possible only on condition either that

$$\lambda_c G_d = G_d = G_d \lambda_c$$

shewing that λ_c is in G_d, or that

$$\lambda_c G_d = G_d \lambda_c,$$

shewing that $\lambda_c G_d$ is a derived derangement of G_d

The first is impossible, because G_d has only unity in common with H_{h+1}; and the second is impossible, because G_d is a maximum group (F.G. 4).

Wherefore all the $1+h$ groups

$$G_{d1} \lambda_1 G_d \lambda_1^{-1},\ \lambda_2 G_d \lambda_2^{-1} \ldots \lambda_h G_d \lambda_h^{-1}$$

are different maximum groups

The equation (d) above is (F.G. 8, 7) in more defined form.

In this theorem m is not limited, being $m \mathrel{\overset{=}{>}} 0$. When

$$m = 0,\ h = t, \qquad I_{t+1} = H_{t+1}, \qquad J_{m+1} = J_1,$$

being unity; and the number of different equivalents of G_d is t. We proceed with $\Sigma = \alpha\beta\gamma\gamma\delta\delta$.

7. In the case before us we take the above $G_d = (356142)$, which has in common with I_{t+1} the sub-group (art. 6)

$$J_2 = 1 + \Theta, \text{ and we have}$$
$$H_2 = 1 + \lambda.$$

Wherefore

$$\lambda G_d \lambda^{-1} = 124356 \cdot 356142 \cdot 124356 = (451632) = G_e$$

and this G_e is to be marked out of our table of 60 equivalents, because

$$\mathfrak{G}_e^{+}\cdot\cdot = \mathfrak{G}_d^{+}\cdot\cdot.$$

We have here no use for θ in I_{t+1}, for it gives

$$\theta G_d \theta^{-1} = \lambda \Theta G_d \Theta^{-1} \lambda^{-1} = \lambda G_d \lambda^{-1} = G_e$$

just found.

Thus it suffices, as was promised in (F.G. 13), to use only the factor-group H_2, and there is no inelegance of repeated outmarking.

Taking next $G_{2d} = (542631)$, we obtain, by the same H_2,

$$G_{2e} = \lambda G_{2d} \lambda^{-1} = (635124) \text{ or its reciprocal } (452631),$$

which is also to be marked out.

We retain G_d and G_{2d}, which have, under Σ, 60 values each of 6 terms (F.G. 13); unless the reader can find a $C = K$ in I_{t+1}, which makes (a) art. 3, true of one or of both.

There remain $60 - 4 = 56$ of our 60 groups which have no Θ in common with I_{t+1}, which now is $(m = 0)$

$$\begin{aligned} I_{t+1} = I_{3+1} = 123456 &= H_{3+1} \\ 124365 &= \theta_1 \\ 123465 &= \theta_2 \\ 124356 &= \theta_3 \end{aligned}$$

Taking as G_D 234561, we form

$$\theta_1 G_D \theta_1^{-1} = 246315, \quad \theta_2 G_D \theta_2^{-1} = 234615, \quad \theta_3 G_D \theta_3^{-1} = 245361,$$

which are G_{E1}, G_{E2}, G_{E3}, and are to be marked out, as all giving the function and value $\mathfrak{G}_D^{+}\cdot\cdot$ under $\alpha\beta\gamma\gamma\delta\delta$.

We then take at random $G_{2D} = 235614$, on which we form G_{2E1}, G_{2E2}, G_{2E3}, to be marked out; and then we proceed to register 14 different standards G_{mD}, each in a line with three marked out by it, all by $\theta_1, \theta_2, \theta_3$, as follows:

$$\Sigma = \alpha\beta\gamma\gamma\hat{\delta}\hat{\delta}.$$

G_D 234561 : 246315, 234615, $245361 = G_{E3}$;
G_{2D} 235164 : 241635, 236145, 241563 ;
G_{3D} 235641 : 236514, 246315, 245613 ;
G_{4D} 251364 ; 264135, 261345, 254163 ;
G_{5D} 251643 ; 265143, 261534, 256134 ;
G_{6D} 254631 : 265314, 264513, 256341 ;
G_{7D} 342615 : 435261, 342561, 436215 ;
G_{8D} 345162 : 431625, 431562, 346125 ;
G_{9D} 345621 : 435612, 346512, 436521 ;
G_{10D} 352641 : 465213, 456231, 362514 ;
G_{11D} 354261 : 462315, 364215, 452361 ;
G_{12D} 354612 : 465321, 364521, 456312 ;
G_{13D} 356214 : 462531, 452613, 365241 ;
G_{14D} 534621 : 564231, 546321, $562341 = G_{14E3}$.

The 14 standards are retained as all giving different functions of twelve terms.

As to the numbers of their values, we see, by 34, 56, 21, in its line, that G_{9D}, if any, has a symmetry under Σ, that may for some $\theta = C$ in I_{t+1} make a, art. 3, true. We soon find that each of the 3 θ's is such a C, and that $\mathfrak{G}_{9D}$ is thereby four times repeated in $\mathfrak{G}_{9d}^{+\cdot\cdot}$, and thus has only 15 values.

$\mathfrak{G}_{9d}$ is the following 15-valued function $(\delta \overset{=}{>} o)$:

$$\begin{array}{c} \alpha\beta \quad \alpha\beta \quad \gamma\gamma\hat{\delta}\hat{\delta} \quad \gamma\gamma\hat{\delta}\hat{\delta} \\ (12 + 21)(3456 + 5634) \\ (34 + 43)(5612 + 1256) \\ (56 + 65)(1234 + 3412) \end{array}$$

which is all to be read under Σ, $1^{\alpha}2^{\beta}3^{\gamma}4^{\gamma}5^{\delta}6^{\hat{\delta}} +$ &c. We have thus proved that there are constructible under

$$\Sigma = \alpha\beta\gamma\gamma\hat{\delta}\hat{\delta}.$$

16 different functions, namely

Two, $\mathfrak{G}_{d}^{+}\cdot\cdot$ and $\mathfrak{G}_{2d}^{+}\cdot\cdot$ each of 6 terms and 60 values.

One $\mathfrak{G}_{9\mathrm{D}}^{+}\cdot\cdot$, of 12 terms and 15 values.

Thirteen others, $\mathfrak{G}_{r\mathrm{D}}^{+}\cdot\cdot$ above written as $G_{r\mathrm{D}}$, each of 12 terms and 60 values.

$$\underline{\Sigma = \alpha\beta\gamma\gamma\gamma\gamma.}$$

8. We consider again the two groups $G_d = 356142$, and $G_{2d} = 542631$ of art. 6. Both have $\Theta = 124365$ in common with our new index group $I_{t+1} = I_{24}$.

But we cannot write I_{24} as the product of two groups H_{12}, and $J_2 = 1 + 124365$, because the only H_{12} contains this J_2. We must then write I_{24} as the product of three groups, thus:

$$\begin{array}{lllll} I_{24} = H_6 \cdot K_2 \cdot J_2 = & 123456 \times & 123456 \times & 123456 & = H_6 \mathfrak{K}_4 \\ & \lambda_1 124536 & 125634 = \eta & 124365 = \Theta & \\ & \lambda_2 125346 & & & \\ & \lambda_3 123546 & & & \\ & \lambda_4 125436 & & & \\ & \lambda_5 124356 & & & \end{array}$$

We require here another theorem.

Theorem U. If I_{t+1} is any group of n elements, of order $t+1$, and is the product of two groups H_{h+1} and $\mathfrak{K}_{(k+1)(m+1)}$ of which the latter is the product of two groups K_{k+1} and J_{m+1}, such that no two of the groups H, K, and J have a common substitution, and where

$$\begin{aligned} H_{h+1} &= 1 + \lambda_1 + \lambda_2 + \,..\, + \lambda_h, \\ K_{k+1} &= 1 + \eta_1 + \eta_2 + \,..\, + \eta_k, \\ J_{m+1} &= 1 + \Theta_1 + \Theta_2 + \cdot\cdot + \Theta_m, \end{aligned}$$

so that, in form more explicit than in (F.G. 8, 7).

$$\begin{aligned} I_{t+1} = 1 &+ \Theta_1 + \Theta_2 + \,..\, + \Theta_m \\ &+ \lambda_1 + \lambda_2 + \,..\, + \lambda_h \\ &+ \eta_1 + \eta_2 + \,..\, + \eta_k \\ &+ \theta_1 + \theta_2 + \,..\, + \theta_{t-m-h-k}\,; \end{aligned}$$

then, if G_d be any maximum group of the n elements, which has in common with I_{t+1} the subgroup J_{m+1} and no more, the h groups

$$\lambda_1 G_d \lambda_1^{-1} + \lambda_2 G_d \lambda_2^{-1} + \,..\, + \lambda_h G_d \lambda_h^{-1}$$

are different equivalents of G_d, and the k groups

$$\eta_1 G_d \eta_1^{-1} + \eta_2 G_d \eta_2^{-1} + \,..\, + \eta_k G_d \eta_k^{-1}$$

are different equivalents of G_d; but it is not hereby affirmed that these $h+k$ groups are $h+k$ different equivalents of G_d.

For let it be supposed that

$$\eta_a G_d \eta_a^{-1} = \eta_b G_d \eta_b^{-1};$$

it follows that

$$\eta_b^{-1}\eta_a G_d = G_d \eta_b^{-1}\eta_a, \ \textit{i.e.}\ \eta_c G_d = G_d \eta_c,$$

which is impossible unless either

$$\eta_c G_d = G_d = G_d \eta_c$$

showing that η_c is in G_d, or

$$\eta_c G_d = G_d \eta_c,$$

shewing that $\eta_c G_d$ is a derived derangement of G_d. But the first is untrue because G_d has only θ's and has no η_c in common with I_{t+1}: and the second is impossible, because G_d is a maximum group.

In like manner can be proved, exactly as in art. 6, that no two of the aforesaid h equivalents of G_d are alike.

Thus theorem U is demonstrated.

9. Returning to (356142) (art. 8 and 6) as our G_d under $\Sigma = \alpha\beta\gamma\gamma\gamma\gamma$, we form with the λ's of H_6 the equivalents

$$\lambda_1 G_d \lambda_1^{-1},\ \lambda_2 G_d \lambda_2^{-1},\ \lambda_3 G_d \lambda_3^{-1},\ \lambda_4 G_d \lambda_4^{-1},\ \lambda_5 G_d \lambda_5^{-1},\ \textit{i.e.},$$

$G_{e1} = 435612, G_{e2} = 364215, G_{e3} = 346512, G_{e4} = 534162, G_{e5} = 451632$

which five are marked out by G_d, as all giving the same $\mathfrak{G}_d^{+\cdot}$.

Taking next (542631) art. 6 for G_{2d}, we get by the same H_6

$G_{2e1} = 354261,\quad G_{2e2} = 452361,\quad G_{2e3} = 436521,$
$G_{2e4} = 345621,\quad G_{2e5} = 536241.$

five groups marked out by G_{2d} as all giving the same $\mathfrak{G}_{2d}^{+\cdot\cdot}$.

Since η in K_2 (art. 8) is in I_{t+1} and is no Θ, G_d is bound (F.G. 8, 5) to mark out the group (F.G. 10)

$$\eta G_d \eta^{-1} = 125634 \cdot 356142 \cdot 125634 = 536241 = G_{2e5} \text{ above.}$$

Wherefore

$$\mathfrak{G}_d^{+}\cdot\cdot = \mathfrak{G}_{2e5}^{+}\cdot\cdot,$$

and we have proved that

$$\mathfrak{G}_{2d}^{+}\cdot\cdot = \mathfrak{G}_{2e5}^{+}\cdot\cdot,$$

whence

$$\mathfrak{G}_d^{+}\cdot\cdot = \mathfrak{G}_{2d}^{+}\cdot\cdot$$

and all the 2·6 functions under $\Sigma = \alpha\beta\gamma\gamma\gamma\gamma$,

$$\mathfrak{G}_d^{+}\cdot\cdot,\ \mathfrak{G}_{e1}^{+}\cdot\cdot \ldots,\ \mathfrak{G}_{2d}^{+}\cdot\cdot\ \mathfrak{G}_{2e1} \ldots,$$

are the same function.

For the function G_d, *i.e.*, 356142, of art. 6 under Σ, is

$$2[(\overset{\alpha\beta}{12} + \overset{\alpha\beta}{21})(3456)^{\gamma} + (\overset{\alpha\beta}{35} + \overset{\alpha\beta}{53})(1246)^{\gamma} + (\overset{\alpha\beta}{64} + \overset{\alpha\beta}{46})(1235)^{\gamma}] \quad (\gamma \overset{=}{>} 0).$$

This is invariable by each of the substitutions

$$1,\ 125634,\ 123654,\ 125436,$$

which are all in I_{t+1} and none of them in G_d (art. 6). Any one of them is C giving (art. 3).

$$C\mathfrak{G}_d = \mathfrak{G}_d,$$

wherefore $\mathfrak{G}_d$ is four times repeated in $\mathfrak{G}_d^{+}\cdot\cdot$, and all the aforesaid 12 are the same 15-valued function with its values.

9_2. The cyclical $G_D = 234561$ ($\Sigma = \alpha\beta\gamma\gamma\gamma\gamma$) has no Θ in common with I_{24}, which is

$$\begin{array}{rll}
I_{24} = 123456 & 123465_{12} & = H_{24} \times J_1 \\
\lambda_1 124365 & 124356_{13} & \\
\lambda_2 126543 & 125643_{14} & \\
\lambda_3 125634 & 126534_{15} & \\
\lambda_4 123564 & 123654_{16} & \\
\lambda_5 125346 & 126345_{17} & \\
\lambda_6 124653 & 124563_{18} & \\
\lambda_7 126435 & 125436_{19} & \\
\lambda_8 123645 & 123546_{20} & \\
\lambda_9 126354 & 125364_{21} & \\
\lambda_{10} 125463 & 126453_{22} & \\
\lambda_{11} 124536 & 124635_{23} &
\end{array}$$

If we name the 23 substitutions following unity,

$\theta_1\theta_2\theta_3 \ldots \theta_{23}$, we get, for $G_{E1} = \theta_1 G_D \theta_1^{-1}$, $G_{E2} = \theta_2 G_D \theta_2^{-1}$, &c.
to $G_{E23} = \theta_{23} G_D \theta_{23}^{-1}$,

the 23 groups here under written after $G_D = 234561$:

$$\Sigma = \alpha\beta\gamma\gamma\gamma\gamma.$$

G_D (234561), 235164, 236514, 234615, 236145, 235641 E20
G_{E1} (246315), 254631, 265143, 245361, 264513, 256134 E21
G_{E2} (261345), 265314, 246531, 251364, 256341, 245613 E22
G_{E3} (254163), 241635, 251643, 264135, 241563, 261534 E23

These 23 are marked out by G_D as all giving $\mathfrak{G}_D^{+\cdots}$. That G_D is 60-valued is plain if we put $\gamma = 0$ in G_D; for

$$\overset{\alpha\beta}{12} + \overset{\alpha\beta}{21} + \overset{\alpha\beta}{23} + \overset{\alpha\beta}{32} + \overset{\alpha\beta}{34} + \overset{\alpha\beta}{43} + \overset{\alpha\beta}{45} + \overset{\alpha\beta}{54} + \overset{\alpha\beta}{56} + \overset{\alpha\beta}{65} + \overset{\alpha\beta}{61} + \overset{\alpha\beta}{16} = \mathfrak{G}_D,$$

is a 60-valued function, and the 23 equivalents must be all 60-valued also. The function on $G_D^{+\cdots}$ is retained.

There are $60 - 12 - 24 = 24$ groups yet unmarked. We take 342615 for G_{2D}. It has no Θ in common with I_{24} On this we form, by the same $\lambda_1\lambda_2 \ldots \lambda_{23}$,

$$\lambda_1 G_{2D} \lambda_1^{-1} = G_{2E1}, \ \lambda_2 G_{2D} \lambda_2^{-1} = G_{2E2}, \ \&c.,$$

which are thus written after G_{2D} which marks the 23 out.

$$\Sigma = \alpha\beta\gamma\gamma\gamma\gamma.$$

$G_{2D} =$ (342615), 352641, 362145, 342561, 362514, 352164, E20
G_{2E1}, (435261), 536124, 634512, 436215, 635142, 534621, E21
G_{2E2}, (654132), 641532, 451263, 564123, 541623, 461235, E22
G_{2E3}, (561324), 465213, 546321, 651342, 456231, 645312, E23

The function of this group under Σ,

$$\begin{array}{lll} G_{2D} = & 123456 & 165432 \\ & 342615 & 546213 \\ & 264531 & 624351 \\ & 456123 & 432165 \\ & 615342 & 213546 \\ & 531264 & 351624 \end{array}$$

is that under Σ of its derivates by 125346, 124536, 124356, 125436, 123546, which are in I_{24}, but not in

G_{2D}. $\mathfrak{G}_{2D}$ therefore has only 10 values, which are 6 times repeated in $\mathfrak{G}_{2D}^{+}\cdot\cdot$. Wherefore G_{2D}, and every group marked out by it give that 10-valued function, and G_{2D} is retained.

Under $\Sigma = \alpha\beta\gamma\gamma\gamma\gamma$,

we have won three functions:

$\mathfrak{G}_d = (356142)$ has six terms and fifteen values:
$\mathfrak{G}_D = (234561)$ has twelve terms and sixty values:
$\mathfrak{G}_{2D} = (342615)$ has twelve terms and ten values.

$$\underline{\Sigma = \alpha\beta\beta\gamma\gamma\gamma.}$$

10. The maximum groups

$$\begin{array}{llllll}
G_d = & 123456 & 132546 & \qquad G_{2d} = & 123456 & 132546 \\
 & 465213 & 564312 & & 251364 & 341265 \\
 & 231645 & 321654 & & 562143 & 463152 \\
 & 654321 & 645231 & & 645231 & 654321 \\
 & 312564 & 213465 & & 436512 & 526413 \\
 & 546132 & 456123, & & 314625 & 215634
\end{array}$$

have each 132546 in common with I_{12}, which here is

$$\begin{array}{lllll}
I_{t+1} = I_{12} = 123456 + 132456 = & & 123456 \times 123456 & = H_6 J_2. \\
\theta_1 123564 & 132564 & 123564\lambda_1 \; 132546 & = \Theta \\
\theta_2 123645 & 132645 & 123645\lambda_2 & \\
\theta_3 123465 & 132465 & 123465\lambda_3 & \\
\theta_4 123654 & 132654\theta_{10} & 123654\lambda_4 & \\
\theta_5 123546 & 132546\theta_{11} & 123546\lambda_5 &
\end{array}$$

Taking $G_d = 465213$, above written, we get, by aid of H_6,

$$\lambda_1 G_d \lambda^{-1},\ \lambda_2 G_d \lambda_2^{-1},\ \lambda_3 G_d \lambda_3^{-1},\ \lambda_4 G_d \lambda_4^{-1},\ \lambda_5 G_d \lambda_5^{-1},\ \text{which are}$$
$$546321,\ 465321,\ 456231,\ 564231,\ 456312,\ \text{or}$$
$$G_{e1}\ G_{e2} \ldots G_{e5},$$

to be marked out by G_d, as all giving $\mathfrak{G}_d^{+}\cdot\cdot$, all functions of 6 terms. (F.G. 13).

It is evident in these five groups that every substitution of H_6 is a C, no Θ, making (art. 3).

$$C\mathfrak{G}_d = \mathfrak{G}_d$$

a true, so that $\mathfrak{G}_d$ is six times repeated in $G_d^{+}\cdot\cdot$ under Σ and is a ten-valued function, as are all the five $\mathfrak{G}_{e1}^{+}\cdot\cdot$, &c., marked out.

Taking now $G_{2d} = 251364$, above given, we obtain by H_6 G_{2e1}, $G_{2e2} \,..\, G_{2e5}$ to be marked out by G_{2d}. These are 261534, 241563, 261345, 251643, 241635. $G_{2\bar{d}}$ has no symmetry under Σ in 23 or in 456, wherefore $\mathfrak{G}_{2d}$ is a function of 6 terms and of 60 values. We retain $\mathfrak{G}_d$ and $\mathfrak{G}_{2d}$ as won functions.

There are $60 - 12 = 48$ groups not marked out. Taking $G_D = 234561$, which has no substitution Θ in common with I_{12}, as is clear by a glance at the substitutions beginning in our paradigm with 1, we name as above the 11 θ's of I_{12}, and obtain 11 groups G_{E1}, $G_{E2} \,..\, G_{E11}$ to be marked out by G_D. Then taking at random, as we require them, three more standards, G_{2D}, G_{3D}, G_{4D}, we obtain three more elevens, G_{2E1}, &c., G_{3E1}, &c., G_{4E1}, &c., to be marked out.

These elevens are all written below, headed by the standards which mark them out.

$$\Sigma = \alpha\beta\beta\gamma\gamma\gamma.$$

$G_D = (234561)$, 235164, 236514, 234615, 236145, 235641,
342561, 352164, 362514, 342615, 362145, 352641.
$G_{2D} = (256341)$, 264135, 245613, 265314, 254163, 246531,
365241, 346125, 354612, 356214, 345162, 364521.
$G_{3D} = (256134)$, 264513, 245361. 265143, 254631, 246315,
365124, 346512, 354261, 356142, 345621, 364215.
$G_{4D} = (436521)$, 462315, 542631, 435612, 452361, 536241,
462531, 436215, 534621, 452613, 435261, 562341.

The reader, if he likes to construct (art. 1) the last three standards, will satisfy himself that by the absence of symmetry under $\beta\beta$ and $\gamma\gamma\gamma$, they are all proved to have 60 values.

Thus we have demonstrated that there are,

under $\alpha\beta\beta\gamma\gamma\gamma$,

six distinct functions constructible, namely,

$\mathfrak{G}_d = 465213$, which has 6 terms and 10 values,
$\mathfrak{G}_{2d} = 251364$, which has 6 terms and 60 values,

and $\mathfrak{G}_D = 234561$, $\mathfrak{G}_{2D} = 256341$, $\mathfrak{G}_{3D} = 256134$, and $\mathfrak{G}_{4D} = 436521$, each of the four having 12 terms and 60 values.

$$\underline{\Sigma = \alpha\alpha\beta\beta\gamma\gamma}.$$

11_1. The group of order 6! has 15_{222} in its title: in our title, art. I. stands 4_{222}. The equation

$$60\cdot 4_{222} = 16\cdot 15_{222}.$$

shows that each of the 15 is found in 16 of our 60 equivalents. Of the 16 containing each 214365, four are

$G_d = 123456$	$G_{2d} = 123456$	$G_{3d} = 123456$	$G_{4d} = 123456$
436521	254631	316245	462315
561234	536142	635124	356241
$\Theta = 214365$	341265	564312	215634
345612	462513	452631	641523
652143	615324	241563	534162
125634	163542	132654	126543
654321	645231	$\Theta = 214365$	532614
341256	432156	425136	643251
216543	351624	546213	$\Theta = 214365$
563412	526413	653421	351426
432165	$\Theta = 214365$	361542	465132

The index group is

$I_8 = 123456 = 123456 \times 123456 \quad = H_4J_2$
124365 $\quad 213465\lambda_1 \; 214365 = \Theta$
123465 $\quad 124365\lambda_2$
124356 $\quad 214356\lambda_3$
213456
$214365 = \Theta$
213465
214356

Taking in turn

$$G_d,\ G_{2d},\ G_{3d},\ G_{4d},$$

above for standards, we get on them by $\lambda_1\lambda_2\lambda_3$ four threes,

$$G_{e1}\ \&c.,\ G_{2e1}\ \&c.,\ G_{3e1}\ \&c.,\ G_{4e1}\ \&c.,$$

to be marked out.

These four threes are written as follows, each three headed by the standard that marks it out.

$$\Sigma = \alpha\alpha\beta\beta\gamma\gamma.$$

$G_d = (436521)$, $G_{2d} = (254631)$, $G_{3d} = (316245)$, $G_{4d} = (462315)$
$G_{\epsilon 1} = 651234$, $G_{2\epsilon 1} = 614523$, $G_{3\epsilon 1} = 235164$, $G_{4\epsilon 1} = 541362$
$G_{\epsilon 2} = 561243$, $G_{2\epsilon 2} = 265314$, $G_{3\epsilon 2} = 412563$, $G_{4\epsilon 2} = 354261$
$G_{\epsilon 3} = 562134$, $G_{2\epsilon 3} = 516342.$ $G_{3\epsilon 2} = 241635$, $G_{4\epsilon 3} = 634125$

Our first standard under Σ $\mathfrak{G}_d$ is invariable by

$$\lambda_1\lambda_2\lambda_3,\ \textit{i.e.}\ \lambda_1\mathfrak{G}_d = \mathfrak{G}_d = \lambda_2\mathfrak{G}_d = \lambda_3\mathfrak{G}_d,$$

so that $\mathfrak{G}_d$ is four times repeated in $\mathfrak{G}_d^{+\cdot\cdot}$, and has only 15 values, as have also those marked out by it. $\mathfrak{G}_{2d}$, $\mathfrak{G}_{3d}$, and $\mathfrak{G}_{4d}$, having no such symmetry under $\alpha\alpha\beta\beta\gamma\gamma$, have 60 values; and all the four standards under Σ have 6 terms.

11_2. The group (356142), (art. 6), has $\Theta = 124365$ in common with I_8, which is now divided into products thus:

$$\begin{array}{lll} I_8 = 123456 \times 123456 & & = H'_4 \cdot J'_2. \\ \quad \lambda_1 214356 & 124365 = \Theta & \\ \quad \lambda_2 213456 & & \\ \quad \lambda_3 124356 & & \end{array}$$

Calling (356142) G_δ, we get on it by $\lambda_1\lambda_2\lambda_3$ in H'_4,

$$G_{\epsilon 1} = 635214,\quad G_{\epsilon 2} = 365124,\quad G_{\epsilon 3} = 642513,$$

all to be marked out by G_δ because they all give $\mathfrak{G}_\delta^{+\cdot\cdot}$.

11_3. The group which we take as $G_{2\delta}$,

$$\begin{array}{lll} G_{2\delta} = & 123456 & 132654 \\ & 456231 & 654321 \\ & 231564 & 321546 \\ & 564312 & 546213 \\ & 312645 & 213465 = \Theta \\ & 645123 & 465132 \end{array}$$

has 213465 in common with I_8, which is now written

$$\begin{array}{lll} I_8 = 123456 \times 123456 & & = H'_4 J''_2 \\ \quad \lambda_1 214356 & 213465 = \Theta & \\ \quad \lambda_2 213456 & & \\ \quad \lambda_3 124356 & & \end{array}$$

The preceding $H'_4 \times J'_2$ being altered only in the second factor. By the same $\lambda_1\lambda_2\lambda_3$ we get on $G_{2\delta}$.

$$G_{2\epsilon} = 532641,\quad G_{2\epsilon 2} = 546132,\quad G_{2\epsilon 3} = 352641,$$

which three are marked out by $G_{2\delta}$.

11_4. We take for $G_{3\delta}$ 462531, which is

$$\begin{array}{ll} G_{3\delta}=123456 & 153624 \\ \phantom{G_{3\delta}=}462531 & 645231 \\ \phantom{G_{3\delta}=}516324 & 214356=\Theta \\ \phantom{G_{3\delta}=}341265 & 361542 \\ \phantom{G_{3\delta}=}254613 & 526413 \\ \phantom{G_{3\delta}=}635142 & 432165 \end{array}$$

and has 214356 in common with I_8, which is now written

$$\begin{array}{lll} I_8=123456\times 123456 & & =H_4''J_2''' \\ \mu_1 213465 & 214356=\Theta & \\ \mu_2 213456 & & \\ \mu_3 123465 & & \end{array}$$

We get on

$$462531=G_{3\delta} \text{ by } \mu_1\mu_2\mu_3 \text{ in } H_4'',$$

$$G_{3\epsilon 1}=541623,\quad G_{3\epsilon 2}=641532,\quad G_{3\epsilon 3}=452163.$$

The groups G_δ, $G_{2\delta}$, $G_{3\delta}$, mark out each three, thus written ;

$$\Sigma=\alpha\alpha\beta\beta\gamma\gamma.$$

$$\begin{array}{llll} G_\delta=(356142), & G_{\epsilon 1}=635214, & G_{\epsilon 2}=365124, & G_{\epsilon 3}=642513\,; \\ G_{2\delta}=(456231), & G_{2\epsilon 1}=532641, & G_{2\epsilon 2}=546132, & G_{2\epsilon 3}=352641\,; \\ G_{3\delta}=(462531), & G_{3\epsilon 1}=541623, & G_{3\epsilon 2}=641532, & G_{3\epsilon 3}=452163. \end{array}$$

We have given account of 7 standards and of 21 groups marked by them.

G_δ, $G_{2\delta}$ and $G_{3\delta}$ have no such symmetry under $\alpha\alpha$, $\beta\beta$, and $\gamma\gamma$, that any C in I_8 can make

$$C\mathfrak{G}_f=\mathfrak{G}_f, \quad \text{art. } 3,$$

true of any one of them. All three have 60 values.

11_5. There remain $60-28=32$ groups unmarked, which have no substitution of I_8, which is now to be written

$$\begin{array}{lll} I_8=123456 & 213456\theta_4 & =H_8\cdot J_1 \\ 214365\theta_1 & 124364\theta_5 & \\ 214356\theta_2 & 124356\theta_6 & \\ 213465\theta_3 & 123465\theta_7 & \end{array}$$

Taking at random from groups unmarked, as we require them,

$$G_D=234561,\quad G_{2D}=245613,\quad G_{3D}=342615,\quad G_{4D}=354612,$$

we get upon them by $\theta_1\theta_2\cdot\cdot\theta_7$, the three sevens here below written under the standards which mark them out.

$$\Sigma = \alpha\alpha\beta\beta\gamma\gamma.$$

$$\begin{array}{llll}
G_D = 123456, & G_{2D} = 123456, & G_{3D} = 123456, & G_{4D} = 123456 \\
\quad 234561, & \quad 245613, & \quad 342615, & \quad 354612 \\
\quad 345612, & \quad 461325, & \quad 264531, & \quad 416235 \\
\quad \vdots & \quad \vdots & \quad \vdots & \quad \vdots \\
G_{E1},\ 415362, & G_{2E1},\ 316524, & G_{3E1},\ 346125, & G_{4E1},\ 456312 \\
G_{E2},\ 245361, & G_{2E2},\ 416532, & G_{3E2},\ 436215, & G_{4E2},\ 534621 \\
G_{E3},\ 314562, & G_{2E3},\ 246531, & G_{3E3},\ 352164, & G_{4E3},\ 562341 \\
G_{E4},\ 246315, & G_{2E4},\ 235641, & G_{3E4},\ 435261, & G_{4E4},\ 364521 \\
G_{E5},\ 314625, & G_{2E5},\ 236514, & G_{3E5},\ 362145, & G_{4E5},\ 564231 \\
G_{E6},\ 234615, & G_{2E6},\ 415623, & G_{3E6},\ 342561, & G_{4E6},\ 465321 \\
G_{E7},\ 416325, & G_{2E7},\ 315642, & G_{3E7},\ 345162, & G_{4E7},\ 546321
\end{array}$$

We have thus given account of our 60 groups under $\Sigma = \alpha\alpha\beta\beta\gamma\gamma$. The reader will easily satisfy himself that no substitution C of I_8 can make

$$C\mathfrak{G} = \mathfrak{G} \qquad \text{(a, art. 3).}$$

true of any one of our 11 retained standards except the first, $\mathfrak{G}_d$. art. 11_1.

We have proved that 11 distinct functions are given under $\alpha\alpha\beta\beta\gamma\gamma$; viz., putting = for given upon,

$\mathfrak{G}_d = 436521$ has 6 terms and 15 values ;
$\mathfrak{G}_{2d} = 254631$, $\mathfrak{G}_{3d} = 316245$, and $\mathfrak{G}_{4d} = 462315$ have each 6 terms and 60 values ;
$\mathfrak{G}_\delta = 356142$, $\mathfrak{G}_{2\delta} = 456231$, and $\mathfrak{G}_{3\delta} = 462531$ have each 6 terms and 60 values ;
$\mathfrak{G}_D = 234561$, $\mathfrak{G}_{2D} = 245613$, and $\mathfrak{G}_{3D} = 342615$, and $\mathfrak{G}_{4d} = 354612$ have each 12 terms and 60 values.

$$\underline{\Sigma = \alpha\alpha\alpha\beta\beta\beta}$$

12. Our index group is I_{33}. The group (456312), viz. :

$$\begin{array}{rl}
G_d = 123456 & +\ 132546\theta_3 \\
456312 & \quad 546213 \\
\theta_2 312645 & \quad 213654\theta_5 \\
645231 & \quad 654321 \\
\theta_1 231564 & \quad 321465\theta_4 \\
564123 & \quad 465132
\end{array}$$

has the subgroup J_6 marked in it in common with

$$\begin{array}{lllll} I_{36} = & 123456 & \times & 123456 & = J_6 \cdot H_6 \\ & 231564\Theta_1 & & 123564\lambda_1 & \\ & 312645\Theta_2 & & 123645\lambda_2 & \\ & 132546\Theta_3 & & 123465\lambda_3 & \\ & 321465\Theta_4 & & 123654\lambda_4 & \\ & 213654\Theta_5 & & 123546\lambda_5 & \end{array}$$

On

$$G_d = 456312 \text{ by } \lambda_1 \cdots \lambda_5 \text{ in } H_6$$

we get the 5 equivalents marked out by G_d, which are
564231, 645123, 465321, 654213, 546132, or $G_{e1} \cdots G_{e5}$.

This G_d, being identical with its five derivatives, $\lambda_1 G_d$, &c., under Σ, has two terms and 10 values, as have the five $G_{e1} \ldots G_{e5}$.

The cyclical $G_D = (234561)$ has, in common with I_{36}’ $\Theta = 321654$. The index group is

$$\begin{array}{lllll} I_{36} = 123456 + & \lambda_9 132564 & \times & 123456 & = H_{18} \cdot J_2, \\ \lambda_1 231456 & \lambda_{10} 321564 & & 321654 = \Theta & \\ \lambda_2 312456 & \lambda_{11} 213564 & & & \\ \lambda_3 132456 & \lambda_{12} 123645 & & & \\ \lambda_4 321456 & \lambda_{13} 231645 & & & \\ \lambda_5 213456 & \lambda_{14} 312645 & & & \\ \lambda_6 123564 & \lambda_{15} 123645 & & & \\ \lambda_7 231564 & \lambda_{16} 321645 & & & \\ \lambda_8 312564 & \lambda_{17} 213645 & & & \end{array}$$

where $H_{18} = 1 + \lambda_2 + \lambda_2 + \cdots + \lambda_{17}$.

We obtain on 234561 by H_{1s} the 17 equivalents $G_{E1} \cdots G_{E17}$ marked out by G_D, which are below headed by G_D.

$$\Sigma = aaa\beta\beta\beta.$$

$$\begin{array}{lll} G_D(234561) & {}_{6}235164 & {}_{12}236514 \\ G_{E1}431562 & {}_{7}531264 & {}_{13}631524 \\ {}_{2}241563 & {}_{8}251364 & {}_{14}261534 \\ {}_{3}342561 & {}_{9}352164 & {}_{15}362514 \\ {}_{4}412563 & {}_{10}512364 & {}_{16}612534 \\ {}_{5}314562 & {}_{11}315264 & {}_{17}316524 \end{array}$$

All these, like ·the standard $\mathfrak{G}_D$, have under Σ 6 terms and 60 values.

There remain 60 − 6 − 18 = 36 groups unmarked which have no substitution of I_{36}. One of these is

$$\begin{array}{rll} G\Delta = & 123456 + & 146253 \\ & 264135 & 432165 \\ & 651243 & 351426 \\ & 532614 & 564312 \\ & 346521 & 623541 \\ & 415362 & 215634 \end{array}$$

If we add to H_{18}, above written, its derivate by 321654, we have I_{36} before us, which is $I_{36} = 1 + \lambda_1 + \lambda_2 + \cdots + \lambda_{35}$.

On $G\Delta = 264135$ we get by these $\lambda_1.\ \lambda_2, \cdots \lambda_{35}$ the 35 equivalents marked out by $G\Delta$. They are all that remain of the 60 groups, and it is not necessary to write them down. They all give the function $\mathfrak{G}^{+}_{\Delta}\cdot\cdot$.

We have proved that under $\Sigma\alpha\alpha\alpha\beta\beta\beta$,
there are three functions obtained :

$\mathfrak{G}_d$ has 2 terms and 10 values ;
$\mathfrak{G}_D$ has 6 terms and 60 values ;
$\mathfrak{G}\Delta$ has 12 terms and 60 values.

$\Sigma = \alpha\alpha\beta\beta\beta\beta$.

13. The Group $G_\Delta = 234561$ has 216543 in common with

$$I_{48} = I_{24} \times \begin{array}{l} 123456 \\ 216543 = \Theta \end{array} \qquad = H_{24}J_2$$

where H_{24} is exactly $H_{\ 4} = I_{24}$ of art. 9_2.

G_Δ here marks out the 23 groups, which under $\Sigma = \alpha\beta\gamma\gamma\gamma\gamma$ it marked in that art. 9_2, and which are there headed by it as G_D, which had no Θ in common with I_{24} under $\alpha\beta\gamma\gamma\gamma\gamma$.

$\mathfrak{G}_\Delta$ is now a 60-valued function of 6 terms.

The group $342615 = G_{2D}$ of art. 9_2 is here our standard $G_{2\Delta}$, and marks out by the same H_{24} in that article the 23 groups that therein stand under it as G_{2D}, which had no Θ of I_{24} under $\alpha\beta\gamma\gamma\gamma\gamma$.

$\mathfrak{G}_{2\Delta}$ is a function here of 6 terms only.

$G_{2\Delta}$ is under this Σ in its 6 terms, as its twelve terms were under $\alpha\beta\gamma\gamma\gamma\gamma$ in art. 9_2, invariable by the same five derivants, 125346, 124536, 124356, 125436, 123546. It has therefore only 10 values.

The group $G\delta = 356142$, which as G_a in arts. 9_1 and 8 had only 124365 in common with I_{24}, has here, as

$$\begin{array}{rl}
G\delta = 123456 + & 124365\Theta_1 \\
356142 & 465132 \\
642315 & 532416 \\
\Theta_2 215634 & 216543\Theta_3 \\
534261 & 643251 \\
461523 & 351624,
\end{array}$$

four Θ's of I_{48}, which is now written

$$\begin{array}{lll}
I_{48} = 123456 \times & 123456 & = H_{12} \cdot J_4 \\
\lambda_1 124536 & 124365\Theta_1 & \\
\lambda_2 125346 & 215634\Theta_2 & \\
\lambda_3 124356 & 216543\Theta_3 & \\
\lambda_4 123546 & & \\
\lambda_5 125436 & & \\
\lambda_6 213456 & & \\
\lambda_7 214536 & & \\
\lambda_8 215346 & & \\
\lambda_9 214356 & & \\
\lambda_{10} 213546 & & \\
\lambda_{11} 215436 & &
\end{array}$$

By this H_{12} we form on $G\delta = 356142$ the 11 to be marked out by $G\delta$, which are thus headed by $G\delta$ under $aa\beta\beta\beta\beta$;

$$\begin{array}{ll}
G\delta(356142) & 536241 G_{\varepsilon 6} \\
G_{\varepsilon 1} 435612 & 345621 \quad {}_7 \\
{}_2 541362 & 452361 \quad {}_8 \\
{}_3 451632 & 542631 \quad {}_9 \\
{}_4 346512 & 436521 \quad {}_{10} \\
{}_5 534162 & 354261 \quad {}_{11}
\end{array}$$

and which were marked out in art. 9_1 under $a\beta\gamma\gamma\gamma\gamma$.

This $356142 = G\delta$, has under Σ three terms only (F.G.13) and being invariable under Σ by 213456, 125436, and 215436, which are in I_{12} and not in $G\delta$, has fifteen values $\mathfrak{G}_\delta$ being four times repeated in $\mathfrak{G}_\delta^{+\cdot\cdot}$.

We have proved that there are given under

$$\Sigma = \alpha\alpha\beta\beta\beta\beta.$$

$\mathfrak{G}\Delta = (234561)$ having 6 terms and 60 values,
$\mathfrak{G}_2\Delta = (342615)$ having 6 terms and 10 values,
$\mathfrak{G}\delta = (356142)$ having 3 terms and 15 values.

$$\underline{\Sigma = \alpha\beta\beta\beta\beta\beta.}$$

There is one function of 6 terms and one value.

14. We appear to have constructed on the first 60 equivalent transitive maximum groups of 6 letters, whose title is

$$6{\cdot}2 = 1 + 2_6 + 2_{33} + 4_{222} + 3_{2211}, \quad Q = 60,$$

all possible many-valued functions, viz.:

under $\alpha\beta\gamma\delta\epsilon\eta$,
60 functions each of 12 terms and of 60 values:

under $\alpha\beta\gamma\delta\epsilon\epsilon$,
30 functions of 12 terms and of 60 values:

under $\alpha\beta\gamma\delta\delta\delta$,
9 functions of 12 terms and of 60 values;
1 function of 12 terms and of 10 values:

under $\alpha\beta\gamma\gamma\delta\delta$,
2 functions of 6 terms and of 60 values;
1 function of 12 terms and of 15 values;
13 functions of 12 terms and of 60 values:

under $\alpha\beta\gamma\gamma\gamma\gamma$,
1 function of 6 terms and of 15 values;
1 function of 12 terms and of 60 values;
1 function of 12 terms and of 10 values:

under $\alpha\beta\beta\gamma\gamma\gamma$,
1 function of 6 terms and of 10 values;
1 function of 6 terms and of 60 values;
4 functions of 12 terms and of 60 values:

under $\alpha\alpha\beta\beta\gamma\gamma$,
1 function of 6 terms and of 15 values;
6 functions of 6 terms and of 60 values;
4 functions of 12 terms and of 60 values:

under $\alpha\alpha\alpha\beta\beta\beta$,
1 function of 2 terms and of 10 values;
1 function of 6 terms and of 60 values;
1 function of 12 terms and of 60 values:

under $\alpha\alpha\beta\beta\beta\beta$,
1 function of 6 terms and of 60 values;
1 function of 6 terms and of 10 values;
1 function of 3 terms and of 15 values:

under $\alpha\beta\beta\beta\beta\beta$.
1 function of 6 terms and of 1 value.
In all, 143 different functions.

I believe that no difficulty, which has not been overcome in the pages preceding, will be found in giving an equally good account of all the many-valued functions constructible on any tribe of maximum groups of *n* letters; and this by inspection of the paradigm of any one only of the equivalent groups, whether transitive or not.

P.S.—I must beg leave to withdraw my unguarded promise in the last page of "Functions given by Groups." *E.G.*, the 6-valued function of Serret (*F.G.* 16) has no value which can be so written, that when exponents are effaced it shall be a single group.

In my 87th year I can safely predict that this will be my last contribution to the theory of Groups and their Functions. My last word on the more difficult, but not less (over 34 years ago) fully worked out, Theory of the Polyedra, is to be found (I have a few copies to give) in Vol. XLIII. of the *Proceedings* of the Literary and Philosophical Society of Liverpool. *Vide* in *C.R.* the Prize Questions, proposed at Paris in 1858, for 1860 and 1861.

Concerning the opinion of any living reader, upon what was 30 years ago by the R.S. permitted to appear of my *Polyedra*, I have to say exactly what I said in *F.G.*, p. 19, about groups and their functions.

General Meeting, November 3, 1891.

EDWARD SCHUNCK, PH.D., F.R.S., F.C.S., President, in the Chair.

Mr. EDWARD HALKYARD, of Knutsford, and Professor ARTHUR W. HARE, M.B., F.R.C.S.E., F.R.S.E., of the Owens College, Manchester, were elected ordinary members of the Society.

Ordinary Meeting, November 3, 1891.

EDWARD SCHUNCK, PH.D., F.R.S., F.C.S., President, in the Chair.

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

Mr. HARRY GRIMSHAW, F.C.S., read a paper "On the Purification of Sewage." An animated discussion ensued, in which Mr. S. CLEMENT TRAPP, Mr. WILLIAM THOMSON, F.C.S., Dr. SCHUNCK, Mr. JOSEPH CORBETT, Mr. S. B. WORTHINGTON, and others took part. The general conclusion was that the possibility of making waters, polluted by sewage and industrial refuse, optically pure by means of chemical precipitation was no longer a matter of doubt, but that the practicableness of any of the methods proposed must depend on cost and on the possibility of disposing of the precipitated matter. Mr. JOSEPH CORBETT spoke in high terms of praise of the results already obtained by the Salford Corporation in dealing with the sewage pollution of the Irwell.

Notes on Sewage Precipitation. By Harry Grimshaw, F.C.S.

(*Received December 10th, 1891.*)

Among the innumerable chemical substances which have been used for the precipitation of the impurities in sewage, the salts of iron have of late years come prominently to the front, and have been much studied and experimented with in this relation. Both the natural and artificial iron compounds have been used with considerable success in different parts of the country.

The authorities of Buxton have taken advantage of a natural iron water, which they have conveyed a distance of a mile and adopted as the precipitating medium for their sewage, with the addition of a little lime.

The success of the Buxton process is such, that the river Wye below the sewage works contains, I believe, fish which greatly exceed in size and number those in the same river above the sewage outfall.

The Metropolitan Board of Works, it is stated, found very considerable benefit accrue from the addition of a few grains per gallon of an iron salt to the London sewage. In fact, experts are apparently coming to the conclusion that the salts of iron, if they can be procured at a cheap enough rate, are bound to be of great assistance in sewage purification. This is not only so in England, but is also being discovered on the Continent, as indicated, for instance, by the work done by some of the foreign chemists, as stated in recent numbers of the *Chemical Trade Journal.*

I do not propose, at present, to go into any exhaustive analysis of the respective merits of the numerous and various salts of iron which have been investigated in this connection, but merely to call attention to some experiments of my own with a special preparation of a per-salt of iron, which is, I understand, coming into use, and which would appear to be destined to take a high place as a sewage precipitant. It is a solution of the perchloride and peroxide of iron prepared in the following manner:—A peroxide of iron, either anhydrous or hydrated, but in either case free from ferrous compounds, is dissolved to saturation in hydrochloric acid, and to this solution hydrated ferric oxide is then added, which dissolves largely in the ferric chloride, forming a basic chloride or oxychloride of iron. This compound appears to have very great power of precipitation on the impurities of sewage, which is possibly due to its great neutrality and to the easy dissociation of the basic compound. The excess of oxide of iron, also, no doubt, "weights" the precipitated matters, and helps to cause a quick subsidence.

The three points I wish to illustrate by my experiments are (1) the remarkably quick action of the salt in causing coagulation and precipitation of the sewage; (2) to show that the conditions of acidity, alkalinity, or neutrality affect the action of sewage precipitants very materially; (3) that by a proper method of treatment some manufacturing effluents are also precipitated directly by this iron salt, whilst those which are not precipitated alone are very completely clarified when mixed with a sufficient quantity of sewage.

(1) The first sample is of the sewage of Failsworth, which is an example of one nearly free from manufacturing refuse, but containing domestic and farm drainage. You will see that one drop of the iron salt completely clarifies this sewage, and on subsidence gives a liquid some degrees clearer and brighter than Manchester water when unfiltered.

The mixed sewage of Salford and Pendleton contains a large proportion of manufacturing refuse, and, in fact, is about as complex a mixture as you can well have, but not what I should call excessively concentrated, being as a rule under 300 grains per gallon of solid matter. This requires a little more of the precipitant than the Failsworth sewage, but is easily coagulated and settles very quickly, giving an effluent of very satisfactory clearness. A slight filtration improves this sewage more than the former one, but with some little time for settling it does not appear to require filtration.

The next is a very filthy sewage, from a cesspool in Clayton, containing domestic and farm refuse, largely from "piggeries." It requires about the same amount as the Salford sample, and the precipitant throws down a comparatively enormous quantity of sediment, much of which is brought out of solution. The supernatant liquor in this sample is brighter-looking than the Salford one after clarification, but its character is not so good.

A notable point to be observed in the action of this salt of iron is that it always brings a considerable amount of impurity out of solution, and, as this is in all cases of a nitrogenous character, the albuminoid ammonia is very considerably reduced, the purification in this respect being, as a rule, from 80 to 90 per cent of alb. ammonia removed, according to the general average of the samples I have analysed.

A striking illustration of this purification from nitrogenous and, therefore, noxious decomposable matter is shown by taking a sample of the water now in the Ship Canal docks at Manchester. This has been settling for a long time, and looks fairly clear, and is free from suspended matter, and, in fact, does not appear to want any treatment. The addition, however, of about 10 grains of the iron salt to the gallon soon brings down a considerable sediment, and the water thus purified is so clear that the original appears of a very inferior character.

The effluent from the ordinary lime process of sewage-treatment, also passable in general appearance, would no doubt show a similar presence of coaguable nitrogenous matter if subjected to the action of the iron salt, but I have not had an opportunity to try this.

The proportion of the iron salt required for the Salford sewage is from 15 to 20 grains as a rule, but sometimes not more than 12 grains to the gallon. I am informed that the cost of this quantity amounts to one to two pounds sterling per million gallons.

(2) The next series of experiments illustrates the peculiarities of condition which are necessary for the successful purification of samples of sewage of different natures.

The sewage last-named would require, in its natural state, a very large excess of the precipitant to clarify it, on account of the unusually large quantity of free ammonia contained. We must, therefore, add a small quantity of a crude acid, say brown vitriol, or mix it with a faintly acid sewage, which is often available ; after which, as shown, a single drop of the iron salt clarifies it completely. On the other hand, a sewage too acid, say with manufacturing waste water, must be almost neutralised by the addition of a little lime, in which case it is best to add the iron salt previously, as is done at Buxton.

Some descriptions of sewage, however, must be rendered distinctly acid if treated alone, or no precipitation can be effected. The sewage of Pendleton is sometimes of this character, but, as a rule, becomes mixed with so much from other parts of Salford that it creates no special difficulty.

These few experiments are, I think, sufficient to show that the chemist requires to know the exact condition of the sewage under treatment, and to make an intelligent allowance for it, or what is really a comparatively simple problem becomes most inexplicably complicated.

(3) A few experiments upon the effluent waters from a

dyeworks, a bleach and sizing works, a paper mill, and a rubber factory will demonstrate the mode of procedure by which they can each be clarified. A drop or two of the iron salt is added to each. There is no apparent effect on the dye-water, which remains like ink. The bleach and paper works' effluents are coagulated, but no effective precipitation takes place. The rubber works' effluent is very satisfactorily clarified. We now mix a portion of the three non-precipitable effluents with varying proportions of sewage, taking preferably the very filthy one from Clayton. When one or two drops of iron salt are now added there is an immediate coagulation and separation of solid matters, and we get a very complete subsidence of the mixture carrying down the former obstinate impurities. In the case of the dye-water, filtration through a proper filter at once shows the " ink " converted into clear water.

This property of many kinds of sewage to coagulate under the action of the iron salt, and carry down even a soluble impurity, is strikingly shown by the addition of a quantity of sewage to a very strong solution of aniline blue, which is, of course, quite unaltered by subsidence or filtration, until, by the addition of two or three drops to the mixture, a clarification is at once effected, and, after subsidence, the former densely blue liquid becomes like town's water, the nitrogenous matter having, as a matter of fact, abstracted the dye just as wool exhausts a dye beck.

The foregoing experimental illustrations will, I think, tend to show the great part which properly chosen iron salts will play in clarifying and disinfecting our sewers and rivers, and they certainly show that a somewhat intimate study of the chemical condition of the sewage and effluents is necessary at the time the purifying agents are added, if anything like uniform success is to be attained.

[*Microscopical and Natural History Section.*]

Ordinary Meeting, November 9th, 1891.

Mr. CHARLES BAILEY, F.L.S., in the Chair.

Mr. H. HYDE gave the result of some observations on the common Ring Snake, which he had kept in captivity. He had found that it was able to twine itself round a gas pipe, and thus raise itself up so as to escape out of the top of the vivarium.

Mr. MARK STIRRUP made a communication about the new mammal lately discovered in Australia by Professor Stirling.

Mr. BOYD exhibited under the microscope the *Gamasus*, so often found parasitic on beetles.

General Meeting, November 17th, 1891.

EDWARD SCHUNCK, PH.D., F.R.S., F.C.S., President, in the Chair.

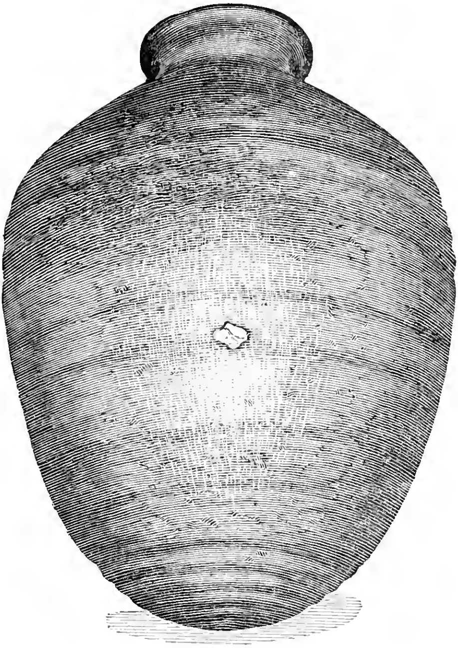
Mr. SAMUEL JOYCE, A.I.Elec.E., Manchester, was elected an ordinary member of the Society.

Ordinary Meeting, November 17th, 1891.

EDWARD SCHUNCK, PH.D., F.R.S., F.C.S., President, in the Chair.

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

Mr. WALTER TAYLOR, A.M.I.C.E., exhibited a jar made of rough, coarse, unglazed clay, found in the cutting of the Ship Canal, and read the following note on the subject:—



"This earthen jar was picked up by myself on the site of the Pomona Docks, now in course of construction by the

Manchester Ship Canal Company. It was lying on the ground opposite the Ordsall Paper Works, in a portion of the old river bed of the Irwell from which the water has been diverted for the purpose of constructing the Manchester Ship Canal. Unfortunately, the spot where it was found was not the exact spot from which it was excavated, it having been thrown on one side by the workpeople. But by enquiry I ascertained very nearly the exact spot. It was about 10 feet below the present river bed, on a deposit of an older age. The present river bed, for about 9 feet thick, is largely composed of ashes, sand, and gravel. Below this, very distinctly marked, comes a greyish silty sand, having coarser gravel below containing boughs and trunks of trees, and the jar, I have little doubt, came from the bed of greyish sand, as the sand inside of the jar was the same and contained no ashes. The shape of the jar is circular, it is 11½ in. high over all, 8 in. high to its greatest breadth, which is 8½ in. diameter, tapering to 5½ in. near the base, which is curved. The neck is 2½ in. wide, the shape is by no means true, the workmanship crude, and the vessel appears to be a dolmia, or wine cask, of common quality. The colour is a yellowish brown, but the fracture shews the centre of the clay burnt to a brightish red. The clay contains quartz pebbles, and what appear to be particles of a metallic substance. The rings, so characteristic of Roman pottery, are very clearly to be seen, especially inside the jar, which has an appearance of glazing in parts."

Professor BOYD DAWKINS said he did not like to speak positively as to the age of the jar, but suggested that it might be of early Roman or late Celtic age.

Mr. ALEX. HODGKINSON, M.B., B.SC., exhibited specimens of clover roots showing, under the microscope, the nodules developed by microbia, which, according to recent investigation, have the property of fixing the free nitrogen of the atmosphere and thus supplying the plants with nitrogenous nutriment.

A paper by Mr. W. J. CLUNIES ROSS, B.SC. (Lond. and Sydney), F.G.S., Principal of the Technical College, Bathurst, New South Wales, "On the Caves of New South Wales," communicated by the Rev. ROBERT HARLEY, M.A., F.R.S., was read by one of the secretaries, and photographs of the caves were exhibited.

The author stated that one of the first things that strikes a geologist from England when he resumes his studies at the Antipodes is the great similarity of Australian rocks to those he was familiar with in the old country. It is quite possible that detailed investigation may shew peculiarities in Australian rocks, especially the igneous ones, which distinguish them to some extent from those of Europe, but at first sight they appear identical. For example, massive limestones, composed almost entirely of encrinite stems, and exactly agreeing in colour and general appearance with the well-known encrinital limestones of England, are found. The scenery, too, in some cases, is very similar. Thus, around Pirate's Bay, in Tasmania, the visitor is reminded of North Devon, especially the neighbourhood of Clovelly, and it is interesting to find that the rocks in both places are of carboniferous age. Following out these similarities there are many caves in the Australian limestones. In New South Wales there are quite a number already known such as the Wellington, Abercrombie, Wombeyan, Jenolan, and Yarrangobilly Caves. Some of these are rather difficult to reach, and have only been partially explored; but the Jenolan, which are the best known, are comparatively accessible, and are both very extensive and singularly beautiful. To a geologist desirous of studying the formation of caves, and the changes they undergo, these caves are especially interesting, since, in the course of a few days, caves in various stages of formation and decay can be seen. The geological situation of the caves is also interesting, being quite close to one of the principal watersheds of the Colony, namely, that dividing the rivers which flow to the Pacific Ocean from the inland system of drainage, the waters of which ultimately reach the sea by the River Murray. The creeks which flow through the caves contribute their waters to the Neapean River, and finally reach the sea by the Hawkesbury, while, within a few miles, is the Fish River, one of the two streams which unite to form the Macquarie, near Bathurst. The Macquarie is a tributary of the Darling, and this joins the Murray. So close are the caves to this system of drainage that they are often called the Fish River Caves, although separated from that stream by the watershed. There is a good deal of similarity between most caves in limestone, but there are certain features about the Jenolan caves which render them especially interesting to a geologist as well as to a non-scientific visitor, amongst which are the great beauty and variety of the deposits of calcite in the caves. In one of the caves, the elder, a curious species of blind spider has been found. One of the caves, only partially explored, is known as the Mammoth Cave, and contains passages 10 miles long. The Wellington Caves are far away to the North-west from the Jenolan, being about six miles from the town of Wellington, which is 248 miles from Sydney, and 995 feet above sea level. They were discovered in 1832 by Sir Thomas Mitchell, and are interesting from the fossil bones which have been obtained there, such as those of *Diprotodon*, *Thylacoles*, and other extinct marsupials. Tools, drawings on the walls, and other indications of man's presence, have also been found, shewing that they were once inhabited, but the period at which they were so is uncertain.

Mr. WILLIAM BROCKBANK, F.G.S., read a paper entitled "On the Permians of the North-west of England—Discovery of two Plant Beds in the St. Bees' Sandstone at Hilton, Westmorland." A discussion ensued, in which Professor W. BOYD DAWKINS, F.R.S., and Mr. C. E. DE RANCE, F.G.S., took part, both gentlemen supporting Mr. BROCKBANK'S determination.

On the Permians of the N.W. of England. Discovery of Two Plant Beds in the St. Bees Sandstone, at Hilton, Westmorland. By William Brockbank, F.G.S., F.L.S.

(*Received November 17th, 1891*).

The late E. W. Binney contributed to the *Proceedings* of this Society several papers on the Permians of the N.W of England. These were the outcome of actual field work continued over many years, and they laid the foundation for what afterwards came to be accepted as the Permian system, in the N.W. of England.

In 1864 a joint communication by Sir R. I. Murchison and Prof. Harkness was made to the Geological Society of London, which summed up all the conclusions arrived at by the Geological Survey at that date, together with the researches of Prof. Sedgwick, Mr. Binney, and others who had given this subject especial attention. This article propounded what was stated to be a new view of the aggregate and component parts of the Permian group in Britain. By this arrangement these rocks were placed in direct correlation with their equivalents in Russia and Germany. In particular the Zechstein (Magnesian limestone) or its equivalents of great masses of superposed red sandstone, were in the N.W. of England, removed from the New Red Sandstone, or Trias, to which they had previously been assigned, to the Permian system, considering them to be the natural upper limit of the palæozoic deposits. In many *Memoirs*, published previously to this date (1864), these rocks had been classed with the New Red Sandstone, a fact which it is important to remember in pursuing this subject in its early literature.

Murchison and Harkness thus affirmed that the tripartite arrangement, which Murchison had insisted on some years before, as existing in parts of Germany, of a lower sandstone, or Rothliegende, a central limestone or Zechstein, and a connected superior sandstone, is clearly developed in the counties of Westmorland, Cumberland, and Lancashire. Sir Roderick added: "It is with great satisfaction that I state that the conviction of Prof. Harkness and myself upon this point has been also arrived at by the independent researches of my friend E. W. Binney, who, more than anyone of our countrymen, has vigorously and ably explored and brought into order the Permian rocks of the N.W. of England, and has also followed out their relations into Dumfriesshire and adjacent parts of Scotland. Incredulous, in the first instance, as he has assured me, regarding the natural connexion in Britain between the upper sandstone above alluded to, and those fossiliferous shales near Manchester that represent the Magnesian limestone, he has no longer any doubt that—and entirely coincides with us in considering—the sandstones of St. Bees Head, Corby, and other places described in this memoir, are the upper members of the Permian group." Sir R. Murchison then explained "that the transference of these sandstones of St. Bees and Corby to the Permian group is not founded on any evidence of a continuation of a similar type of a fossil fauna or flora, but that it was based on the evidence afforded by clear and unmistakable sections which show that these upper sandstones are connected with the lower sandstone, or Rothliegende, through the intervention of the Magnesian limestone, or its equivalent, and that, thus united, all these strata, from the base to the summit, form a continuous series. In truth, the central, or calcareous, member has alone, as yet, proved to be really fossiliferous, certain footsteps only having been found in the lower sandstone."

The Permian system, as thus laid down by Sir R. Murchison and Prof. Harkness, in 1864, has been accepted by geologists almost up to the present time, when, by the intervention of Mr. J. G. Goodchild, of the Geological Survey, the upper member of the group is again relegated to the Trias, and one of the newest maps of the survey is published with the upper member of the Permian described as Triassic.

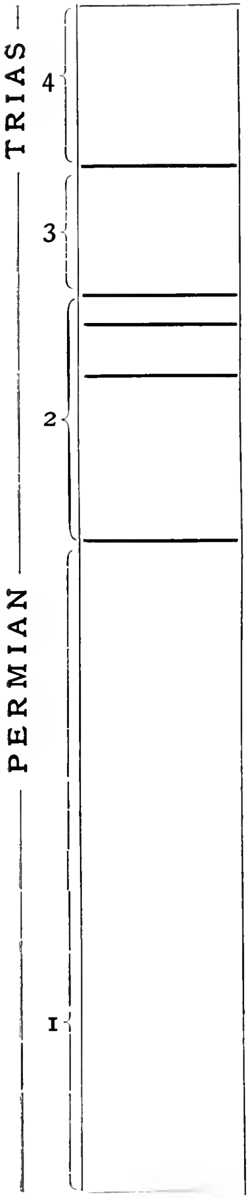
Mr. Goodchild's section, which is now exhibited by the kindness of Mr. W. Topley, F.R.S., of the Geological Survey, gives the following order of strata as applicable to the Cumberland and Westmorland district. (*See Diagram next page*).

My attention was directed to this question in connection with the paper I communicated to this Society last session, on the section at Frizington Hall, near Whitehaven, where the upper coal measures with *Spirorbis* limestones had been proved, immediately overlaid by the Permian breccia ; and near thereto the St. Bees sandstone. I had also traced these Permian rocks to the east of the Whitehaven Coal Field, resting high up on the Silurians of Dent and Copeland Forest, near Calder Abbey and Gosforth. Before resuming the study of these Permian strata in West Cumberland, I was wishful to examine the sections in Westmorland, where similar strata were lifted high up the flanks of the Crossfell range ; and more particularly the complete typical section at Hilton Beck, where the plant remains were acknowledged to be undoubtedly Permian.

As the Geological Survey map of the district was not yet published, I wrote to Mr. Topley for information, and he kindly sent me down a plan, section, and draft memoir, giving the survey and results in that district. I was astonished to find that the surveyors had abandoned the arrangement, settled by Sir R. Muchison, in 1864, and again by Sir A. Ramsay, the Director in 1881, and that the St.

GENERAL SECTION OF THE RED ROCKS,

In the Southern part of the Vale of Eden. By J. G. Goodchild, F.G.S.



ST. BEES SANDSTONE. Sun cracks, footprints (*Cheirotherium*) and poikolitic colouration, as seen East of Langwathby, Ousby, etc.

Passage beds downwards into Red Shales and Marls.

Ocaasional bands of brecciated quartziferous conglomerate.

MAGNESIAN LIMESTONE of Bela, Hilton Beck, etc.

CHOCOLATE SHALES AND MARLS with Gypsum.

PLANT BEDS. Alternations of Magnesia-calcareous sandstone and impure Magnesian limestones with shales and saffron-coloured sandstones. Occasional bands of Lignite, and one or two thin coals. Fragmentary remains of plants, much carbonized.

YELLOW SANDSTONES, with waterstones, graduating downwards into thinly bedded red sandstone.

UPPER BROCKRAM. Alternations of breccia and thin sandstones, graduating north-westwards into sandstone, and south-eastwards into the hard Brockram of Kirkby Stephen.

FALSE BEDDED BRIGHT COPPER RED SANDSTONE.

Lignite beds of the Giants Caves, Penrith.

LOWER BROCKRAM, of Burrells, Stank, and the Bela.

Bees sandstone was now classed as Trias; the line being drawn at the top of the Magnesian limestone, where the Permians were in future to end.

It will thus be seen that a very important change is taking place under the present Director General of the Geological Survey, whereby the tripartite Permian series in England is to be assimilated to the Dyas of Germany, and all the labours of Binney, Harkness, and others, with whom Lancashire geologists were and are in accord, are to be discarded, and in spite of the facts which are clearly in favour of the old arrangement.

HILTON BECK SECTION.

The rare occurrence of fossils in the Permians of England makes the section at Hilton Beck, near Appleby, the more interesting, as there we find plant beds of a distinctly Permian "flora." Prof. Harkness was, I believe, the discoverer of the plant bed, and he describes it in the paper before mentioned.

The Hilton shales, sandstones, and limestones are the equivalents of the Magnesian limestones of the East of England, and here they form the central part of the Permian series of the N.W. of England. Below them lie the Penrith sandstones and the breccia, or "brockram," which form the basement of the Permian group in the district. A similar section occurs on the Belabrook, near Brough, a few miles southwards—a description of which is given by Mr. Binney in our *Proceedings*, and later by Mr. James Eccles in the *Proceedings* of the Manchester Geological Society. A plant bed occurs in the Bela section, but the plants are in a very fragmentary condition. The sections may, however, be considered as similar, and this establishes the general group of rocks in the Hilton and Brough districts.

Mr. Harkness states that the basement beds of the middle Permian rocks, as seen at Hilton Beck, consist of cream-coloured shaly sandstone with thin partings of grey shale, and occasionally a narrow band of impure sandy limestone. These beds contain a considerable number of vegetable remains, among which Mr. Etheridge recognised the following :—*Sphenopteris Naumanni*, *S. dichotoma*, *Alethopteris Goepperti*, *Ulmannia Selaginoides*, *U. Bronnii*, (base of cones shewing bracts) *Odontopheris*, *Sphenopteris*, and *Cardiocarpum triangulare;* portions of coniferous wood also occur. Of these plants, two, viz., *Ulmannia Selaginoides* and *U. Bronnii* are common at the base of the Magnesian limestone of Durham, and the other forms occur also with the Ulmanniæ in the Kupferschiefer of Germany. These Hilton fossils, therefore, indicate an absolute identity in fossil remains with the Magnesian Limestone or Zechstein.

Mr. Harkness remarks that these plant beds are succeeded, upwards, by thin bedded sandstones, with impure limestones and shales, the highest member of the middle series being red clays, and that no clear evidence of the occurrence of plants has yet been detected except by the sides of Hilton Beck. In a similar section at Barrowmouth on St. Bees Head, succeeding quite conformably to a Magnesian limestone band, is the highest member of the middle series of Permian rocks. It is a mass of red shales, containing fine white gypsum, which Mr. Binney estimated at 29ft. thickness.

The mineral character of this band is identical with the middle portion of the Permian formation in the valley of the Eden. At Barrowmouth also the Magnesian limestone (which affords no fossils at Hilton) yields Permian fossils—*Schizodus Bakevillia*, &c.—just as we find them in the Permian marls of Manchester. At Hilton the contemporaneous strata contain yellow and grey shales with true Permian plants.

Above these beds in the N.W. of England we have the Upper Permians, the St. Bees, and Corby sandstones, which consist of red sandstones with courses of red shales, all perfectly comformable to the underlying Permians, there being a regular transition, or passage, into these, from the Middle Permians just described. (These are the beds which are to be relegated to the Trias, unless we can prove them to be Permian—and this, I think, we shall be able to do.)

" In all situations," say Messrs. Murchison and Harkness, "where we have examined them, whether in Westmorland, the east of Cumberland, or on the north portion of St. Bees Head, where they are largely and clearly displayed, they exhibit not only a perfect conformity to the middle Permian strata, on which they rest, but also an intimate connexion with them. Whatever may be the angle of inclination of the one is always that of the other, and nowhere is there to be seen a trace of erosion on the upper parts of the supporting strata, from which a separation might be inferred, such as would be expected between rocks of palæozoic age, and others of a mesozoic date. We have, therefore, no hesitation in expressing our conviction that these sandstones of St. Bees Head and Corby must be removed from the New Red or Trias, with which they have hitherto been grouped, and viewed as the upper zone of the Permian Group."

THE HILTON PLANT BEDS.

The special object of my visit to the Hilton section was with the upper portion of it, known as the St. Bees Sandstone, or Upper Permian; and I wished to make myself fully acquainted therewith, because of its bearing upon the similar group of rocks in West Cumberland. I examined the whole section of Hilton Beck, but will confine my remarks to its upper portion.

The plant beds occur at Ashgill, about a mile below the village of Hilton. The section here is well known geologists, being the only locality hitherto known in the

N. W. of England where plant remains of true Permian character have been found. The whole section is interesting, as it shews the curious Permian breccias or "brockrams." The plant beds occur at a bend of Hilton Beck, in a wood where there is a good escarpment of red rocks. At the base there is a dark purple soft sandstone, above which are several laminated beds of yellow sandstone, with some seams of almost yellow ochre. The plant beds occur just below these yellow beds, and are in greyish whitish stone, with thin clay partings. The plants are much comminuted, and wholly carbonised, and shew clearly, on the light coloured stone, like black etchings. I was fortunate in obtaining a very representative collection of specimens of truly Permian facies (*see* Plate II.), including *Ulmannia*, *Walchia*, &c., and in a very thin waferlike grey shale parting I found what I take to be *Chondrites*, which I have not seen noted before, and which agrees, as also do the others, with a figure in Geinitz 'Dyas.'

Above these beds come a series of yellow sandstones which are much spotted with plant remains, and amongst these occurs the representative of the magnesian limestone. These beds bear a very striking resemblance to those occurring at Barrowmouth, on St. Bees Head, where they yield *Schizodus*, *Bakevillia*, and other Permian shells. Here Mr. Goodchild draws the line as the limit of the Permians in the new survey sections at the top of the Magnesian Limestone.

Above this point came a mass of red marls, which Mr. Goodchild classes with the lower gypseous marls at the base of the Bunter ("Excursion to Edenside," p. 2), and he states that they graduate upwards into the St. Bees sandstone, which he calls Trias.

Proceeding up the valley beyond the marls, and on the opposite side of Hilton Beck, there is a sandstone quarry by the road side, a quarter of a mile or so below Hilton Bridge. It shews a face of rock about 30 feet high. The upper portion is a red bedded sandstone, below which are thin bedded yellow sandstones with clay partings. This stone is full of red clay small nodules, and here again occurs a plant bed with true Permian plants of the *Ulmannia* and *Walchia* types (*see* Plate III.). These thin beds are about 2ft. 6in. thick. The red rocks below them are also thin bedded,and show ripple marks, sun cracks, and other interesting peculiarities, with numerous small clay nodules about the size of coffee beans. All these sandstones are much spotted with black carbonaceous markings, and have clay partings, and the surfaces of the beds are ripple marked, and seamed with sun cracks. Some plant remains occur in the thin clay partings, and are very perishable.

The next good exposure of red rocks is about three-quarters of a mile further up the stream, beyond the village of Hilton, and here again plant remains were found. There is a rock outcrop here, the upper 20 feet of which is a bedded red sandstone of Permian colour, below which are several thin beds of yellow sandstone, with red marl partings. All these rocks contain the small clay nodules, so perfect in form as to suggest fossils, but I was not able to discover any traces of shell structure. Beneath these a soft red rock, blotted all through with black carbonaceous spots, and full of the small oval and circular clay lumps. On examining the specimens collected from this furthest group I found that one of the white sandstones which was faced with a shaley film contained very beautifully preserved plant remains under the shaley surface, of the same facies as the other Hilton beds—showing *Ulmannia*, *Walchia*, and fern fragments (*see* Plate IV.). All these red rocks, with their thinner grey and white beds and the plant remains, are evidently one series, the whole of them being much intermixed with carbonaceous matter, and all of them having plant beds of true Permian types. If, therefore, the plant beds of Ashgill are Permian, there can be no doubt whatever that the whole series are Permian, right up to the Pennine fault, and thus the St. Bees sandstone is proved to be Permian and not Triassic. Drawings of all these plant remains have been submitted to Prof. Boyd Dawkins, F.R.S., and to Mr. Goodchild, F.G.S., who agree in considering them of Permian facies.

This is the last exposure of red rocks, and occurs some 50 yards below the Old Hilton Smelt Mill. Just beyond it the great Pennine fault crosses Hilton Beck, Silurian rocks being seen crossing the stream tilted at a high angle; and here we come upon the Cross Fell inlier described by Professor Nicholson and Mr. Marr in the *Quarterly Journal of the Geological Society*, November 2nd, 1891.

It will thus be seen that the whole series of rocks from the Ashgill beds to the Smelt Mill are undoubtedly Permian.

It has been suggested that as this is a district of great disturbance, the recurrence of the plant beds may be the result of faults which may have brought in again the Hilton plant beds, but this is almost an impossibility. The beds are not the same bed, but are one series. The sequence was mapped by Prof. Harkness, and his accuracy has not since been questioned, and has been confirmed by the geological survey. It is quite clear also that no faults could alter their Permian character, as proved by the fossils. Although Harkness did not discover the fossils in these uppermost beds, he called them Permian from other observations.

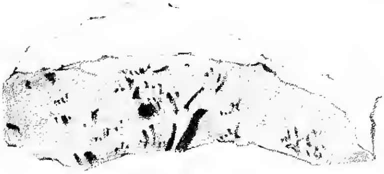
Mr. James Eccles, F.G.S., read a paper to the Geological Society of Manchester in 1874, describing the Bela Valley section a few miles to the south where similar red rocks occur, and there he found a plant bed as already stated. I forwarded the drawings of the Hilton plants to Mr. Eccles, and he says they agree with what he saw in the Bela Valley 20 years ago, only they were too fragmentary to be particularly recognized. I think, therefore, we may safely say that the sandstones from Bela to Hilton are thus proved to be Permian.

Prof. H. A. Nicholson published in 1868 an interesting essay on the Geology of Cumberland and Westmorland, in which he describes the upper part of the Hilton Beck section as follows :—"The Magnesian breccias are conformably succeeded at Ashbank by the Middle Permians, or Hilton Shales, consisting of thin bedded sandstones of various colours, with thin courses of marly shales and impure Magnesian limestones, the two former containing numerous remains of plants. They are surmounted by sandstones overlaid by a single stratum of impure limestone about 6ft. in thickness, and apparently without fossils. To this succeeds a mass of red laminated clays of no great thickness, forming the highest member of the middle Permians. The total thickness of the middle Permians, as exhibited at Hilton Beck, is from 120 to 150 feet. The Hilton shales are directly succeeded by the upper Permians, which extend up the stream as far as the Hilton Smelt Mill, where they are cut off by the Pennine fault, and are brought abruptly against the Skiddaw slates, which form the base of Roman Fell. They consist of fine grained dark red sandstone, seldom, if ever, false bedded, often beautifully ripple marked, and having intercalated with them beds of white sandstone and way boards of red shale—the whole attaining a thickness of 700ft."

To this excellent description we can now add that the white sandstones contain Permian plant remains. Prof. Nicholson writes me, "You are quite right in thinking that I never discovered any plant beds in the Hilton section above the red marls, or rather above the Magnesian limestone. Your discovery that plant beds occur higher up in the section, and that the remains of these have the general 'facies' of the Ashfield beds below is a very important one, and ought to be conclusive, it seems to me, as to the Permian age of the series throughout."

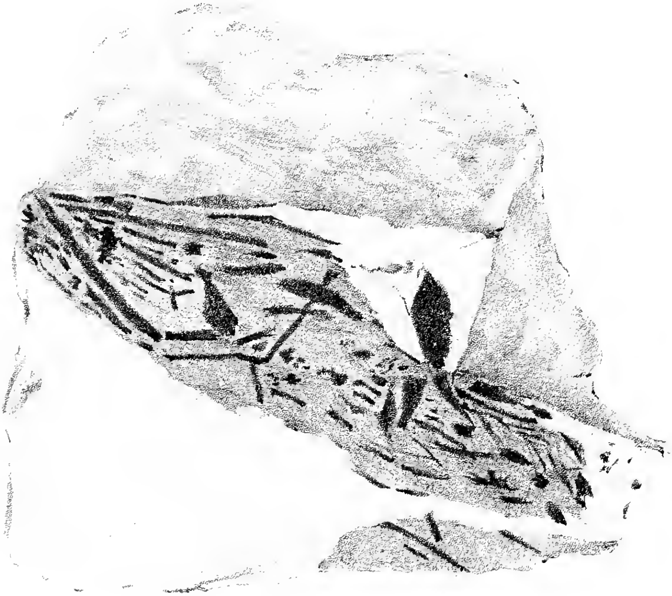
HILTON PLANT BED, (ASHGILL).

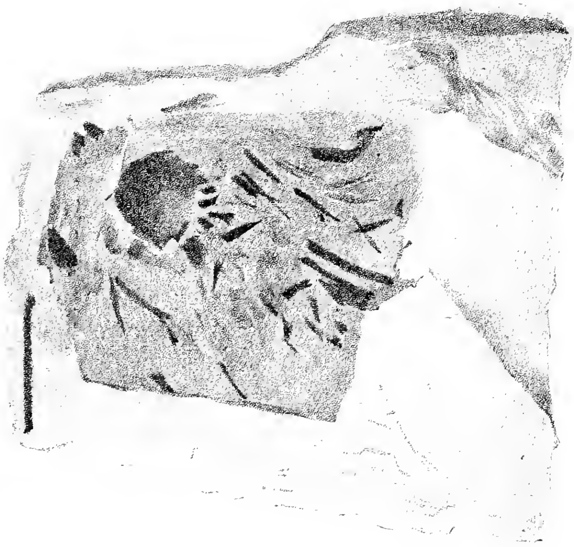
HILTON PLANT BED, (AT QUARRY).



HILTON PLANT BED, (NEAR SMELTMILL).

Plate. IV.





General Meeting, December 1st, 1891.

JAMES BOTTOMLEY, D.Sc., B.A., F.C.S., Vice-President, in the Chair.

Mr. JOHN EDWARD KING, M.A., High Master, Manchester Grammar School, was elected an ordinary member.

Ordinary Meeting, December 1st, 1891.

JAMES BOTTOMLEY, D.Sc., B.A., 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. ALEX. HODGKINSON, M.B., B.Sc., gave an account of some curious cores of sand, observed protruding from the ends of burrows in the perpendicular sides of a sand-pit, the burrows having been made by moles from the surface of the land.

Mr. W. E. HOYLE, M.A., exhibited a specimen of the giant earth-worm, of Gippsland, *Megascolides australis*, and read the following note on the subject :—

"The specimen now exhibited was presented to the Manchester Museum by Professor Baldwin Spencer, of the University of Melbourne, formerly a student in the Owens College, who has written an elaborate memoir on its anatomy. The worm lives principally in the sloping sides of creeks, but is sometimes found among fallen logs or turned up by the plough. The largest living one hitherto measured had a length of 6 feet, but about 4 feet may be put down as the average; the thickness being roughly ¾ inch. It secretes a milky slime in such quantities that jets will spurt out of it to a height of several inches when it is held in the hand. This fluid lubricates the burrows in which it lives, and enables it to move with very great rapidity; as it does so it produces a gurgling sound, which is one of the readiest and surest means of detecting its presence. When alive it has a curious odour resembling that of creosote, which, when it dies, becomes much stronger and more objectionable. It is hardly surprising to learn that fowls refuse to touch it dead or alive; in decaying, the body passes into an oily fluid, said by the natives to be very good for rheumatism. Beside the worm is exhibited the cocoon, which contains a single embryo enclosed in a tough leathery case. At the present time we know of three specially large kinds of earthworms, one from S. Africa, one from India and Ceylon, and one from the south of Australia; if future research should reveal the presence of another in South America, it would suggest the theory that these large worms are relics of a once widely-spread race, just as we believe to be the case with other forms of life found only in the southern parts of the great land masses."

The Rev. ROBERT HARLEY, M.A., F.R.S., read a paper on "The Interchange of Two Differential Resolvents."

On the Interchange of Two Differential Resolvents.

By the Rev. Robert Harley, M.A., F.R.S., Corresponding Member.

(*Received December 22nd, 1891.*)

1. The doctrine of differential resolvents rests on the following theorem, discovered by Sir James Cockle,[1] viz.:—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 degree $n-1$, which is satisfied by the roots of the algebraic equation. The derived equation is called with reference to the algebraic equation, its "differential resolvent"; and the two equations considered together are sometimes called "co-resolvents."[2] The solution of the algebraic equation gives the particular integrals of the differential equation, and, on the other hand, the integration of the differential equation gives the roots of the algebraic equation.

2. The above theorem, with its enunciation and proof was given more than thirty years ago, and, considering its importance in relation to both algebraic and differential equations, it is curious that it has not yet found its way into any of the ordinary text-books on these subjects. Its value, however, has been recognised by some of our most eminent analysts, and contributions to the general theory

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[1] Cockle. "On Transcendental and Algebraic Solution." *Philosophical Magazine*, Vol. XXI., May, 1861, pp. 379-383.

[2] Cockle. "Introductory Chapter on Co-resolvents." *Quarterly Journal of Mathematics*, Vol. VI., 1863, pp. 9-20, 151-162, 226-229.

will be found in the writings of Boole,[3] Cayley,[4] Spottiswoode,[5] Russell,[6] Rawson,[7] and others.

3. In early numbers of the *Proceedings* of this Society,[8] I showed that every differential resolvent is satisfied not only by the roots, but also by the constituents of the roots of the co-resolvent: these constituents are, in fact, particular integrals of the differential equation. In the same series of papers, I also showed that any homogeneous linear function of the roots will satisfy the differential resolvent provided only that such resolvent be also homogeneous.

4. In a later paper[9] I have enunciated and proved the

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[3] BOOLE. "On the Differential Equations which determine the form of the Roots of Algebraic Equations." *Philosophical Transactions* for 1864, pp. 733-755.

"Differential Equations." Supplementary Volume, 1865, pp. 190-199.

[4] CAYLEY. "Note on a Differential Equation." *Manchester Memoirs*, Vol. II., Third Series, 1861-2, pp. 111-114.

[5] SPOTTISWOODE. "Note on Differential Resolvents." *Manchester Memoirs*, Vol. II., Third Series, November, 1862, pp. 227-232.

"On Differential Resolvents." *Quarterly Journal of Mathematics*, Vol. VI., 1864, pp. 262-266.

[6] RUSSELL. "Solutions of the Quartic Resolvent." *Manchester Proceedings*, Vol. II., 1862, p. 240.

"Solution of the Differential Resolvent." *Manchester Memoirs*, Vol. II., Third Series, March, 1863, pp. 296-301.

[7] RAWSON.—"On a New Method of Determining the Differential Resolvents of Algebraical Equations." *Proceedings of the London Mathematical Society*, Vol. IX., 1878, pp. 202-215.

"On the First Resolvent of the Quartic $y^4+\alpha y^2+x,y-\frac{1}{12}\alpha^2=0$." *Messenger of Mathematics*, Vol. XI., 1881, pp. 19-23.

"On Differential Resolvents and Partial Differential Resolvents." *Manchester Memoirs*, Vol. VIII., Third Series, 1882, pp. 41-53.

[8] "Remarks on the Transcendental Solution of Algebraic Equations." *Manchester Proceedings*, Vol. II., Sessions 1860-61 and 1861-62, pp. 181-186, 199-203, 237-241.

[9] "Notes on a Differential Equation." *Quarterly Journal of Mathematics*, Vol. XVIII., 1881, pp. 41-46.

following theorem, viz. :—That if u represent the m^{th} power of any root of the algebraic equation

$$a_0y^n + a_1y^{n=1}. \quad . \quad . + a_{n-1}y + a_n = 0,$$

whereof the coefficients a are functions of a single parameter x, then u satisfies a certain linear differential equation which is, in general, of the order n. This differential equation admits, when m is a whole number, of a first integration, and may therefore be reduced to an equation of the order $n-1$; not, however, always of the same type as the higher equation. And I have shown, more generally, in the same paper, that if

$$u = b_0y^m + b_1y^{m-1}. \quad . \quad . + b_{m-1}y + b_m,$$

where the coefficients b are functions of x only, and m is an integer, we may by known processes, transform the above n—ic equation in y into an n—ic equation in u, and thence derive a linear differential equation of the order $n-1$, which will be satisfied by any one of the values of u, or by any of the constituents of u.

5. The object of this paper is to show that if two algebraic equations be so connected as that either can be changed into the other by assuming, without loss of generality, certain relations among the disposable quantities, then cases exist in which the two differential resolvents may also be interchanged by means of the same substitutions. Such interchanges, if practicable, are manifestly important, because they enable us, when one of the differential resolvents is calculated, to determine the form of the other by a simple substitution, and without the labour of an independent calculation.

6. We have a good example in the following case. The differential resolvents of the two trinomial algebraic equations

$$y^n - ny + (n-1)x = 0 \quad . \quad . \quad . \quad . \quad . \quad (\alpha)$$

$$y^n - ny^{n-1} + (n-1)x = 0 \quad . \quad . \quad . \quad . \quad (\beta)$$

(to which all algebraic equations of a degree not greater than 5 may be reduced,) are

$$n^{n-1}\left[x\frac{d}{dx}\right]^{n-1}y-(n-1)^{n-1}\left[\frac{n}{n-1}\,x\frac{d}{dx}-\frac{2n-1}{n-1}\right]^{n-1}x^{n-}y^{1}=0\quad . \quad . \quad (\alpha')$$

$$n^{n-1}\left[(n-1)x\frac{d}{dx}\right]^{n-1}y-(n-1)\left(nx\frac{d}{dx}-n-1\right)$$
$$\left[nx\frac{d}{dx}-2\right]^{n-2}xy=[n-1]^{n-1}x\,.\quad . \quad . \quad (\beta')$$

respectively, where the usual factorial notation

$$[a]^{b}=(a)(a-1)(a-2)\quad . \quad . \quad . \quad (a-b+1)$$

is adopted.

7. I may observe here that these forms were obtained originally by induction.[10] The determination of the differential resolvents of the two trinomial equations (α) and (β) for the particular cases $n=2$, 3, 4, 5, on which the induction was founded, necessitated many complicated and laborious calculations, which, however, led in all cases to remarkably simple and uniform results. Much of the labour might have been saved had I noticed at the time, what I now proceed to show, viz., that either of the general forms is implicitly contained in the other; in fact, I might have derived (β') from (α'), or *vice versâ*, merely by a change of the variables. When once the general forms had been suggested, there was not much difficulty in completing the induction, and showing that the equations held for all values of n, excepting only $n=2$. The exception occurs in the first form (α'), which, when $n=2$, should evidently coincide with (β'), seeing that in this case, (α) and (β) become identical. Now in (α) when $n=2$, the sum of the roots (Σy) is not, as in other cases, equal to zero, and the

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[10] "On a Certain Class of Linear Differential Equations." *Manchester Memoirs*, Vol. II., Third Series, 1861-62, pp. 232-245.

"On the Theory of the Transcendental Solution of Algebraic Equations." *Quarterly Journal of Mathematics*, 1862, Vol. V., pp. 337-360.

differential resolvent must therefore contain a term independent of y. This term written on the dexter $=x$, and the terms on the sinister follow the law indicated in (a').

8. If in equation (a) we write—

$$-n',\ \left(\frac{n'^{n'-1}}{x'}\right)^{\frac{1}{n'+1}},\quad \left(\frac{1}{n'^2x'}\right)^{\frac{1}{n'+1}}y,$$

for n, x, y respectively, it becomes—

$$y'^{n'+1}-(n'+1)y'^{n'}+n'x'=0 \quad . \quad . \quad . \quad . \quad (\gamma)$$

an equation which is, in form, the same as (β), and coincides with (β), when we drop accents and write $n-1$ for n. Here observe that

$$x\frac{d}{dx}=-(n'+1)x'\frac{d}{dx'},$$

or

$$\mathrm{D}=-(n'+1)\mathrm{D}',$$

where, for shortness, D and D′ are written for

$$x\frac{d}{dx}\text{ and }x'\frac{d}{dx'},$$

respectively.

Effecting in the differential resolvent (a') the same substitutions which changed (a) into (γ), and reducing by means of the formula

$$f(\mathrm{D})x^r u=x^r f(\mathrm{D}+r)u,$$

we are led to

$$(n'+1)^{n'+1}[-(n'+1)\mathrm{D}'+1]^{-(n'+1)}$$
$$-n'^2[-(n'\mathrm{D}'+1)]^{-(n'+1)}x'y'=0 \quad . \quad . \quad . \quad (\gamma'_0)$$

a result which I obtained many years ago, when I was seeking to pass from the differential resolvent of (a) to the differential resolvent of (β). The form was considered "curious and interesting," and I placed it on record in the *Memoirs* of this Society, remarking that it involved an "anomaly," and that I should "probably discuss it at some future time."[11] The supposed "anomaly" may be cleared

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[11] "On a Certain Class, &c." (paper cited in the last footnote) Art. 13, p. 244.

up, and the transformation carried forward to a satisfactory conclusion, by observing that, in conformity with the laws of the factorial notation, $[-a]^{-b}$ may be replaced by

$$\frac{(-1)^b}{[a-1]^b},$$

as may be readily shown, thus:—

$$[a]^b = (a)(a-1)(a-2) \quad . \quad . \quad . \quad (a-b+1),$$

$$[a-b]^c = (a-b)(a-b-1)(a-b-2) \quad . \quad . \quad . \quad (a-b-c+1),$$

and therefore

$$[a]^b[a-b]^c = [a]^{b+c}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (1)$$

an equation of identity which, we will assume, holds universally, that is to say, for all values of a, b, and c.

First, in (1), make $b=0$; then

$$[a]^0[a]^c = [a]^c, \text{ or } [a]^0 = 1.$$

Next, in (1), write $-b$ for c; then

$$[a]^b[a-b]^{-b} = [a]^0, \ = 1:$$

changing the signs of a and b,

$$[-a]^{-b}[b-a]^b = 1:$$

or, since

$$[b-a]^b = (b-a)(b-a-1)(b-a-2) \quad . \quad . \quad . \quad (-a+1),$$
$$= (-1)^b[a-1]^b,$$

therefore

$$[-a]^{-b} = \frac{(-1)^b}{[a-1]^b} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (2).$$

Applying the formula (2) to the differential equation (γ_0'), we have

$$[-(n'+1)D'+1]^{-(n'+1)} = \frac{(-1)^{n'+1}}{[(n'+1)D'-2]^{n'+1}},$$

$$[-(n'D'+1)]^{-n'+1} = \frac{(-1)^{n'+1}}{[n'D']^{n'+1}},$$

and, therefore,

$$\frac{(n'+1)^{n'+1}}{[(n'+1)D'-2]^{n'+1}}y' - \frac{n'^2}{[n'D']^{n'+1}}x'y' = 0.$$

or, more simply,

$$(n'+1)^{n'+1}[n'\mathrm{D}']^{n'+1}y' - n'^2[(n'+1)\mathrm{D}' - 2]^{n'+1}x'y' = 0,$$

an equation which contains the factor $(\mathrm{D}' - 1)$. The integration gives

$$(n'+1)^{n'+1}[n'\mathrm{D}']^{n'}y' - n'(n'+1\mathrm{D}' - n'+2)$$
$$[(n'+1)\mathrm{D}' - 2]^{n'-1}x'y' = \mathrm{C}x',$$

an equation which must be satisfied by any one of the roots of (γ). To determine the constant, sum for the $(n'+1)$ roots; then, since $\Sigma y' = n'+1$, we have

$$(n'+1)^{n+1}[n'\mathrm{D}']^{n'}(n'+1) - n'(\overline{n'+1}\mathrm{D}' - \overline{n'+2})$$
$$[(n'+1)\mathrm{D}' - 2]^{n'-1}x'(n'+1) = \mathrm{C}(n'+1)x',$$

which, reducing by the aid of the formula

$$f(\mathrm{D}')x'^r = x'f(r),$$

gives

$$\mathrm{C} = [n']^{n'}.$$

Hence the differential resolvent of (γ) is

$$(n'+1)^{n'}[n'\mathrm{D}']^{n'}y' - n'(\overline{n'+1}\mathrm{D}' - n' - 2)$$
$$[(n'+1)\mathrm{D}' - 2]^{n'-1}x'y' = [n']^{n'}x' \quad . \quad . \quad . \quad (\gamma').$$

Drop the accents and write $n-1$ for n; the result is the differential resolvent of (β), viz.:

$$n^{n-1}[(n-1)\mathrm{D}]^{n-1}y - (n-1)(n\mathrm{D} - n - 1)[n\mathrm{D} - 2]^{n-2}xy$$
$$= [n-1]^{n-1}x,$$

an equation which coincides in every point with (β').

9. It may be noticed here that if we write

$$-(n'-1), \quad \left(\frac{(n'-1)^{n'-2}}{x'}\right)^{\frac{1}{n'}}, \quad \frac{y'}{((n'-1)^2x')^{\frac{1}{n'}}},$$

for n, x, y respectively, and after substitution, drop the accents, (α) will be changed into (β); also that the same substitutions enable us, by the foregoing process, to change directly (α') into (β').

10. I now proceed to show how a certain set of substitutions which change (β) into (α), will also change (β')

into (a'). Here it will be convenient to write (β) and (β') as under :—

$$Y^m - mY^{m-1} + (m-1)X = 0 \quad . \quad . \quad . \quad . \quad (\beta_0)$$

$$m^{m-1}[(m-1)D']^{m-1}Y - (m-1)(mD' - m - 1)$$
$$[mD' - 2]^{m-2}XY = [m]^m X \quad . \quad . \quad . \quad (\beta'_0)$$

where

$$D' = X\frac{d}{dX}.$$

Now (β_0) is changed into (a) by substituting

$$-(n-1),\ \left(-\frac{1}{n}\right)^{n+1}x^{n-1},\ -\frac{ny}{x}$$

for m, X, Y respectively. Making the same substitutions in (β'_0), and remembering that in this case

$$D' = \frac{D}{n-1},$$

we obtain the differential equation

$$(-\overline{n-1})^{-n}\left[-\frac{nD}{x-1}\right]^{-n}\left(-\frac{ny}{x}\right) + n(-D + n - 2)$$
$$[-(D+2)]^{-(n+1)}\left(-\frac{1}{n}\right)^n x^{n-2}y$$
$$= [-(n-1)]^{-(n-1)}\left(-\frac{1}{n}\right)^{n+1} x^{n-1},$$

which, by the process employed in Art. 8, reduces to

$$n^n[D]^{n+1}y - (n-1)(D - n + 1)\left(\frac{nD}{n-1} - \frac{2n-1}{n-1}\right)^n x^{n-1}y = 0.$$

Operating on both sides of this equation with

$$(D - n + 1)^{-1}(D - n)^{-1},$$

we have

$$n^{n-1}[D]^{n-1}y - (n-1)^{n-1}\left(\frac{nD}{n-1} - \frac{2n-1}{n-1}\right)^{n-1} x^{n-1}y$$
$$= c_1x^n + c_2x^{n-1} \quad . \quad . \quad . \quad (a'_0)$$

c_1, c_2 being arbitrary constants. In order to determine these constants, it should be observed that the sum of all the roots of (a) is a constant, viz., 0 or 2; let us therefore write for the moment, c in place of Σy. Using the last found differential equation (a'_0), and summing for the n roots of (a), we have

$$n^{n-1}[\mathrm{D}]^{n-1}c - (n-1)^{n-1}\left(\frac{n\mathrm{D}}{n-1} - \frac{2n-1}{n-1}\right)^{n-1} cx^{n-1} = c_1 nx^n + c_2 x^{n-1},$$

or, by reduction,

$$-c(n-1)^{n-1}\left(\frac{n^2-3n+1}{n-1}\right)^{n-1} = c_1 nx + c_2 n,$$

a relation which must hold universally. Hence $c_1 = 0$, and

$$\frac{c}{c_2} = -\frac{n}{(n-1)^{n-1}\left(\dfrac{n^2-3n+1}{n-1}\right)^{n-1}}.$$

When n is greater than 2, $\Sigma y = 0$, and therefore $c = 0$, $c_2 = 0$, and the differential equation becomes

$$n^{n-1}[\mathrm{D}]^{n-1}y - (n-1)^{n-1}\left[\frac{n\mathrm{D}}{n-1} - \frac{2n-1}{n-1}\right]^{n-1} x^{n-1}y = 0,$$

which agrees, as it ought to do, with (a').

In the particular case $n = 2$, we have $\Sigma y = 2$, and therefore $c = 2$ and $c_2 = 1$. Hence

$$2(\mathrm{D})y - (2\mathrm{D} - 3)xy = x,$$

the differential resolvent of

$$y^2 - 2y + x = 0.$$

11. Interchanges similar to the foregoing may sometimes be effected without any change of the variables x and y. I give an example.

If u represent the m^{th} power of any root of the algebraic equation

$$ay^n + by^r + cx = 0 \quad . \quad . \quad . \quad (\mathrm{A})$$

where the co-efficients a, b, c, are independent of x, then

u, considered as a function of x, satisfies the linear differential equation.

$$\left(\frac{r}{n-r}\mathrm{D}-\frac{m}{n-r}\right)^r[\mathrm{D}]^{n-r}u$$
$$=(-)^n\frac{a^rc^n}{b^nc^a}\left(\frac{n}{n-r}\mathrm{D}-\frac{m}{n-r}-1\right)^n x^{n-r}u \quad . \quad . \quad . \quad . \qquad (\mathrm{A}')$$

where,[12] as before,

$$\mathrm{D}=x\frac{d}{dx}.$$

Now the substitution

$$\begin{pmatrix} r, & n, & b \\ -r, & n-r, & c \end{pmatrix}$$

changes the algebraic equation (A) into

$$ay^n+bxy^r+c=0 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (\mathrm{B})$$

and the same substitution changes the differential equation (A′) into

$$\left(-\frac{r}{n}\mathrm{D}-\frac{m}{n}\right)^{-r}[\mathrm{D}]^n\, u$$
$$=(-)^{n-r}\,\frac{b^nc^r}{a^rc^n}\left(\frac{n-r}{n}\mathrm{D}-\frac{m}{n}-1\right)^{n-r}x^nu,$$

which, since

$$[-a]^{-b}=\frac{(-1)^b}{[a-1]^b}$$

is equivalent to

$$[\mathrm{D}]^nu=(-)^n\frac{b^nc^r}{a^rc^n}\left[\frac{r}{n}\mathrm{D}+\frac{m}{n}-1\right]^r\left[\frac{n-r}{n}\mathrm{D}-\frac{m}{n}-1\right]^{n-r}x^nu \quad . \; . \; . \qquad (\mathrm{B}')$$

in which u is the m^{th} power of any root of the algebraic equation (B).

It is hardly necessary to remark that the same substitution will change (B) into (A) and (B′) into (A′).

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[12] Addendum to Mr. Robert Rawson's paper, "On a New Method, &c." (cited in footnote 7). *Proceedings of the London Mathematical Society*, Vol. IX., 1878, pp. 216-221.

"On Certain Linear Differential Equations." *British Association Report*, for 1878, pp. 466-470.

12. The above is an extension of Boole's Theorem. For, make $r=n-1$, $a=1$, $b=-1$, and $c=-1$; then (B) becomes

$$y^n - xy^{n-1} - 1 = 0 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (\mathrm{B}_0)$$

which is the algebraic form dealt with by Boole, and (B′) becomes

$$n[\mathrm{D}]^n u = \left(\frac{n-1}{n}\mathrm{D} + \frac{m}{n} - 1\right)^{n-1}(\mathrm{D} - m - n)x^n u \quad . \quad . \quad (\mathrm{B}'_0)$$

which is connected with (B_0), as Boole shews,[13] through the relation

$$u = y^m.$$

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[13] See Boole's paper "On the Differential Equations," &c., cited in footnote 2. See also a paper of mine "On Differential Resolvents," printed in the *Proceedings of the London Mathematical Society*, Vol. I., 1865, Paper IV. I may add here that the explicit form of the complete cubic differential resolvent, published in the *British Association Report* for 1886 (pp. 439—443), was calculated independently by Mr. Robert Rawson and myself.

[*Microscopical and Natural History Section.*]

Ordinary Meeting, December 7th, 1891.

ALEX. HODGKINSON, M.B., B.SC., President of the Section, in the Chair.

There were exhibited :—

By Mr. R. WHEELER, a collection of weapons, articles of dress, etc., belonging to the native tribes inhabiting the district around the Ogowe River, Equatorial West Africa.

By Mr. J. COSMO MELVILL, an almost complete set of the ferns of Simla, N. W. Himalayas, collected by Mr. H. F. BLANFORD, F.R.S., and numbering over one hundred specimens of about eighty-seven species; also a perfect specimen of *Papilio Antimachus* (Drury), the rarest butterfly known, on which Mr. MELVILL communicated the following note :—

"For nearly 120 years, ever since Drury figured, and that most excellently, a specimen of this rare butterfly in his well-known work on exotic *Lepidoptera*, it remained almost unique, until a few specimens were secured in the damp forests at the base of Clarence Peak, in the island of Fernando Po, off the Gold Coast region of Tropical Western Africa. The late Mr. William Chapman Hewitson possessed two specimens, and a few others existed in other cabinets or came to hand from time to time. But its extreme rarity was proved by the inadequacy of a very high quotation to cause the demand to be supplied. Not seven years ago one was offered for £36, and two years ago £10 was paid severally for a few specimens in fine condition. Even now the female, being scarcer than the male, would secure a high price. Professor Aurivillius made this insect the type of a new genus *Druryia*, as in many ways it differed from the typical *Papilio* or swallow-tail butterfly. Both by the nervures, by the habit, and much greater breadth of wing, of any species excepting the *Ornithoptera*, it seemed to merit generic distinction, since fine specimens measure seven inches across the wings. There are many points of resemblance, however, between this fine insect and the smaller *P. Ridleyanus*, also from Tropical Africa. Both seem to resemble certain *Acrææ* in form, a group almost peculiar to Africa. Mr. H. D. Wheeler recently sent to his father, Mr. R. Wheeler, of Manchester, six specimens captured by himself in the neighbourhood of the Ogowe River, about 300 miles from the sea. Of these six specimens, five were in very good condition, and one of these I have the pleasure to exhibit this evening."

Mr. P. CAMERON, F.E.S., communicated Part IV. of his *Hymenoptera Orientalis*. The PRESIDENT of the Section gave an address on the hive bee ; which was illustrated by diagrams and by a number of anatomical preparations shown under the microscope by Mr. BOYD.

Ordinary Meeting, December 15th, 1891.

EDWARD SCHUNCK, PH.D., F.R.S., F.C.S., President, in the Chair.

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

Mr. JAMES COSMO MELVILL, M.A., F.L.S., read the following "Description of a New Species of *Latirus*":—

"L. PRÆSTANTIOR, *sp. nov.*

L. testâ fusiformi, turritâ, solidâ, rufofuscescente, anfractibus decem, longitudinaliter fortiter angulatim crassicostatis, transversim undique regulariter filoliratis, ad suturas lævibus, duâbus vel tribus liris in medio anfractuum omnium apud angulos costarum distinctioribus, canali productâ, aperturæ fauce intus fortiter costulatâ, albidâ, columellâ quadriplicatâ.

Long. 2½ inch.

Lat. ⅞ inch.

Habitat. Mauritius.

It is to be regretted that this fine shell did not arrive into my hands prior to the publication of my 'Historical Account of the Genus *Latirus*' in the *Memoirs and Proceedings* of the Society in the early part of this year (1891), for it exceeds in size any of the eleven species of *Latirus* and *Peristernia* described in that monograph for the first time. The shell is rufous-brown, elegantly fusiform, turreted, somewhat solid, possessed of ten whorls, each regularly ornamented with thick longitudinal ribs, crossed transversely (excepting at the sutures, where the shell is smooth) with equidistant filamentous liræ. The canal is produced, the mouth distinctly ribbed within, columella four plaited, white. There is some little resemblance to *Fasciolaria filamentosa* (Lam.) in miniature, or, among the *Latiri*, to *L. Gracilis* (Reeve), and especially

L. concentricus, also of Reeve, next which it must be placed. This specimen, at present the only one known, formed part of the collection of Sir David Barclay, Bart. I also acquired, at the same opportunity, and from the same collection, the fine type of *Latirus* (*Leucozonia*) *Belcheri* (Ad.), and two varieties of *L. rudis* (Reeve), of a light fawn colour, with darker shading at the channels of the angles, which at first sight, seemed a distinct species. Also two very extraordinary varieties of *L. nodatus*, which Sir David Barclay valued highly, and considered different from that species, though at present I cannot see my way to separate them. They have the umbilicus widely developed, which is not the case in normal *nodatus*, but as I have before shown this trait varies in most of the known species, especially amongst the larger kinds."

Mr. FARADAY described some phenomenal effects of the recent and previous gales on buildings—windows and walls being apparently drawn out in the teeth of the wind instead of being blown in—and suggested that approximate vacua, or great diminutions of external pressure, might result from the swirling or other action of the wind when sweeping round corners, or encountering obstructions, the result being a kind of suction similar to what might be observed in the eddies of streams. A discussion ensued, in which Professor OSBORNE REYNOLDS, Mr. HARRY GRIMSHAW, Mr. FRANCIS NICHOLSON, Mr. GWYTHER, and others, took part, various suggestions being made as to possible pressure of wind entering by chimneys or doors on the inside of the windows or walls of buildings.

Mr. ALEX. HODGKINSON, M.B., B.SC., read a paper, entitled "On Iridescent Colours and a Method of Examining Iridescent Objects—Birds, Insects, and Minerals—so as to ensure Uniformity of Description."

Ordinary Meeting, December 29th, 1891.

JAMES BOTTOMLEY, B.A., D.SC., 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. ALEX. HODGKINSON, M.B., B.Sc., exhibited a specimen of colouring matter extracted from decayed wood; the pigment is not peculiar to one kind of wood. It is of a blueish-green colour, soluble in boiling acetic acid. It is separable into two distinct pigments—one green, soluble in cold acetic acid, the other blue, insoluble in cold acetic acid, but soluble in nitric acid. The spectrum shows that it is not chlorophyll.

Two fragments of the decayed wood containing the colouring matter, picked up in widely severed localities, (North Wales and Radnorshire) were exhibited, and were described by Mr. CHARLES BAILEY as apparently hazel and oak respectively.

A paper by Mr. P. CAMERON, entitled *Hymenoptera Orientalis*, Part IV., was communicated by Mr. JOHN BOYD.

Ordinary Meeting, January 12th, 1892.

Professor ARTHUR SCHUSTER, PH.D., 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.

Reference was made to the deaths of Dr. W. C. Henry, ordinary member, and Sir George Airy, Baron Emile de Laveleye, and Dr. Ferdinand Römer, honorary members, which had occurred since the previous meeting, Dr. Henry being the oldest member, and Sir George Airy the oldest honorary member of the Society at the time of their deaths.

Dr. SCHUSTER read a note on the late Dr. Joule's thermometers.

Mr. W. E. HOYLE, M.A., exhibited specimens of rare cuttle-fish from the Mediterranean.

[*Microscopical and Natural History Section.*]

Ordinary Meeting, January 18th, 1892.

ALEX. HODGKINSON, M.B., B.Sc., President of the Section, in the Chair.

Mr. E. HALKYARD was elected a member, and Mr. R. WHEELER an associate of the Section.

Mr. CHAS. BAILEY presented, for the Microscopical Cabinet, twenty-five mounted objects from the collection of the late Mr. John Barrow, which had been kindly sent by Mr. Barrow's family. A vote of thanks for this highly valued set of specimens of the manipulative skill of the Section's late member was passed.

Mr. JAMES COSMO MELVILL exhibited a fine ♂ specimen of the Oleander Hawk Moth (*Chaerocampa Nerii*), collected by the late Mr. George Crozier, at Prestwich, in 1846. The insect was quite perfect, and finely coloured. He also mentioned that two other specimens from the same locality, both collected at light, in 1886 and 1891 respectively, are in the possession of Mr. J. R. Hardy and the Manchester Museum, Owens College. As only twenty-one individuals have been recorded as having occurred in these islands, it is interesting to consider that one-seventh of the total number have occurred within five miles of Manchester. It is as yet impossible to ascertain whether there is a colony of this insect established in this locality, and, if so, on what they have been accustomed to feed, and it is well worthy the attention of the entomologists of this neighbourhood.

Mr. SCOWCROFT exhibited some varieties of *Argynnis aglajo*, from Scotland; a series of *Xanthia cerago* (*silago* South), and a set of dried flowers preserved most successfully so as to show their natural forms and colours. The results obtained, even in such difficult flowers as orchids and the Christmas rose, were very remarkable and perfect.

Hymenoptera Orientalis; or Contributions to a knowledge of the Hymenoptera of the Indian Zoological Region. By P. Cameron. Communicated by John Boyd.

(Received December 29th, 1891.)

PART IV.

SCOLIIDÆ.

The identification of these striking insects is rendered very easy by the well-known *Catalogus Specierum Generis Scolia* of Messrs. Saussure and Sichel. I have followed their arrangement of the species, and have adopted the genera as defined by them, namely :—

Liacos, with its two divisions of *Triliacos* and *Diliacos* ;
Scolia „ „ „ „ „ *Triscolia* and *Discolia* ;
Elis „ „ „ „ „ *Trielis* and *Dielis.*

LIACOS.

I. *With three closed cubital cellules* = Triliacos.

1. LIACOS ANALIS.

Scolia analis, Fab., *Syst. Piez.*, p. 245, 37.

Scolia dimidiata, Guerin, *Voy. de Coq.*, II., p. 247 ; Burmeister, Scolidæ, p. 15, 2 ; Smith, *Cat. Hym.* III., 138 ; *Jour. Linn. Soc.*, IV., p. 118, 10.

Campsomeris Urvillii, Lep., *Hym.* III., 503, 12 ; Smith, *Cat. Hym.*, III., p. 112, 127.

Scolia Penangensis, Saussure, *Mélanges Hym.* p. 39, **17,** ♀, var. b.

Liacos (Triliacos) analis, Saussure and Sichel, *Cat. Specierum gen. Scolia*, p. 33.

Hab. Java, Borneo, Malacca, Philippines, Mollucas, Celebes Bouru, Sulu, Senegal.

2. LIACOS FULVO PICTA, *sp. nov.*

Black, the third and following segments, pale fulvous, and covered with long fulvous hairs; the wings deep violaceous. Head and thorax marked with large, clearly separated punctures, the punctures on the head and pleuræ smaller than on the mesonotum; the front above and between the antennæ raised; the apex slightly incised; the surface longitudinally punctured; and above it is an impunctate border, which extends to near the middle of the eye incision. The front ocellus in a pit. The mesonotum has the furrows slightly curved, and extending from the apex to a little beyond the middle; the apex of the scutellum is impunctate, and has a short longitudinal channel in the centre at the apex. The median segment shallowly concave at the apex; the sides convex; there are two converging furrows in the middle; the space on the outer side of these at the base being impunctate. Abdomen punctured like the thorax; the hairs on the basal two segments black; and they have a bluish tinge; the base of the third segment is black, the black being dilated in the middle. The antennæ bare, dull black; the joints not dilated; the third joint distinctly shorter than the fourth. The second cubital cellule is dilated at the top; the transverse cubital nervures bulging out.

Length, 25 mm.

Allied to *analis* and *erythrosoma*, but easily known by the fulvous, not red, apex of abdomen; differing otherwise in the head being much more strongly punctured, this being also the case with the thorax.

Hab. Barrackpore (*Rothney*).

3. LIACOS ERYTHROSOMA.

Scolia erythrosoma, Burmeister, *Mon. Scol.* 15[1]; Smith, *Cat. Hym.*, III., 113, 134.

Scolia dimidiata, Smith, *l.c.*; *Journ. Linn., Soc.* VII., 29 12, part, var. from Bachian and Gilolo.[2]

Liacos (Triliacos) erythrosoma, Sauss. and Sichel, *Cat. Scol.* 35.

Hab. Poona, Sumatra[1]; Bachian and Gilolo.[2]

Smith, *Jour. Linn. Soc.*, 1869, p. 348, sinks *erythrosoma* as a variety of *analis.*

II. *With two closed cubital cellules* = Diliacos.

4. DILIACOS SICHELI.

Liacos Sicheli, Saussure, *Stett. Ent. Zeit.*, 1859, p. 172, f. 1, ♀; *Cat. Scol.*, 36.[1]

Hab. Sumatra.[1]

SCOLIA.

I. *Three cubital cellules* = Triscolia (Species 1—16).

1. SCOLIA NUDATA.

Scolia nudata, Smith, *Cat. Hym.*, 110, 120; Sauss. and Sichel, *Cat. Scol.*, 38, 7.[1]

Hab. North Bengal.[1]

2. SCOLIA BREVICORNIS.

Scolia brevicornis, Saussure, *Stett. Ent. Zeit.*, 1858, p. 198, 2; Sauss. and Sichel, *Cat. Scol.*, p. 39, 8[1].

Hab. Java,[1] Borneo.[1]

3. SCOLIA KOLLARI.

Scolia kollari, Saussure, *Stett. Ent. Zeit.*, 1858, p. 174; Sauss. et Sichel, *Cat. Scol.*, 40[1].

Hab. Java[1].

4. SCOLIA FORAMINATA.

Scolia foraminata, Saussure, *Stett. Ent. Zeit.*, 1858, p. 173; Sauss. et Sichel, *Cat. Scol.*, p. 40.[1]

Hab. Java.[1]

5. SCOLIA UNIMACULATA.

Scolia unimaculata, Kirby, *Trans. Ent. Soc.*, 1889, 446.[1]

Hab. India.[1]

6. SCOLIA TYRIANTHINA.

Scolia tyrianthina, Kirby, *l.c.* pl. XV., fig. 2.[1]

Hab. Andaman Islands.[1]

7. SCOLIA VELUTINA.

Scolia velutina, Saussure, *Stett. Ent. Zeit.*, 1858, 175; Sauss. et Sichel, *Cat. Scol.* 41, 13[1].

Hab. Java.[1]

8. SCOLIA OPALINA.

Scolia opalina, Smith, *Proc. Linn. Soc.* II., 89, 9[1]. ; Sauss. et Sichel, *Cat. Scol.* 45.

Hab. Borneo.[1]

9. SCOLIA PROCER.

Scolia procer, Illiger, *Mag.*, I., 196, 26; Fab., *Syst. Piez.*, 238; Burmeister, *Mon. Scol.*, 19, 9; Lepel, *Nat. Hist. Hym.*, III., 519, 3; Sauss. et Sichel, 43, 16.[1]

Scolia capitata, Fab., *Syst. Piez.*, 239, 3; Smith, *Cat.*[1] *Hym.*,[2] III., 111, 122.

Scolia patricialis, Burm., *Mon. Scol.*, 19, 10.

Hab. Java,[2] Sumatra,[2] Singapore,[2] Borneo,[1] Moluccas, Malacca.[1]

Smith, *Journ. Linn. Soc.*, 1869, p. 343, regards *patricialis* as a good species, but does not indicate the essential points in which it differs from *procer*.

10. SCOLIA SPECIOSA.

Scolia speciosa, Smith, *Proc. Linn. Soc.*, II., 90, 10[1]; Sauss. et Sichel, *Cat. Scol.* 44, 17.[1]

Hab. Borneo.[1]

11. SCOLIA MAGNIFICA.

Scolia magnifica, Sauss., *Stett. Ent. Zeit.*, 1859, 175; Sauss. and Sichel, *Cat. Scol.*, 44.[1]

Hab. Java.[1]

12. SCOLIA CINCTA.

Scolia cincta, Smith, *Proc. Linn. Soc.*, II., 89, 7[1]; Sauss. and Sichel, *Cat. Scol.*, 45, 19.

Hab. Borneo, Sumatra, Sulla, Java.[1]

13. SCOLIA RUBIGINOSA.

Scolia rubiginosa, Fab. *Ent. Syst.*, II., 230, 8; *Syst. Piez.*, 241, 10; Coquebert, *Illust.*, t. 13, f. 4; Klug, Weber, u. Mohr, *Beitr.*, II., 211, 38; Lepell, *Nat. Hist. Hym.*, III., 5, 18, 2; Burm., *Cat. Scol.*, 19, 11; Smith, *Cat. Hym. Ins.*, III., 123[1]; Sauss. and Sichel, *Cat. Scol.*, 46, 20.

Scolia ornata, Lepell, *l.c.* 517, 1.

Hab. China, Siam, India, Borneo, Java, Malacca.[1]

14. SCOLIA INSIGNIS.

Scolia insignis, Sauss., *Ann. Fr. Ent. Soc.*, 1858, 197, 1; pl. v., fig. 1, ♀; Sauss. and Sichel, *Cat. Scol.*, 47, 22.[1]

Hab. Persia?[1] East Indies.[1]

16. SCOLIA DUCALIS.

Scolia ducalis, Smith, *Proc. Linn. Soc.*, V., 118, 9; Sauss. et Sichel, *Cat. Scol.*, 49.

Hab. Moluccas,[1] Ceram.[1]

15. SCOLIA CAPITATA.

Scolia capitata, Guérin, *Voy. Coq.*, 248; Burmeister, *Scol.*, 20, 13, a ♂; Sichel and Sauss., *Cat. Scol.*, 47.

Scolia ruficeps., Smith, *Cat.*, 111, 126.[1]

Hab. Philippines.

16. SCOLIA HÆMORRHOIDALIS.

Scolia hæmorrhoidalis, Fab., *Mant.*, I., 280, 7; Lep., *Nat. Hist. Ins. Hym.*, III., 552, 5; Burm. *Scol.*, 187; Smith, *Cat.*, 110, 119; Sauss. and Sichel, *Cat. Scol.*, 50.

This is a Palæarctic species only known from our region on the authority of Fabricius.

II. *Two cubital cellules* = Discolia

17. SCOLIA HUMERALIS.

Saussure and Sichel, *Cat.*, 321.[1]

Hab., Singapore.[1]

18. SCOLIA SCAPULATA.

Gribodo, *Ann. d. Museo Civico di Storia Nat. di Genova*, 1.

Hab. Burma.

19. SCOLIA CEPHALOTES.

Scolia cephalotes, Burmeister, *Mon. Scol.*, 37, 60;[1] Smith, *Cat. Hym.*, III., 90, 20; Saussure, *Stett. Ent. Zeit.*, 1859, 184?[2] Sauss. and Sichel, *Cat. Scol.*, 102, 90.

Hab. Java,[1] Borneo.[2]

20. SCOLIA CYANIPENNIS.

Scolia cyanipennis, Fab., *Syst. Piez*, 244, 35;[1] Burm., *Mon. Scol.*, 37, 59; Smith, *Cat. Hym.*, III., 90, 21; Sauss., *Ann. Ent. Soc. Fr.*, 1858, 209, 16; Sauss. and Sich., *Cat. Scol.*, 103, 91.[2]

Hab. Java, Ceylon.[2]

21. SCOLIA COERULANS.

Scolia coerulans, Lep., *Nat. Hist. Hym. Ins.*, III., 526-7[1]; Sauss. and Sichel, *Cat. Scol.*, 104, 92.

Hab. "East Indies."[1]

22. SCOLIA MELANOSOMA.

Scolia melanosoma, Sauss., *Stett. Ent. Zeit.*, 1859, 185[1]; Sauss. and Sichel, *Cat. Scol.*, 105, 94.

Hab. Java.[1]

23. SCOLIA REDTENBACHERI.

Scolia Redtenbacheri, Sauss., *Stett. Ent. Zeit.*, 1859, 186[1]; Sauss. and Sichel, *Cat. Scol.*, 105, 95.

Hab. Java,[1] Barrackpore.

24. SCOLIA CARBONARIA.

Scolia carbonaria, Sauss., *Ann. Ent. Fr.*, 1858, 210, 17[1]; Sauss. and Sichel, *Cat. Scol.*, 106, 96.

Hab. "East Indies,"[1] Java.[1]

25. SCOLIA AUREIPENNIS.

Scolia aureipennis, Lep., *Nat. Hist. Hym.*, III., 523, 9[1]; Sauss. and Sichel, *Cat. Scol.*, 109, 102.[2]

Scolia Jurinei, Sauss., *Mélan. Hym.*, 45, 21.

Scolia instabilis, Smith, *Cat. Hym.*, III., 88, 11.

Scolia ruficornis, Klug, Weber u. Mohr, *Beitr.*, I., 25, 8.

Hab. "East Indies," Java,[2] Poona.

26. SCOLIA ERRATICA.

Scolia erratica, Smith, *Cat. Hym.* III., 88, 10;[1] *Linn. Soc.*, 88, 1; *l.c.*, 9, 1; Sauss. and Sichel, *Cat. Scol.*, 110, 103.

Scolia verticalis, Burm., *Mon. Scol.*, 37, 61 (*nec.* Fab.)[1].

„ *westermanni*, Sauss. and Sichel, *Ann. Ent. Fr.*, 1858, 212, 19.[2 3]

Hab. Java,[1] Borneo,[2] Sumatra;[3] "East Indies."[1]

27. SCOLIA MOLESTA.

Scolia erratica, Sauss. (*nec.* Smith), *Ann. Ent. Fr.*, 1858, 211, 18; *Stett. Ent. Zeit.*, 1859, 187.

Scolia molesta, Sauss. and Sichel, *Cat. Scol.*, 111, 104.[1]

Hab. Pulvo-Penang,[1] Siam,[1] Singapore,[1] Sumatra,[1] Java,[1] Borneo.[1]

28. SCOLIA VOLLENHOVENI.

Scolia vollenhoveni, Sauss., *Stett. Ent. Zeit.*, 1859, 188; Sauss. and Sichel, *Cat. Scol.*, 112, 105.[1]

Hab. Sumatra.[1]

29. SCOLIA OBSCURA.

Scolia obscura, Lep., *Nat. Hist. Hym. Ins.*, III., 527, 14; Smith, *Cat. Hym.*, III., 89, 16.[1]

Hab. East Indies.[1]

30. SCOLIA QUADRIPUSTULATA.

Scolia 4-pustulata, Fab., *Spec. Ins.*, I., 453, 13; *Ent. Syst.* II., 234, 6; Burm., *Mon. Scol.*, 36, 58; Lep., *Nat. Hist. Hym. Ins.*, 528, 16; Smith, *Cat. Hym.*, III., 87, 7; Sauss. and Sichel, *Cat. Scol.*, 113, 108.

Larra 4-pustulata, Fab., *Syst. Piez.*, 244, 34.

Scolia binotata, Fab., *Syst. Piez.*, 244, 36.

Scolia bipunctata? Klug, Weber u. Mohr, *Beitr.* I., 36, 32.

Scolia 6-pustulata, Klug, *l.c.* 35, 30, var. ♂

Scolia fasciatopunctata, Guérin, *Voy. d. Coq.*, II., 254.

Scolia fervida, Smith, *Ann. Mag. Nat. Hist.*, IX., 46; *Cat. Hym.*, 89, 15.

Hab. Barrackpore, Bombay, Java, Sumatra.

31. SCOLIA BENGALENSIS, *sp. nov.*

Black; the flagellum of the antennæ red; two small on the second and two larger yellow marks on the third abdominal segments. Clypeus impunctate, except a row of pustules round the apex; the space above and between the antennæ very strongly and coarsely punctured; the vertex with groups of punctures round the ocelli, above these and almost impunctate to near the edge, which is closely and finely punctured. Thorax closely covered with long black hair and strongly and coarsely punctured all over, except the edges of the pleuræ. Apex of median segment transverse with a sharply oblique slope. Abdomen covered all over with widely separated punctures; the ventral segments with the punctures stronger, but with the base impunctate; the hair thick, longish and black. The ♂ is similar but not quite so strongly punctured; the third joint of the antennæ is shorter than the fourth, and the yellow marks are on the third and fourth abdominal segments.

Length, 25mm.

Hab. Poona (*Wroughton*).

Comes near to 4-*pustulata*; but that species has the antennæ black; the marks on the abdomen red, not yellow; and the thorax is not punctured all over.

In one example of *bengalensis* there is, in the ♀, two small marks on the fourth abdominal segment.

32. SCOLIA BILUNATA.

Scolia bilunata, Sauss., *Ann. Ent. Fr.*, 1858, 212, 20; Sauss. and Sichel, *Cat. Scol.*, 115, 109.

Hab. Nepaul.[1]

33. SCOLIA BIOCULATA.

Scolia bioculata, Sauss., *Stett. Ent. Zeit.*, 1859, 189; Sauss. and Sichel, *Cat. Scol.*, 115, 110.'

Hab. Java, Sumatra.[1]

34. SCOLIA FULVIFRONS.

Scolia fulvifrons, Sauss, *Mélang. Hym.*, 43, 19, f. 11; Sauss. and Sichel, *Cat. Scol.*, 116, 111.[1]

Scolia personata, Smith, *Cat. Hym.*, 91, 23.

Scolia bipunctata? Klug, Weber u. Mohr, *Beitr.*, I., 36, 32.

Hab. East Indies.[1]

[35. SCOLIA SPLENDIDA.

Scolia splendida, Sauss., *Ann. Ent. Fr.*, 1858, 213, 21, pl. V., f. 2; Sauss. and Sichel, *Cat. Scol.*, 116, 112.[1]

Hab. Asia[1] (India)?].

36. SCOLIA NOBILIS.

Scolia nobilis, Sauss., *Ann. Ent. Fr.*, 1858, 214; Sauss. and Sichel, *Cat. Scol.*, 117, 113.[1]

Hab. East Indies.[1]

37. SCOLIA SPECIFICA.

Scolia specifica, Smith, *Cat. Hym. Ins.*, III., 89, 13[1]; Sauss. and Sichel, *Cat. Scol.*, 117, 114.

Hab. East Indies.[1]

38. SCOLIA STIZUS.

Scolia stizus, Sauss. and Sichel, *Cat. Scol.*, 118, 115.[1]

Hab. Tranquebar,[1] Poona (*Wroughton*).

39. SCOLIA NITIDULA.

Scolia nitidula, Sauss., *Ann. Ent. Fr.*, 1858, 215, 23; Sauss. and Sichel, *Cat. Scol.*, 119, 117.[1]

Hab. Java.[1]

40. SCOLIA INDICA.

Scolia indica, Sauss., *Mélang. Hym.*, 46, 22, f. 10; Sauss. and Sichel, *Cat. Scol.*, 119, 118.

Scolia ignita, Smith, *Cat. Hym.* III., 101, 77.

Hab. Bengal, Silbet.

41. SCOLIA ELIFORMIS.

Scolia eliformis, Sauss. *Ann. Ent. Fr.* 1858, 215, 24[1]; Sauss. and Sichel, *Cat. Scol.*, 120, 119.

Hab. East Indies,[1] Ceylon.[1]

42. SCOLIA VENUSTA.

Scolia venusta, Smith, *Cat. Hym.*, III., 90, 17; Sauss. and Sichel, 120, 120.[1]

Hab. East Indies.[1]

43. SCOLIA HISTRIONICA.

Scolia histrionica, Fab., *Ent. Syst. Suppl.*, 256, 35; Klug, Weber u. Mohr, *Beitr.*, I., 25, 9?; Sauss. and Sichel, *Cat. Scol.*, 121, 121.

Scolia Picteti, Sauss., *Mél. Hym.*, 42, 18.

Scolia pulchra, Smith, *Cat. Hym.*, III., 88, 12.[1]

Hab. India, Poona (*Wroughton*).

44. SCOLIA DECORATA.

Scolia decorata, Burm., *Mon. Scol.*, 30, 39; Sauss. and Sichel, *Cal. Scol.*, 122, 122.[1]

Scolia flavopicta, Smith, *Cat. Hym.*, III., 91, 22.

Hab. Sumatra.

45. SCOLIA VIVIDA.

Scolia vivida, Smith, *Cat. Hym.*, 89, 14;[1] Sauss. and Sichel, *Cat. Scol.*, 123, 125.[1]

Hab. Madras,[1] Poona (*Wroughton*).

46. SCOLIA MODESTA.

Smith, *Cat. Hym.*, III., 91, 25;[1] Sauss. and Sichel, *Cat.*, 124, 126.

Hab. Philippines.[1]

ELIS.

I. *With two closed cubital cellules* = Dielis.

1. ELIS AZUREA.

Elis azurea, Saussure, *Stett. Ent. Zeit.*, 1859, 269[1]; Sauss. and Sich., 185, 194.

Hab. Java, Sumatra.[1]

2. ELIS BICOLOR.

Elis bicolor, Saussure, *l.c. Ann. Soc. Ent. Fr.*, 1858, 233, 46, pl. v., f. 4;[1] Sauss. and Sich. 156, 195.

Hab. Java.[1]

3. ELIS MARGINELLA.

Elis marginella, Klug, Weber u. Mohr, II., 214, 44;[1] Sauss. and Sich., 186, 196.

? *Colpa parvula*, St. Farg., *Hym.*, III., 548, 17.

? *Scolia hirtella*, Klug, *l.c.* 215, 45.

Hab. East Indies.[1]

4. ELIS THORACICA.

Tephia thoracica, Fab., *Ent. Syst. Supp.*, 254, 15; *Syst. Piez.*, 235, 19.

Sphex albicollis, Christ, *Hymen.*, 260, t. 26, f. 1.

Sphex flavifrons, Christ., *l.c.* 261, t. 26, f. 2.

Tiphia nigra, Fab., *Ent. Syst.*, II., 225, 9; *Syst. Piez.*, 234, 13.

Campsomeris aureicollis, Lep., *Hym.*, III., 499.[c]

Elis thoracica, Saus. and Sich., *Cat.*, 188, 197.

Hab. Java, China, Barrackpore, Poona.

5. ELIS FIMBRIATA.

Elis fimbriata, Burmeister, *Scol.*, 25, 6; Sauss. and Sich., 189, 198.

Scolia thoracica, Klug, Weber, and Mohr, I., 33, 24.

Campsomeris collaris, Lepel., *Hym.*, III., 498, 5.

Hab. Java.

6. ELIS ASIATICA.

Elis Asiatica, Saussure, *Ann. Soc. Ent. Fr.*, 1858, 231, 34;[1] *Ent. Zeit*, 1859, 266; Sauss. and Sichel, *Cat.*, 190, 200.

Hab. Java, East Indies.[1]

7. ELIS RETICULATA, *sp. nov.*

Black, the wings fusco-violaceous. Clypeus coarsely punctured at the base; the space above and between the antennæ coarsely and closely punctured; the vertex with a few scattered punctures, behind the ocelli with the punctures closer together and more numerous. The entire head thickly covered with long black hairs. Thorax closely and strongly punctured all over, except the apex of the scutellum and the apex of the mesopleuræ, and the base of the metapleuræ: the pronotum transverse in front; the apex of the median segment, almost transverse; without furrows and with an oblique slope, and punctured closely all over; the entire thorax bearing long black hair. Abdomen shining, having a bluish tinge, sparsely punctured and densely black haired all over; the apex of the anal segment impunctate; the ventral segments sparsely punctured all over. Antennæ dull black; the third and fourth joints subequal; the apical joints dilated beneath. ♂.

Length 19 mm.

Hab. Poona (*Wroughton*).

Comes near to *Javana* but that species has in the ♂ the abdominal segments cinereo-ciliated, and the mesonotum impunctate in the middle.

8. ELIS JAVANA.

Elis Javana, Lepel., *Hym.*, III., 498, 402;[1] Sauss. and Sich , *Cat.*, 191, 202.

Hab. Java.[1]

9. ELIS TRISTIS.

Elis tristis, Saussure, *Ent. Zeit.*, 1859, 265;[1] Sauss. and Sich., *Cat.*, 193, 205.

Hab. Java, Borneo, East Indies.[1]

10. ELIS LUCTUOSA.

Elis luctuosa, Smith, *Cat. Hym.*, 101, 77 (*Scolia*); Sauss. and Sich., *Cat.*, 194, 206.

Scolia 4-guttulata, Sauss., *Mél. Hymén.*, 58, f. 12.

Hab. India, Java, Philippines.

11. ELIS QUADRIGUTTULATA.

E. quadriguttulata, Burmeister, *Scol.*, 21. 17 (*Scolia*);[1] Sauss. and Sich., *Cat.*, 195, 207.

Hab. Java.[1]

12. ELIS EXIMIA

Elis eximia, Smith, *Cat. Hym.*, III., 99, 69 (*Scolia*);[1] Sauss and Sich., *Cat.*, 195, 208.

Hab. India.[1]

13. ELIS RUBROMACULATA.

Elis rubromaculata, Smith, *Cat. Hym.*, III., 99, 67 (*Scolia*); Sauss. and Sich., *Cat.*, 196, 209.

Hab. Java.

14. ELIS ANNULATA.

Elis annulata, Fab., *Ent. Syst.*, II., 225, 7 (*Tiphia*); Burmeister, *Scol.*, 25, 27; Sauss. and Sichel, *Cat.*, 196, 210.

Campsomeris Servillii, Lepel, *Hym.*, III., 501, 9.

Hab. China, Japan, Barrackpore, Poona, Burma, Java, Manilla.

15. ELIS DREWSENI.

E. Drewseni, Sauss., *Ann. Ent. Fr.*, 1858, 232, 44;[1] Sauss. and Sich., *Cat.*, 197, 211.

Hab. Java.[1]

16. ELIS HABROCOMA.

E. habrocoma, Smith, *Cat. Hym.*, III., 100, 71[1] (*Scolia*); Sauss. and Sichel, *Cat.* 198, 212.

Hab. India.[1]

17. ELIS SNELLENI.

E. Snelleni, Sauss., *Stett. Ent. Zeit.*, 1859; 268, tab. 2, f. 4;[1] Sauss. and Sichel, *Cat.*, 198, 213.

Hab. Sumatra.[1]

18. ELIS GROSSA.

E. grossa, Fab., *Syst. Piez.*, 232, 4 (*Tiphia*); Burmeister, *Scol.*, 23, 22 (*Scolia*); Sauss. and Sich., *Cat.*, 199, 215.

Elis sericea, Sauss., *Mél. Hym.*, 63, 31.

Hab. India, Java.

19. ELIS HIRSUTA.

Elis hirsuta, Sauss., *Ann. Ent. Fr.*, 1858, 234, 47; Sauss. and Sich., *Cat.*, 200, 216.

Hab. Tranquebar.

20. ELIS IRIS.

Elis Iris, Lepel, *Hym.*, III., 547, 16; Sauss. and Sichel, *Cat.*, 201, 217.

Elis phalerata, Sauss., *Ann. Ent. Fr.*, 1858, 233, 45.

Hab. Java.

21. ELIS CEYLONICA.

Campsomeris ceylonica, Kirby, *Trans. Ent. Soc.*, 1889, 452.

Hab. Ceylon.[1]

22. ELIS HINDENII.

Elis hindenii, Lepel, *Hym.*, III., 500. 8 (*Campsomeris*); Sauss. and Sich, *Cat.*, 204, 219.

Scolia quadrifasciata, Fab., *Ent. Syst. Supp.*, 255, 16-17.

Hab. Japan, China, India, Moluccas.

23. ELIS LIMBATA.

Elis limbata, Sauss. *Cat.*, 206, 220.[1]

Hab. Java.[1]

24. ELIS AURULENTA.

Elis aurulenta, Smith, *Cat. Hym.*, III., 206; Sauss. and Sich., *Cat.*, 206, 221.

Hab. Philippines, Celebes, Bachian.

25. ELIS CYANEA.

Saussure, *Cat.*, 323.

Hab. Nicobar Islands.

26. ELIS LITIGIOSA.

Elis litigiosa, Smith, *Cat. Hym.*, III., 113, 133;[1] Sauss. and Sich., 158, 164.

Hab. East Indies.[1]

II. *With three cubital cellules* = Trielis.

27. ELIS ORIENTALIS, *sp. nov.*

Black; the wings dark violaceous. The clypeus impunctate, with a row of punctures round the apex; the vertex impunctate, except a semi-circle of punctures round the hinder ocelli to near the eye incision; front strongly punctured above the antennæ, and there is a row of punctures at the edge of the vertex, the front densely covered with blackish, the cheeks and outer orbits with greyish, hair. Thorax moderately strongly punctured, except on the mesopleuræ behind the margin of the propleuræ, the metapleuræ at the base, and the centre of the mesonotum; the latter having the punctures sparser; and with the parapsidal furrows deep, and reaching from the apex to beyond the middle. Scutellum sparsely punctured; the sides of the metanotum very closely rugosely punctured. Median segment short, transverse at the apex, which has a rather sharply oblique slope and is impunctate between the furrows. Abdomen shining, sparsely punctured, the hair black, longish, and sparse; pygidial area coarsely longitudinally rugose; the ventral segment sparsely punctured on the apical half and bearing long black hairs. The third cubital cellule of nearly equal width throughout. The hair on the legs is black, except on the fore femora, which have it greyish; the hind femora have behind a row of punctures in the middle.

Length 17 mm.

Hab. Ceylon (*Rothney*).

MYZINE, *Latr.*

In his *Catalogue of Indian Hymenoptera*, Smith omits, curiously enough, all the species described by himself in his *Cat. Hym.*, III.

1. MYZINE ANTHRACINA.

Smith, *Cat. Hym.*, III., 71, 9.

Hab. India.

2. MIZINE COMBUSTA.

Smith, *New species of Hym.*, 179.

Hab. India? or Africa?

3. MYZINE DIMIDIATA.

Guérin, *Dict. pitt. d. Hist. Nat.*, v. 575, 17; Smith, *Cat. Hym.*, 71.

Hab. Bombay, Bengal.

4. MYZINE FUSCIPENNIS.

Smith, *Cat. Hym.*, III., 72.
Hab. India.

5. MYZINE MADRASPATANA.

Smith, *Cat. Hym.*, III., 72.
Hab. Madras.

6. MYZINE NITIDA. (Pl. IV., f. 2.)

Black, shining, the abdomen with a bluish gloss; the wings fuscous, hyaline to the transverse basal nervure. Head covered with longish greyish hair, especially long and thick below the antennæ; coarsely rugosely punctured below the ocelli, the vertex with the punctures small, shallower and more widely separated; the ocellar region slightly raised, a depression on the outerside of the lateral; a not very distinct channel runs down from the anterior. Mandibles testaceous black at the apex; antennæ stout, opaque, as long as the abdomen, the first and second joints subequal, the third, if anything, longer than the fourth. The pronotum punctured, somewhat like the vertex; the mesonotum in front finely and closely punctured; behind with the punctures larger and widely separated; the scutellum slightly raised, very coarsely rugose; the median segment rugosely punctured; the mesopleura convex, coarsely punctured; behind there is a smooth, shining oblique depression. The thorax bears a thick greyish hair. Abdomen very smooth and shining; the pygidium margined laterally, carinate down the centre; the space between with some large punctures; the apical segments bearing longish blackish hairs. Legs bearing a greyish pubescence; the fore tibiæ yellowish in front. The second cubital cellule at top and bottom shorter than the third; the first recurrent nervure received beyond, the second in front of middle of cellule. Length nearly 15 mm.

Hab. Poona (*Wroughton*).

Allied to *M. fuscipennis;* but that species differs in having "a central channel, which is margined by too slightly elevated carinæ," the abdomen strongly punctured at the base, &c.

7. MYZINE ORIENTALIS.

Smith, *New species of Hym.*, 179.
Hab. Beloochustan.

8. MYZINE PALLIDA.

Smith, *New Species of Hym.*, 179.
Hab. North West Provinces.

9. MYZINE PETIOLATA.

Smith, *Cat. Hym.*, III., 72.
Hab. Poona (*Wroughton*).

10. MYZINE TRICOLOR.

Smith, *Proc. Linn. Soc.*, II., 91, 1.
Hab. Borneo.[1]

TIPHIA, *Fab.*

1. TIPHIA COMPRESSA, Smith, *Cat. Hym.*, III., 82, 4.
Hab. Philippines.

2. TIPHIA HIRSUTA, Smith, *l.c.* 83, 5.
Hab. North India.

3. TIPHIA RUFIPES, Smith. *l.c.* 83, 6.
Hab. North India.

4. TIPHIA RUFO-FEMORATA, Smith, *l.c.* 83, 7.
Hab. North India.

5. TIPHIA FUMIPENNIS, Smith, *Proc. Linn. Soc.*, II., 90. 1.
Hab. Borneo.

6. TIPHIA CONSUETA, Smith, *New Species of Hymenoptera*, 184.
Hab. Ceylon.

MUTILLIDÆ.

MUTILLA, *Linn.*

1. MUTILLA ACCEDENS, Radoszkovsky and Sichel, *Mon. d. Mutill*, 89.
Hab. Manilla, Luzon.[1]

2. MUTILLA AESTUANS, Gerstacker, *Peter's Reise*, 487, pl. 31, f. 6[1]; Radoszkovsky and Sichel, *Mongr. J. Mutill*, 85.[2]
Hab. Ceylon,[2] Mozambique,[1] Caffreria.[2]

3. MUTILLA ANALIS, Lep., *Hym.*, III., 630, 52[1]; Rad. and Sichel, *Mon. d. Mutill*, 146.[2]
Mutilla fuscipennis, Fab., *Syst. Piez.*, 436, 35.
Mutilla rufogastra, Smith, *Cat. Hym.*, 36, 185.
Hab. India,[1] Ceylon.[2]

4. MUTILLA ANONYMA, Kohl, *Verb. z-b. Ges. Wien.*, 1882, 482, f. 20.
Hab. Sumatra.[1]

5. MUTILLA ANTENNATA, Smith, *Cat. Hym.*, III., 31, 166.[1]
Hab. India.[1]

6. MUTILLA ARGENTEOMACULATA, Smith, *New Species of Hym.*, 199.[1]
Hab. Bombay Presidency.[1]

7. MUTILLA ARGENTIPES, Smith, *Cat. Hym.*, III., 31, 167.[1] (Pl. IV. f. 3 ♂, f. 14 ♀).
Hab. India,[1] Poona (*Wroughton*).

8. MUTILLA AULICA, Smith, *Cat. Hym.*, III., 37, 189[1]; Rad. and Sich., *Mon. d. Mutill.*, 120. (Pl. IV. f. 4).
Hab. North India,[1] Poona (*Wroughton*).

9. MUTILLA AUREORUBRA, Rad. and Sich., *Mon. d. Mutill.*, 166.

MUTILLA EGREGIA, Saussure, *Non* Klug. *Ann. Soc. Ent. Fr.*, 1867,351. Pl. VIII. f. 1.
Hab. Trincomalia, Ceylon.

10. MUTILLA AURIFEX, Smith, *New Species of Hym.*, 198.
Hab. Bombay Presidency.

11. MUTILLA AURIFRONS, Smith, *Cat. Hym.*, III., 31, 168.[1]
Hab. India.[1]

12. MUTILLA BASILIS, Smith, new species of Hym., 200.[1]
Hab. Bombay Presidency.[1]

13. MUTILLA BENGALENSIS, Lep., *Hym.*, III., 637, 63;[1] Rad. and Sich, *Mon. d. Mutill.*, 122.
Hab. Bengal.[1]

14. MUTILLA BICINCTA, Saussure, *Ann. Soc. Ent. Fr.* 1867[1] 355, t. 8, f. 4.[1]
Hab. Paradinie, Ceylon.[1]

15. MUTILLA BLANDA, Smith, *Cat. Hym.*, III., 32, 170.
Hab. India.[1]

16. MUTILLA BUDDHA, Cam. (Pl. IV., f. 9).
Hab. Poona (*Wroughton*).

17. MUTILLA CALLIOPE, Smith, *Proc. Linn. Soc.*, II., 85, 8.[1]
Hab. Borneo.[1]

18. MUTILLA CASSIOPE, Smith, *Proc. Linn. Soc.*, II., 86, 12.[1]
Hab. Borneo.[1]

109.[1]

19. MUTILLA CEYLANENSIS, Rad. and Sich., *Mon. d. Mutill,*
Hab. Ceylon.[1]

20. MUTILLA CHRYSOPHTHALMA, Klug, *Hym. b. phys.*, 17, pl. V., f. 3., Rad. and Sich., *Mongr. Mutill*, 95.[1]
Hab. Arabia, Ceylon.[1]

21. MUTILLA COMOTTII, Gribodo.
Hab. Burma.

22. MUTILLA CONSTANCEÆ, Cam. (Pl. IV., f. 10)
Hab. Poona (*Wroughton*).

23. MUTILLA CORONATA, Saussure, *Novara Reise*, 106.
Hab. Ceylon.[1]

24. MUTILLA COROMANDELICA, Motsch., *Bull. Mosc*, 1863. 23.
Hab. India, Madurà.

25. MUTILLA DARDANUS, Smith, *Proc. Linn. Soc.*, II., 86, 13.[1]
Hab. Borneo.[1]

26. MUTILLA DECORA, Smith, New Species of Hym., 200.[1]
Hab. Pulo Penang.[1]

27. MUTILLA DEIDAMIA, Smith, *Proc. Linn. Soc.*, II.,83, 3.[1]
Hab. Borneo.

28. MUTILLA DENTICOLLIS, Motsch, *Bull. Mosc.*, 1863, 22.
Hab. Ceylon, Mountains of Nura Ellia.

29. MUTILLA DIMIDIATA, Lep., *Hym.*, III., 628, 50;[1] Rad. and Sich., *Mon.*, 147.
Mutilla rufogastra, Lep., *l.c.*, 629, 51.
Mutilla sexmaculata, Smith, *Cat, Hym.*, III., 37, 188.
Hab. India,[1] Pondechery, Triconomale, Timor, Luzon.

30. MUTILLA DIVERSA, Smith, *Cat. Hym.*, 32, 171.[1]
Hab. India.[1]

31. MUTILLA DIVES, Smith, *Cat. Hym.*, III., 32, 172.[1]
Hab. India.[1]

32. MUTILLA ERYTHROCERA, Cam.
Hab. Poona (*Wroughton*).

33. MUTILLA FAMILIARIS, Smith, *Proc. Linn. Soc.*, II., 84, 7.
Hab. Singapore, Borneo.[1]

34. MUTILLA FUNERARIA, Smith, *Cat. Hym.*, III., 37, 190.[1]
Hab. North India.

35. MUTILLA GLABRATA, Fab., *Syst. Piez.*, 438, 45;[1] Olivier, *Ent. Méth.*, VIII., 65, 64.
Hab. India.[1]

36. MUTILLA GRACILLIMA, Smith, *Proc. Linn. Soc.*, II., 84, 6.[1]
Hab. Borneo.[1]

37. MUTILLA HEXAOPS, Saussure, *Ann. Soc. Ent. Fr.*, 1867, 169, 7.[1]
Hab. Nattan, Ceylon.[1]

38. MUTILLA HUMBERTIANA, Saussure, *Ann. Soc. Ent. Fr.*, 1867, 353, t. 8, f. 2.
Hab. Trincomalia.[1]

39. MUTILLA HYMALAYENSIS, Radosykowsky, *Horae. Soc. Ent. Ross.*, XIX.
Hab. Himalaya.[1]

40. MUTILLA INDICA, Linné, *Syst. Nat.*, I., 966, 3.[1]
Hab. India.[1]

41. MUTILLA INDOSTANA, Smith, *Cat. Hym.*, III., 33, 175.[1]
Hab. Madras.[1]

42. MUTILLA INSULARIS, Cam.
Hab. Sober Island, Trincomalia, Ceylon (*Yerburgh*).

43. MUTILLA INTERMEDIA, Saussure, *Ann. Soc. Ent. Fr.*, 1867, 354, 4.[1]
Hab. Ceylon.[1]

44. MUTILLA KAUARÆ, Cam. (Pl. IV., f. 2.)
Hab. Ceylon (*Yerburgh*).

45. MUTILLA KAUTHELLÆ, Cam.
Hab. Kauthella, Ceylon (*Yerburgh*).

46. MUTILLA MACULOFASCIATA, Saussure, *Novara Reise, Hym.*, 107, 5.
Hab. Ceylon, Timor, Luzon.[1]

47. MAHAGANAYENSIS, Cam.
Hab. Mahaganay, Ceylon.

48. MUTILLA METALLICA, Cam.
Hab. Trincomali, Ceylon (*Yerburgh*).

49. MUTILLA MIRANDA, Smith, *Cat. Hym.*, III., 33, 176.[1]
Hab. India.[1]

50. MUTILLA NEREIS, Kohl, *Verb. z. b. ges. Wien*, 1882, 476, f. 2.[1]
Hab. Java,[1]

51. MUTILLA NIGRIPES, Fab., *Syst. Piez.*, 439, 51.
Hab. India.[1]

52. MUTILLA NOBILIS, Smith, *Cat. Hym.*, III. 33, 178.
Hab. Madras.

53. MUTILLA OCCELLATA, Saussure, *Ann. Soc. Ent. Fr.*, 1867, 169, 6.[1]
Hab Ceylon.[1]

54. MUTILLA OPTIMA, Smith, *Cat. Hym.*, III., 34, 179.[1]
Hab. India.[1]

55. MUTILLA OPULENTA, Smith, *Cat. Hym.*, III., 34, 180.[1]
Hab. India,[1] Kauthalla, Ceylon (*Yerburgh*).

56. MUTILLA PANDORA, Smith, *Proc. Linn. Soc.*, II., 85, 10
Hab. Borneo.[1]

57. MUTILLA PHILIPPINENSIS, Smith, *Cat. Hym.*, III., 40, 200;[1] Rad. and Sich., *Mongr. Mutil.*, 88.
Hab. Philippines,[1] Luzon.

58. MUTILLA PLACIDA, Smith, *New Species of Hym.*, 198.[1]
Hab. Bombay Presidency.[1]

59. MUTILLA PONDICHERENSIS, Radosykovsky and Sichel, *Monog. d. Mutilles*, 66.
Hab. Pondichery.[1]

60. MUTILLA POONAENSIS, Cam
Hab. Poona (*Wroughton*).

61. MUTILLA PROSPERINA, Smith, *Proc. Linn. Soc.*, II., 85, 9.[1]
Hab. Borneo.[1]

62. MUTILLA PULCHRICEPS, *Cam.* (Pl. IV., f. 17)
Hab. Poona (*Wroughton*).

63. MUTILLA PULCHRINA, Smith, *Cat. Hym.*, III., 34, 181,[1] (Pl. IV., f. 6-8 and 16).
Hab. Madras,[1] Savoy, Poona (*Wroughton*).

64. MUTILLA PULCHRIVENTRIS, *Cam.* (Pl. IV., f. 5)
Hab. Poona (*Wroughton*).

65. MUTILLA PUSILLA, Smith, *Cat. Hym.*, III., 37, 191.[1]
Hab. North India.[1]

66. MUTILLA REGIA, Smith, *Cat. Hym.*, III., 38, 192[1] (Pl. IV., f. 7).
Hab. North India,[1] Poona (*Wroughton*).

67. MUTILLA RUFITARSIS, Smith, *New Species of Hym.*, 199.[1]
Hab. India.[1]

68. MUTILLA RUFIVENTRIS, Smith, *Cat. Hym.*, III., 36, 184.[1]
Hab. India.[1]

69. MUTILLA RETICULATA, *Cat. Hym.*, III., 35, 183.[1]
Hab. India.[1]

70. MUTILLA RUGOSA, Olivier, *Ency. Méth.*, VIII., 61, 35; Rad. and Sich., *Mon. d. Mutill.*, 121. (Pl. IX. f. 4).
Hab. India,[1]

71. MUTILLA SEMIAURATA, Smith, *Cat. Hym.*, III., 36, 187.
Hab. India.[1]

72. MUTILLA SERRATULA, Cam. (Pl. IV., f. 12).
Hab. Poona (*Wroughton*).

73. MUTILLA SEXMACULATA, Swed., *Nov. Act. Holm.*, VIII., 286, 44; Rad. and Sich., *Mon. d. Mutill*, 109[1] (*non* Smith).
Hab. Bengal,[1] South India, Calcutta.

74. MUTILLA SIBYLLA, Smith, *Proc. Linn. Soc.*, II., 86, 11.[1]
Hab. Borneo, Celebes, Arn.[1]

75. MUTILLA SUBINTRANS, Rad. and Sich., *Mon. d. Mutill*, 90.[1]
Hab. Ceylon, Timor.[1]

76. MUTILLA SOROR, Saussure, *Ann. Soc. Ent. Fr.*, 1867, 354, t. 8, f. 3.[1]
Hab. Habourenne, Ceylon.[1]

77. MUTILLA SUSPICIOSA, Smith, *Proc. Linn. Soc.*, II., 94, 5.[1]
Hab. Borneo, Celebes, Amboyna, Bourn, Flores.[1]

78. MUTILLA TETRAOPS, Rad. and Sich., *Mon d. Mutill.* 119.[1]
Mutilla leucopyga, Smith, *Cat Hym.*, III., 12, 74 (*nec* Klug).
Mutilla sexmaculata, Smith, *l.c.* 37, 188 (*nec* Swed.).[2]
Hab. China, India.[2]

79. MUTILLA TRIMACULATA, Cam.
Hab. Poona (*Wroughton*).

80. MUTILLA TRINCOMOMALICA, Rad.
Hab. Trincomalia.[1]

81. TROPBANÆ, Cam.
Hab. Trincomalia (*Yerburgh*).

82. MUTILLA UNIFASCIATA, Smith, *Cat. Hym.*, III., 38, 193.
Hab. India, Celebes.

? MUTILLA VICINISSIMA, Gribodo, *Ann. d. Mus. Civ. a. Storia Nat. d. Genova.*
Hab. Burma.

83. MUTILLA UNIMACULATA, Smith, *Proc. Linn. Soc.*, II., 87, 14.
Hab. Borneo, Celebes.[1]

84. MUTILLA URANIA, Smith, *Proc. Linn. Soc.*, II., 83, 4.[1]
Hab. Borneo.[1]

85. MUTILLA VEDA, Cam.
Hab. Poona (*Wroughton*).

86. MUTILLA WROUGHTONI, Cam. (Pl. IV. f. 15).
Hab. Poona (*Wroughton*).

87. MUTILLA YERBURGI, Cam.
Hab. Mahaagang, Ceylon (*Yerburgh*).

The following table may enable the new species here described to be more easily recognised :—

1. (2) Abdomen without spots. The apex of the second and the third abdominal segments with golden bands ; the head covered densely with a golden pubescence ; thorax elongate-quadrate, concave, dilated at the apex. *Kanarae.*
2. (1) Abdomen with spots.
3. (14) The spots golden.
4. (9) Head black.
5. (6) Sides of thorax irregularly serrulate ; tibiae and tarsi testaceous. Second abdominal segment without a large golden spot. Length 5 mm. *serratula.*
6. (5) Sides of thorax not irregularly serrulate ; tibiae and tarsi black.
7. (8) Thorax laterally concave, dilated at apex, abdomen at base with two large dilated marks, legs not densely pilose. *insularis.*
8. (7) Thorax laterally not concave, narrowed towards the apex, abdomen at base with a small spot, legs densely pilose. *Buddha.*
9. (4) Head red.
10. (13) Abdomen with two golden spots : the sides of thorax not irregularly serrulate.

11. (12) Head large, more than half the length of the thorax: the pubescence sparse, fuscous. *erythrocera.*

12. (11) Head small, less than half the length of the thorax, the pubescence dense, golden. *pulchriceps.*

13. (10) Abdomen with one small golden spot at the base; the sides of thorax irregularly serrate. *veda.*

14. (3) The spots white.

15. (20) The head red, wholly or in part.

16. (17) Abdomen with one spot and one band. *Poonaensis.*

17. (16) With two or three spots and no band; abdomen purple.

18. (19) With two spots, thorax laterally slightly convex, not much narrowed towards the apex. *metallica.*

19. (18) With three spots, thorax laterally concave in middle, distinctly narrowed towards the apex. *pulchriventris.*

20. (15) Head black.

21. (24) Abdomen with no white band.

22. (23) ,, ,, two spots placed transversely. *Wroughtoni.*

23. (24) ,, ,, three spots placed longitudinally. *trimaculata.*

24. (21) ,, ,, a band or two.

25. (26) ,, ,, one spot, the thorax dilated at apex. *Taphanae.*

26. (25) ,, ,, two or three spots, the thorax not dilated at apex.

27. (28) With two spots; thorax without spines. *Constanceaæ.*

28. (27) With three spots; thorax more than twice the length of the head, spined. *Kauthellæ.*

MUTILLA KAUTHELLAE, *sp. nov.*

Black, the mesonotum dull red; a broad macula on the apex of the first segment, two oval ones on the second; and two irregular ones on the apex of the third, white; the ventral segments fringed with white hairs. Head large, distinctly wider than the thorax, very coarsely, irregularly rugosely punctured, forming almost reticulations beneath. Antennal tubercles obliquely striated. The hair on the vertex is fulvous, intermixed with longer fuscous hair;

on the lower part of the head pale to silvery. Eyes oval, convex; vertex convex, raised above the top of the eyes. Scape of the antennæ punctured, covered with glistening, silvery hairs; the flagellum thick, tapering towards the apex, where it is brownish; the third joint more than twice the length of the fourth, and longer than the fourth and fifth united. Thorax elongate quadrate, with the punctures larger and deeper than on the head, the mesopleuræ almost opaque, aciculate; above the line of separation, between the meso—meta—and median, segment is obliterated; the prothorax is very short; the mesothorax becomes a little dilated towards the apex; the sides at the apex with two obtuse tubercles; the base being also dilated, so that the central region is narrower than the basal and apical. On the base of the median segment, at the side, is a large, shining, oblique tooth. Abdomen deep black, at base subsessile; longer than the head and thorax united; above thickly covered with black hairs; there is a line of dark, fulvous hairs on the side of the second segment; pygidium finely rugose, covered with long brownish hairs. Legs covered with long white hairs; the calcaria pale yellowish-testaceous; the tibiæ with stout spines.

Length, 12mm.

MUTILLA TAPROBANÆ, *sp. nov.*

Black, the thorax ferruginous; an ovate mark on the second segment in the middle, a square one at its apex, and the third segment silvery-white. Head as wide as the thorax, coarsely rugosely punctured; sparsely covered with long pale hairs; convex above, but not much developed above the eyes; antennal tubercles smooth shining. Scape of antennæ and the second joint piceous; the third joint more than twice the length of the fourth, and as long as the fourth and fifth united. Thorax punctured like the head, quadrate; the hairs long and black; the sides very slightly concave, rough, hardly dilated towards the apex. Mesopleuræ shining, impunctate in the middle, the metapleuræ the same except at the apex. Median segment rounded, and with a very slight slope. Abdomen as long as the head and thorax united; subpetiolate; less strongly punctured than the thorax; the hairs at the base black, at apex pale; the ventral segments fringed with long silvery hair; pygidium longitudinally striated, rufous in the centre. Legs bearing whitish hairs: the calcaria pale; the tibial spurs thick and of four pairs. Mandibles piceous at the base.

Length, 7 mm.

M. rufitarsis, Sm., appears to have pretty much the same colouration and markings as the above, but it is larger (4½ lines).

MUTILLA TRIMACULATA, *sp. nov.*

Black, the thorax dark rufo-testaceous, a round mark on the base and apex of the second segment, and a larger longish one on the fourth, glistening white. Antennæ stout, the flagellum dull brownish beneath, the scape obscure rufo-testaceous, the third joint clearly longer than the fourth. Head as wide as the thorax, rather strongly punctured; covered with long blackish hairs; antennal tubercles shining, dull rufo-testaceous, this being also the colour of the mandibles at the apex. Thorax somewhat more strongly punctured than the head; the pleuræ impunctate; the sides of the thorax above straight, becoming slightly, but distinctly, narrowed from base to apex; the median segment with a rather sharply rounded slope. Abdomen not much longer than the head and thorax united, the pygidium shining, finely punctured. The ventral segments and pleuræ dull piceous, the thorax and abdomen bearing long blackish hairs; the apical ventral segments fringed with whitish hairs; the legs bear white hairs; the fore tarsi piceous; calcaria pale. Nearly related to *M. metallica*, but wants the metallic gloss on the thorax and head; the abdomen black, the base of the second segment with a white mark, the fascia on its apex being continuous; the third antennal joint shorter in proportion to the fourth; the thorax more distinctly narrowed from base to apex; the median segment with the slope more gradual, not so sharply oblique.

Length, nearly 5 mm.

MUTILLA WROUGHTONI, *sp. nov.*

Black, the thorax above rufous, the base of the second abdominal segment with two oval white marks, Antennæ stout; the third joint about one-half longer than the fourth. Head broader than the thorax, coarsely rugosely punctured; eyes moderate, oblong, the head well developed behind them. Thorax more coarsely rugose than the head, the pleuræ apparently impunctate; the sides of the thorax above rough, becoming gradually dilated to the apex; the apex of median segment oblique, black. Abdomen shorter than the head and thorax united; the subsessile pygidum apparently punctured, covered with long hairs. The upper surface of the insect has the hair black; the ventral longer and whitish. Legs covered with white hairs.

Length, 8½ mm.

MUTILLA PULCHRIVENTRIS, *sp. nov.*

Head and antennæ red, the latter covered on the top thickly with pale golden pubescence, hiding the ground colour; thorax dull red; abdomen a small spot longer than broad at the base and two broader than long on the apex of the second segment, white; legs red; the femora and tibiæ more or less purple. Head wider than the thorax; eyes large, oval, reaching quite close to the top of the head. The third antennæ joint as long as the fourth and fifth united. Thorax elongate, rounded at base and apex concave near the middle, distinctly narrowed towards the apex, above coarsely punctured; the median segment with the punctures larger, rounder, deeper, and more widely separated; pleuræ coppery, the meso covered thickly with white hair; the mesonotum with long black hair, and with a short white glistening sparse pubescence. Abdomen oval, wider than the thorax, narrowed at base and apex, closely punctured and bearing long black hairs; pygidium impunctate; from the apex of the penultimate segment spring two masses of white hair; ventral segments filled with long pale hair. Legs covered with pale hair; there are three rows of tibial spines; the calcaria white.

Length, 9 mm.

Very closely related to *metallica*, but easily separated by the different shape of the abdomen, which in *M. metallica*, is longer, narrower, not dilated in the centre, but becomes gradually narrower towards the apex; it has also the punctuation on the median segment as on the mesonotum.

MUTILLA METALLICA, *sp. nov.*

Head and thorax coppery, metallic, with greenish tints; abdomen bright metallic purple; the legs, antennæ, and oral region widely pale ferruginous. Head slightly wider than the antennæ; shining, moderately strongly pnnctured; the oral region with a glistening white pubescence; the upper part with long blackish hairs. The second and fourth joints of the antennæ about subequal; half the length of the third. Thorax above, somewhat more strongly punctured than the head; the propleuræ in the middle punctured; the mesopleuræ in the middle aciculate; above the middle legs there is a small space finely longitudinally striated. The sides of the mesothorax almost straight, but very slightly narrowed towards the apex; the median segment with a gradual rounded slope to the apex, where it is distinctly narrowed. Abdomen as long as the head and thorax united, more closely punctured than the thorax; at the base, narrowed, narrower than the apex of the median segment; it bears longish black hairs; and they become longer in the apical segments; the ventral segments fringed with pale hairs; on the apex of the second segment are two spots of white hairs, broader than long; pygidium finely punctured. Legs covered with long white hairs; the tibiæ and femora more or less metallic coppery green behind. Eyes large, oval, convex; head not much convex on top. There are three tibial spines.

The quantity of ferruginous on the head varies; the extreme base of the thorax and abdomen are also of this colour.

Length, 7 mm.

MUTILLA POONAENSIS, *sp. nov.*

Head, thorax, base of abdomen rufo-testaceous, abdomen black, with a purplish gloss, a small white mark on the second segment near the base and a band on its apex, glistening white. Antennæ of moderate length, stout, the third joint not much longer than the fourth. Head a little broader than the thorax, closely and coarsely punctured, covered with white glistening hairs; the antennal tubercles impunctate; eyes large, oblong, reaching quite close to the head. Thorax much more coarsely punctured than the head; the prothorax rounded in front; the median segment with a gradual rounded slope to the apex, coarsely punctured; mesopleuræ shining, impunctate; the thorax covered with longish, fuscous to glistening white hairs. Abdomen subpetiolate, narrowed at the base; pygidium impunctate, covered with long fuscous and white hairs. Legs covered with long white hairs; the calcaria white. The sides of the thorax slightly narrowed from base to apex.

Length, 6 mm.

MUTILLA VEDA, *sp. nov.*

Head and thorax ferruginous; abdomen black; the extreme base ferruginous; a mark, broader than long, on the base, and a large band (dilated in the centre) on the apex of the second segment, pale fulvo-golden; the scape and the basal joints of the flagellum and the legs reddish; the apical joints of the flagellum brownish beneath; the apices of the femora broadly blackish.

Very closely allied to *M. serratula*, having the same form of the thorax; differing in having the head red, and in there being a spot on the base of the second segment, in the pygidium being covered all over with pale fulvous hairs; in the thorax at the base laterally being not so rounded; the sides at the extreme base project into a broad tooth, roundly incised at the apex; the sides in the middle are not contracted, nor continuously serrate, but broadly waved; the apex of the median segment is rounded, not brought to a point in the middle and serrate, the metapleuræ are distinctly punctured. Legs covered with longish hair. The third joint of the antennæ a little longer than the fourth. Eyes moderate, oblong; clypeus covered with long fulvous hairs; the base of the mandibles rufo-piceous.

Length, 5 mm.

MUTILLA PULCHRICEPS, *sp. nov.*

Thorax ferruginous, the scape and base of the flagellum and legs rufo-testaceous: abdomen black, two large round maculæ on the second, and the third and fourth segments golden-fulvous; the head apparently black, but hid by a thick covering of fulvous pubescence. Head coarsely punctured; convex above, not much developed above the top of the eyes. Antennal tubercles coarsely punctured, eyes large, oblong. Second antennal joint shorter than the fourth, the third about twice the length of the fourth.

Thorax coarsely punctured; the hairs long and black; the pleuræ shining impunctate. Sides of thorax from above distinctly concave, irregular; the apex hardly wider than the base; the sides of median segment serrate. Median segment with an abruptly oblique slope. Abdomen as long as the head and thorax united, subpetiolate. Pygidium longtudinally rugose and covered with long pale fulvous hairs. The ventral segment fringed with golden fulvous hairs. The coxæ and apex of the femora are black; the hairs on femora are pale; on tibiæ and tarsi pale rufous; the tibial spines five in number, longish, and like the calcaria, pale rufous. Basal half of mandibles and antennal tubercles rufo-piceous.

Length, 8 mm.

Allied to *M. soror* and *intermedia*, with which it agrees in colouration; but differs in the head, being densely covered with a golden fulvous pubescence. *Soror* is further distinguished from it in the thorax, not being concave, but straight; and *intermedia* has the metapleuræ rugose.

MUTILLA ERYTHROCERA, *sp. nov.*

Antennæ, head, thorax and legs, for the greater part, ferruginous; abdomen black, two large round maculæ on the second segment, and the third and fourth segments golden-fulvous. Head coarsely rugosely punctured, and sparsely covered with long blackish hairs; the hairs on the clypeus pale fulvous; antennal tubercles shining, impunctate. Palpi testaceous; eyes small, oval, in length about as long as the third antennal joint, and situated before the lateral middle line of the head, *i.e.*, the space behind them is greater than in front. Vertex roundly convex. The third antennal joint not quite twice the length of the fourth, which is longer than the second. Head wider than the thorax. Thorax more coarsely punctured than the head; the mesonotum impunctate, the pro—and metapleuræ rufose; the sides of mesothorax rough, very slightly concave; eyes of median segment bluntly serrate. Abdomen about as long as the head and thorax united; the hairs on the first and second segment black. Pygidium apparently finely punctured; ventral segments fringed with fulvous hairs. Legs: femora and coxæ piceous; tibiæ and tarsi ferruginous; the tibial spines (6 in a row) black; the hair long and pale fulvous.

Length, 9 mm.

MUTILLA BHUDDA, *sp. nov.*

Black, the thorax ferruginous; an oval spot on the base of second segment and the whole of the third pale golden-fulvous. Head narrower than thorax, very coarsely punctured, almost reticulated; eyes large, oval, antennal tubercles impunctate; vertex not much raised above the eyes, roundly convex; the clypeus fringed with long fulvous, the rest of the head sparsely with fuscous hairs; mandibles piceous in the middle. Scape covered with pale fulvous hairs; the flagellum with a pale down, brownish beneath; the third joint not much longer than the fourth, shorter than the fourth and fifth united. Thorax coarsely longitudinally reticulated, the pleuræ entirely impunctate; becoming gradually but not much narrowed from extreme base to apex; the edges rough, but without any distinct tubercles; apex of median segment obliquely sloped. Abdomen longer than the head and thorax united; the first segment dilated, longitudinally punctured on the second segment; the others with their apices shining, impunctate, glabrous; the pygidium coarsely punctured; the extreme apex finely transversely striated; the apical ventral segments fringed with long fulvous hairs. Legs: the femora sparsely covered with longish blackish hairs; the tibiæ and tarsi thickly with pale fulvo-golden; the calcaria and the bristles on the underside of the tarsi rufous; the four tibial spines stout black.

Length, 11 mm.

MUTILLA SERRATULA, *sp. nov.*

Black; the thorax red; the scape and legs pale rufo-testaceous; the apex of second abdominal segment with a pale fulvous band (dilated in the middle). Head as wide as the thorax, coarsely punctured; the antennæ tubercles impunctate. Pale testaceous, as well as the cypleus; mandibles reddish, the apices piceous black; eyes large, oval, reaching close to the top of the head. The third joint of antennæ about one-half longer than the fourth. The sides of the thorax coarsely irregularly serrate, contracted in the middle; closely and coarsely longitudinally punctured; the apex of median segment above ^-shaped; coarsely serrated; the acute apex terminating in a spine. The sides of the median segment serrate; the pleuræ impunctate. First abdominal segment not dilated; the apical pale, testaceous, impunctate; the apical ventral segments fringed with pale fulvous hairs. Tibiæ and tarsi sparingly covered with testaceous hairs; the apices of femora fuscous.

Length, 5 mm.

MUTILLA INSULARIS, *sp. nov.*

The antennæ and head black; thorax ferruginous; abdomen black, with two large oval united fasciæ on the second segment; the third segment and the apex of the fourth, golden-fulvous; legs black, the femora for the greater part ferruginous. Head coarsely rugosely punctured; the hairs fulvous. Eyes large, oblong; reaching quite close to the top of the head, which is slightly convex—Antennal tubercles red, shining, finely striated. Antennæ inclining to piceous beneath towards the base; the third joint twice the length of the fourth; the second and third joints subequal. Thorax bluntly rounded at base and apex, twice the length of head, more strongly punctured than the head; the pleural punctured, except at the apex; the sides of the thorax above rough, almost straight—pygidium longitudinally striated; the sides fringed with long fulvous hair—apical ventral segment slightly fringed with fulvous hair; the basal segment with large deep punctures; the others with the punctures much smaller. Legs covered thickly with long pale fulvous hairs, rufo-fulvous on the tarsi; the calcaria; the tibial spines four, pale.

Length, 11 mm.

MUTILLA KAUARÆ.

Head covered all over with a golden fulvous pubescence completely hiding the colour; the basal three joints of the antennæ and the thorax and legs ferruginous; abdomen black, segments three and four the apex of the second and the apical covered with golden fulvous pubescence. Head a little wider than the thorax; eyes large, oval; mandibles ferruginous at the base; palpi testaceous; antennæ stout, the third joint a little shorter than the fourth and fifth united. Thorax about twice as long as the head, rounded at base and apex; the sides concave, the edge rough, hardly wider at the apex than at the base; the thorax above coarsely rugosely punctured; the pluræ impunctate, shining; apex of medium segment with a gradually rounded slope. Abdomen as long as the head and thorax united, subsessile; coarsely punctured; the fourth and fifth segments bearing long, dull, fulvous hairs; pygidium longitudinally striated, the apex more finely transversely: the sides fringed with long golden hairs; ventral segments punctured, fringed with fulvous hairs. Legs covered with fulvous hair; the tibiæ with four long spines; the coxæ are black; the hair of tarsi dense and long.

Length 11 mm.

MUTILLA CONSTANCEÆ, *sp. nov.*

Black, the thorax pale, ferruginous above, an irregular mark on the base and apex of the second segment and the third segment white. Antennæ with the third joint about one quarter longer than the fourth; the first at apex, the second and the terminal beneath more or less piceous. Head not much wider than the thorax, coarsely punctured, densely covered with silvery hair; the antennal tubercles piceous, aciculate. Eyes oval, moderate, reaching quite close to the top of the head. Thorax quadrate, rounded at base and apex, the sides rough, slightly concave; above coarsely longitudinally punctured, the pleuræ impunctate, densely covered with white hairs, the upper also densely covered with white hairs. Abdomen as long as the head and thorax united, subsessile, dilated at the base of second segment, becoming gradually narrowed to the apex; coarsely punctured, in the middle bearing rufous hairs, the sides with silvery hair; pygidium rufous, longitudinally striated, the ventral segments fringed with long silvery hairs. Legs covered with long silvery hairs; the tibial spines testaceous; the spurs white.

Length, a little over 6 mm.

MUTILLA YERBURGHI, *sp. nov.*

Metallic-blue, covered with a whitish pubescence; the antennæ black; wings fusco-hyaline. Antennæ of moderate length; the third joint shorter than the fourth. Eyes emarginate. Head punctured, behind the ocelli almost smooth; a channel runs down from the lateral ocelli. Thorax rather strongly punctured, very slightly convex; the median segment reticulated; pro- and metapleuræ with an oblique excavation, shining, almost smooth except for an indistinct striation. Parapsidal furrows distinct. Abdomen strongly punctured; the second and following segments thinly fringed with pale hair. Thorax truncated in front, rounded behind. Legs covered with white hairs; the calcaria white. Abdomen subsessile.

Length, 9 mm.

MUTILLA PULCHERINA, *Smith.*

Head and thorax ferruginous, the antennæ, mandibles, legs and abdomen black: a small, somewhat triangular, spot on the basal segment, a broad band, dilated roundly in the middle at the apex, on the base of the second; the third segment entering a broad band in the fourth (the latter two interrupted in the middle), and a fringe on the apical abdominal segments, golden fulvous. Antennæ short, thick; the third joint about one-half longer than the fourth, and shorter than the fourth and fifth united. Head narrower than the thorax, very coarsely rugosely punctured; the antennal tubercles shining, impunctate; eyes small, oval, vertex convex, not much elevated above the eyes; the long hair on the vertex blackish; on front and oral region fulvous. Thorax coarsely longitudinally, irregularly strialate; but the furrows are not continuous; mesopleuræ shining, impunctate. The sides become gradually and slightly narrowed from base to apex; a little before the middle there is a stout tooth; and there is a blunt tubercle a little beyond the middle. Abdomen distinctly longer than the head and thorax united, subessile; pygidial area apparently strongly transversely aciculate; the second ventral segment very coarsely transversely punctured. Legs (including the tarsi) densely covered with long fulvous hair; the femora coarsely punctured; the calcaria pale testaceous.

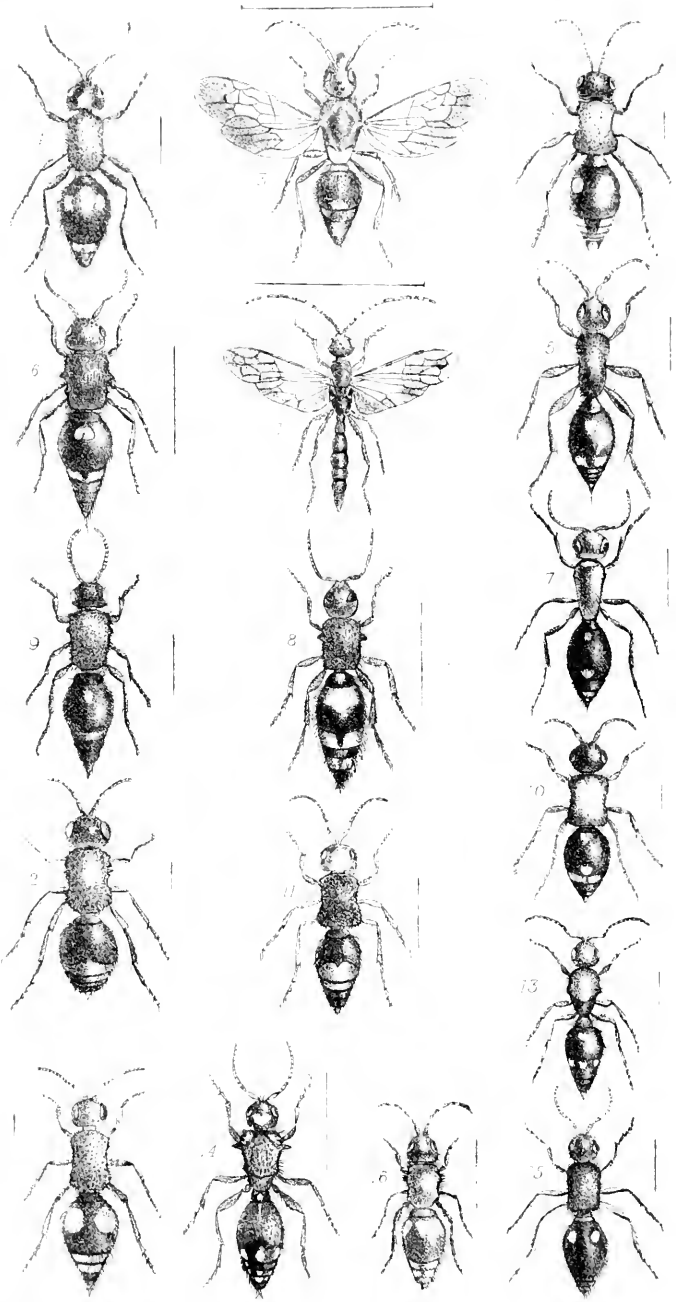
The band on the second abdominal segment varies, and may become broken up into three rounded spots.

M. Aurifex is probably a variety; but the description is imperfect.

MUTILLA INTERRUPTA, *var?*

Black; the thorax rufous; the abdomen with two oval spots on the base of the second segment, and a broad

HYMENOPTERA — Plate I.



[illegible] Hock[illegible] Lith. [illegible] & [illegible] Manr.

interrupted band on the third and fourth segments, white. Antennæ with the third joint about twice the length of the fourth. Head wider than the thorax, coarsely rugosely punctured; the lower part bearing a white pubescence. Eyes elongate. Thorax quadrate much more strongly and deeply punctured than the head, the pleuræ impunctate; the sides of the thorax above slightly concave, the apex more dilated than the base, the apex of median segment subperpendicular. Abdomen a little longer than the head and thorax united, narrowed at the base; pygidium finely longitudinally striated. Tibial spines pale, four in number.

Nearly 9 mm.

APTEROGYNA, *Latr.*

1. APTEROGYNA MUTILLOIDES, Smith, *Cat. Hym.*, III., 64, 5.
Hab. India.

MYRMOSIDA, *Smith.*

1. MYRMOSIDA, PARADOXA, Smith, *Proc. Linn. Soc.*, II., 88, 1, tab. 2, fig. 1.
Hab. Singapore.

THYNNIDÆ.

ISWARA *West.*

1. ISWARA LUTENS, Westwood, *Trans. Ent. Soc.*, I. pl. 7, f. 5.
Hab. India.

2. ISWARA FASCIATA, Smith, *Ann. Mag. Nat. Hist.* 253.
Hab. Sind.

Ordinary Meeting, January 26th, 1892.

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

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

The congratulations of the members were presented to the President on the jubilee of his connection with the Society, Dr. SCHUNCK having been elected a member on January 25th, 1842. Mr. CHARLES BAILEY remarked that it was pleasant to find a member who began his work for the Society very soon after his election half a century ago as one of its secretaries still manifesting his interest in it in the presidential chair; and Dr. SCHUNCK replied that his association with the Society had been throughout one of the chief pleasures of his life.

Mr. GWYTHER referred to the death of the Society's honorary member, John Couch Adams, F.R.S., elected in 1847, who shared with Leverrier the distinction of predicting, in 1845, the place where the then undiscovered planet Neptune would be found, and pointed out that Adam's calculations were so accurate that Professor Challis, of the Cambridge Observatory, searching for the planet under Adam's instructions, without the aid of the German star maps, actually saw the planet twice in the place predicted six weeks before the Berlin telescope was directed to the sky by Dr. Galle to look for it according to the indication of Leverrier.

Mr. GWYTHER read a paper entitled "On an intrinsic differential equation of conics, and its relation to the invariants," showing the method of deriving the ordinary invariants of a conic from the differential equation discovered by Monge, and called by Halphen the differential invariant of a conic. Considerable simplification results from taking as variables, magnitudes of which the connection with the curve is of an intrinsic nature.

Ordinary Meeting, February 9th, 1892.

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

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

By the nomination of the PRESIDENT, Mr. C. S. TRAPP and Mr. CHARLES O'NEILL were appointed auditors of the accounts for the current year.

The PRESIDENT drew attention to a copy of the "History of the Siege of Gibraltar," presented to the Society by the author, Colonel Drinkwater, who served with the Manchester Regiment during the famous siege, and who was elected a member of the Society in the same year in which the work was published and presented, 1786; and also to a work on the "Department of Comptrollers of Army Accounts" from the same pen, presented by Colonel Drinkwater to the Society just fifty years later, and containing an autograph inscription by him. A conversation on the Manchester Regiment and its officers of the period of the siege ensued.

Professor OSBORNE REYNOLDS described the principle of Mr. Edison's proposed system of telephoning over great distances at sea by means of condensers.

Mr. C. O'NEILL, F.C.S., made a communication to the effect that he had found that the solubility of lead formate was greatly increased by the addition of a small quantity of lead nitrate. It had been previously known that nitrate of lead can be dissolved in a small weight of water, compared with its own weight, by the addition of acetate of lead, but the observation with regard to lead formate and lead nitrate was apparently new.

[*Microscopical and Natural History Section.*]

Ordinary Meeting, February 15th, 1892.

Mr. CHARLES BAILEY, F.L.S., Vice-President of the Section, in the Chair.

Mr. H. HYDE described two specimens of perfectly white moles, which had been sent to him, and mentioned that in these albino examples the eye is much more conspicuous than in those of the ordinary colour.

Mr. T. ROGERS exhibited some beetles from Vancouver, and a selection of plants from the herbarium of the late George Crozier, which has been presented to the Free Library, by the family of his son, the late Robert Crozier, the artist.

Mr. CUNLIFFE described some experiments made upon a caged lion. When an article saturated with a strong scent was introduced into his cage, the lion showed great excitement and pleasure, and rolled himself about in the scent, sniffing up its fragance with evident relish.

Mr. P. CAMERON read a paper on the natural history of gall insects.

General Meeting, February 23rd, 1892.

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

Mr. R. M. PANKHURST, LL.D., Barrister-at-Law, St. James's Square, Manchester, and the Rev. CANON JULIUS LLOYD, M.A., Kersal, Manchester, were elected ordinary members.

Ordinary Meeting, February 23rd, 1892.

EDWARD SCHUNCK, Ph.D., F.R.S., F.C.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 theory of Mr. HENRY WILDE, F.R.S., and his experiments respecting the variation in the direction of the magnetic needle, and Mr. FARADAY pointed out that Mr. Charles A. Schott, of the United States Geodetic Survey, had stated that he had records of magnetic variations with which Mr. WILDE was not acquainted, and that when these were used as tests, in addition to the large number of verifications Mr. WILDE had presented, the latter's theory still held good.

Dr. SCHUNCK, in pursuance of remarks made at the previous meeting, read a letter from Colonel Drinkwater, one of the officers of the Manchester Regiment during the siege of Gibraltar, accompanying a copy of a work on the battle of St. Vincent, presented by him to the Society in 1797. In this communication Colonel Drinkwater acknowledged the authorship of the work named.

Mr. W. BROCKBANK, F.L.S., F.G.S., read a paper on "The Artificial Colouration of Flowers," and exhibited a large number of flowers which had been artificially coloured by Mr. Wm. Dorrington and himself. They had observed that cut flowers, placed in a solution of aniline scarlet, absorbed the colour, and became tinged thereby. Later on they found that a beautiful blue was imparted to cut flowers by the colour called indigo-carmine. A large number of dyes were tried, and other sorts were partially successful; but none proved so good as the two above-named. They tried indigo, cochineal, and sulphate of copper, with only partial success. The fact, however, was easily established, viz., that cut flowers can be coloured rapidly by placing them in a solution of aniline colour, of about the transparency of claret—also that new features of great beauty are imparted to many flowers thereby. The lily of the valley flowers become beautifully tinted pink in six hours. Narcissi are changed from pure white to deep scarlet in twelve hours. Yellow daffodils are beautifully striped and fringed with dark scarlet in twelve hours. The larger subject, of how this rapid change is brought about, soon attracted Mr. BROCKBANK'S attention, and proved extremely interesting; as the method thus adopted opens out modes for investigating and demonstrating phenomena in vegetable physiology, which promise to be of great value. The cellular theory of sap circulation, which is well-known to botanists, Mr. BROCKBANK maintained does not account for these results. He arrived at the conclusion that there is a complete vein system in plants, the vein tubes being clearly seen under the microscope, passing through the leaves of the plants, and also through the petals and other parts of the flowers. In these tubes the motion of the fluid colour could be seen, and it is these veins which convey the colour. In the cases of cut flowers the action is very rapid. The experiments and observations in proof of this were at first made entirely with cut flowers; but the author afterwards tried the experiment of taking a hyacinth and narcissi out of the soil very carefully, and then placing the root fibres in aniline water. In twelve hours the petals began to colour, and the plant gradually became tinctured throughout by the pink dye. The filtering appendages, found at the tips of the rootlets, apparently prevent the absorption of much of the colour, because the petals do not become so deeply tinged, nor so quickly, as with cut flowers; but it is clearly seen that the vein tubes proceed from the roots, and thus complete the system from root to flower. The veins are beautifully shewn by the microscope as clean tubes—running in parallel lines, gradually branching out as they proceed, and as they approach the margins being much and finely branched. When the coloured water reaches the margins of the petals, they thus become deeply tinctured, especially in the narcissi,—illustrating the cause whereby the daffodil so frequently obtains the deeper colour at the margins of the corona. It is the same with the *Leucojum* and snowdrop. The most singular results were obtained from variegated leaves of the ivy and acuba—plants which, in the winter season, one would suppose, had the leaves quite dormant. Single leaves of these plants, with the leaf stalk placed in aniline red water, began to colour in about three hours, and in twelve hours had the margins deeply coloured. Leaves thus separated from the stem of the plant were thus shewn to have an absorptive and circulating power in themselves, even if detached from the stem. The pistils of the flowers always become coloured—which the author considers an important fact, as shewing that the solid matter of the colouring fluid is secreted by the fruiting vessels of the flower. It has been stated lately, that the free use of sulphate of copper for dressing the vines in France, and watering the vineyards for the prevention of the Phylloxera, has been found to produce a copper flavour in the clarets. This is seen to be exceedingly probable from these experiments.

An animated discussion ensued, in which Mr. CHARLES BAILEY, Professor HARE, Dr. REE, Mr. CUNLIFFE, and others, took part, Mr. BAILEY describing various experiments on the artificial colouration of flowers during the last two centuries, and Professor HARE suggesting elaborations of Mr. BROCKBANK'S experiments as likely to prove extremely helpful in elucidating the structure and vital processes of plants.

Mr. CHARLES O'NEILL, F.C.S., read a paper on "The action of formic and acetic acids with oxydizing agents on indigo blue."

Ordinary Meeting, March 8th, 1892.

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

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

It was announced that the Annual Meeting would be held on Tuesday, the 26th, instead of the 19th of April (Easter Tuesday).

A question was raised as to the possibility of a human flying machine. Professor REYNOLDS stated that the limits of size were determined by the strength of the material used. The machine must be strong enough, light enough, and go fast enough, and the less efficient as a flying machine the faster it must go. The difficulty was not one of kinematics or construction of the machine, but in the conditions under which the machine must be used.

Dr. SCHUNCK read a paper, entitled "Notes on some Ancient Dyes." The materials examined by Dr. SCHUNCK were supplied by Mr. Flinders Petrie through Mr. R. D. DARBISHIRE, and are mainly scraps of woollens, fillings from coffins from tombs in Lower Egypt, of date about 400 or 500 A.D. The discussion which followed turned mainly on the methods of producing the fabrics, some of which were of the nature of what are called dhooties, and some seemed to be produced by the aid of a jacquard loom.

[*Microscopical and Natural History Section.*]

Ordinary Meeting, March 14th, 1892.

ALEX. HODGKINSON, M.B., B.SC., President of the Section, in the Chair.

Mr. H. HYDE and Mr. SCOWCROFT were appointed to audit the accounts.

Mr. BOYD exhibited a number of flowers which had been artificially coloured by immersing their stems in various aniline dyes.

The PRESIDENT of the Section gave an account of the causes of the very remarkable colours seen in some fishes, and explained how, under certain conditions, these colours are changed; illustrating his remarks by a number of prepared specimens shown under the microscope.

Ordinary Meeting, March 22nd, 1892.

EDWARD SCHUNCK, Ph.D., F.R.S., F.C.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 deaths of Mr. OLIVER HEYWOOD, ordinary member, and Professor HERMANN KOPP, of Heidelberg, honorary member.

The discussion on Dr. SCHUNCK's paper on "Some Ancient Dyes," read at the previous meeting, was resumed by Dr. BOTTOMLEY, Mr. W. THOMSON, Mr. C. O'NEILL, and the PRESIDENT.

A discussion also took place on the artificial colouration of flowers through the roots, some additional experiments being described, and Mr. CHARLES BAILEY giving an account of experiments by M. Maxime Cornu, a dozen years ago, who stated that the dyes appeared to stop the growth of the plants. Professor HARE pointed out that a similar paralysing influence is observable in staining microbia with aniline dyes.

Professor H. B. DIXON, F.R.S., read a paper on "The Explosion of Carbonic Oxide and Oxygen with other Gases," relating to experiments by Professor Bekstoff, of St. Petersburg, confirming the result arrived at by Mr. DIXON, that the mixture of gases dried by phosphoric acid does not explode. Bekstoff found that cyanogen confers inflammability on the mixture. This had been previously recorded by Mr. DIXON, who also found that carbon bisulphide and oxygen could be fired in a mixture of carbonic oxide and oxygen without causing the union of more than 10 per cent of the latter.

Ordinary Meeting, April 5th, 1892.

JAMES BOTTOMLEY, D.Sc., B.A., F.C.S., Vice-President, in the Chair.

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

There was a discussion on the supposed periodicity of meteorological phenomena.

On Iridescent Colours and a Method of examining Iridescent objects, Birds, Insects, Minerals, &c., so as to ensure uniformity in their description. By Alex. Hodgkinson, M.B., B.Sc.

(*Received March 1st, 1892.*)

On taking a general survey of coloured objects, whether natural or artificial, we become aware of the fact that whilst the colours of some remain unchanged as regards tint, whatever their position in relation to the incident light, the tint of others varies with every alteration in their relationship to such light source. We thus see that so far as their colours are concerned all bodies may be arranged in two groups according as their colours change or do not change in tint as their angular relationship to the light varies. Nor is this classification entirely an artificial one, since, as will shortly be seen, though this change in tint with variation in the light source is an essential difference, it is not the only difference, even in the colour manifestations of the two groups, for it is also characteristic of the nature of the colour-producing structure. It is to the above-mentioned varying colours that we apply the term iridescent, from the resemblance they have in the sequence or play of colours to the tints of the rainbow. The unvarying group of colours, having no equivalent term to "iridescence" to express the nature of their colour production, are spoken of as "pigmentary," or absorption colours. In naming examples of objects, natural and artificial, grouped as above in accordance with the nature of their colours, it is difficult to make a selection where all are so varied and characteristic. I have preferred therefore to cite only such instances as I myself possess, and am therefore able to show you. As examples of pigmentary colours, I need only name one or two for the sake of comparison, since the colours of most objects ordinarily met with are pigmentary. Leaves, flowers, dyes, birds, fish, insects, minerals, &c., exhibit these colours, some almost entirely, and all, excepting fish, in far the majority of instances. Of objects displaying iridescent colours we have also examples in the various divisions of the animal, vegetable, and mineral kingdoms. Amongst birds the most striking examples are found amongst the Humming Birds, Sun Birds, Birds of Paradise, &c. Insects, again, furnish numerous examples, more especially amongst tropical species, though not, perhaps, proportionally in greater numbers than amongst those belonging to our own more temperate regions. The colours of fish are almost entirely iridescent, since their very whiteness, or silvery sheen, is due to the admixture of the iridescent colours of innumerable minute thin lamellæ, too small to be seen individually with the naked eye, but plainly perceptible under the microscope. In the Vegetable kingdom iridescent colours are far more numerous than is ordinarily recognized, since the surfaces of the cell walls produce interference colours which are more or less obscured by the pigmentary colours of leaves and coloured flowers, but may be readily seen in the case of white flowers by the aid of a lens and sunlight. Under these conditions each cell may be seen to sparkle with its own iridescent colour, forming, by admixture of the interference tints of neighbouring cells, the varying shades of white seen in numerous flowers which are devoid of pigmentary colour. Mineral bodies displaying iridescent colours are also numerous; opals, sunstone, fire-marble, felspar, mica films, tarnish on various metallic crystals, certain crystals of chlorate of potash, &c., are examples.

In describing the various natural objects for purposes of identification, or mere description, no account can be considered complete which omits all reference to their colours, and more especially is this the case where the colours constitute such a striking feature, as in the case of iridescent bodies. In innumerable instances, more especially amongst birds and insects, their specific names are taken from some conspicuous colour they possess. It thus becomes evident that a correct description of the colours of bodies is of importance, and where these colours are of the pigmentary, or unchanging kind, this is a matter of no difficulty. How different, however, in the case of objects, the colours of which not only vary with every change of position, but disappear altogether, unless viewed with special relation to the light source. Nor can it be wondered at that descriptions of these objects, even by observers of undoubted repute, vary according to the different angles from which they have been viewed; or are vague and profuse, owing to fruitless attempts to describe their changing tints produced by every movement. The fact is, no words can convey an adequate impression of the gorgeous effects produced by most of such objects, whether birds, insects, or fish, when in motion in brilliant sunshine. Some notion of the difficulties to contend with in describing the colours of humming birds, for example, may be gathered from the remarks of Wallace in his work on "Tropical Nature," when speaking of humming birds:—"In some species they must be looked at from above, in others from below; in some from the front, in others from behind, in order to catch the full glow of the metallic lustre; hence, when the birds are seen in their native haunts, the colours come and go and change with their motion, so as to produce a startling and beautiful effect." Most observers, in describing the colours of iridescent bodies, do so by attempting to depict the varied effects produced by casually changing the position of the object in relation to the light, omitting to mention the exact *sequence* of the play of colours, or the relation of these colours to the direction of the iridescent light, *i.e.*, whether produced by perpendicular or oblique illumination. Here is a description of the tufted neck humming bird, *Trochilus ornatus*, taken haphazard from a well-known work:—"The throat is of a fine green colour, variable in different lights to a golden hue with a yellow or brown metallic lustre, and below that the whole of the belly is a rich brown, glossed with green, and golden." Such descriptions as the above, which happen to be the first I met with in seeking for an instance, are vague, and fail to give a definite idea of the appearance of the object. But vagueness in the description of these objects is not the only result of the changing character of their colours. As might be expected, where such variation in appearance exists, the descriptions of different authors are almost as variable as the colours. Few attempt descriptions without acknowledging the hopelessness of the task. Thus Jardine, after describing this humming bird, *Chryslampis mosquitus*, remarks: "It is impossible to convey by words the idea of these tints, and having mentioned those substances to which they approach nearest, imagination must be left to conceive the rest." And I adduce this quotation as fairly expressing the feeling of naturalists in reference to the description of iridescent objects generally. Recognizing the admitted inability of observers to convey by description an idea of the appearance of these iridescent objects, and having myself, for many years, constantly experienced the same difficulty, I have been led to adopt a method for the examination of such objects, which, whilst extremely simple and available in its application, yields unvarying results with different observers, results, moreover, which admit of the simplest description.

Before describing this method, I may say that long experience in the examination of iridescent objects, has proved to me that, almost without exception, the colours of natural iridescent objects are due to interference produced by thin plates. In order, therefore, to render clear the principles on which the method I propose is founded, I will briefly refer to certain fundamental facts in connection with colour production by thin plates, and for this purpose will select a thin film of mica, which, with light at perpendicular incidence, appears red, iridescent red. If, now, this plate be inclined so that the light falls on it at a more oblique angle, it is, of course, reflected at the same angle, and now appears orange, and if the plate be still further inclined, the reflected light appears yellow, then yellowish green, green, and bluish green, and if the light were not too copiously reflected from the first surface to allow of perceptible interference by further inclination of the plate, all the colours of the spectrum in their proper sequence might be observed. The same results, but much more vividly, may be seen in these crystals of chlorate of potash. Thus, we see that by rendering the incident light more and more oblique, the reflected light changes from a lower to a higher tint, that is, from the red towards the violet end of the spectrum. And this is what occurs in the case of all iridescent bodies, as the incident light becomes more oblique the colour changes to the tint above it in the spectral order, so that, if we know what colour any such object appears when seen at a certain angle, we can infer what colour it will change to on varying the incidence. This beetle (*Sagra purpurea*), for instance, is red at perpendicular incidence, it will, therefore, appear orange yellow and green when examined by successively increased obliquity of light. And the same is true of all other iridescent red objects. If the object at perpendicular incidence be green, as in the case of this beetle (*Bupristis*), it will become blue and then violet as the incidence is increased. We thus see that an iridescent object varies in colour, simply because it is examined by light incident, and therefore reflected, at different angles. Thus, different observers see the same iridescent object of a different colour, when they view it illuminated by light at a different angle of incidence. If, however, the object is seen by all at the same angle of the incident light it will present the same colour, and this is, in fact, what the method I propose ensures, *i.e.*, that iridescent objects shall always be seen by light at one and the same angle of incidence. The angle I select is one of 90, so that the incidence and reflection are normal or perpendicular to the reflecting surface. By selecting this angle all trouble of measuring angles is avoided, since we know that the incidence is perpendicular when it coincides with reflection. Now, the reflected light may be made to coincide with the incident light by reflecting it on to the object by means of a mirror, and so adjusting the object that the light reflected from it passes to the eye through a perforation in the mirror. When examined in this way iridescent objects are marvellously altered in appearance, their changing colours are replaced by one fixed tint, visible only in one position, a fact which serves at once to distinguish them from bodies coloured by absorption, which remain coloured whatever the relation to the incident light. Such methods of examining bodies scarcely takes more time than by the eye alone. The mirror may be attached to a spectacle frame so as to leave both hands free, such as the one I show, or may be a simple hand mirror. For objects too small to be seen by the unaided eye, I have so arranged the microscope that light is made to pass down the tube of the instrument, through the object glass on to the objects, and by a special arrangement, so adjusted the position of the object that the light is reflected back again through the instrument to the eye. The method is thus available for macroscopic as well as microscopic objects.

To illustrate the practical value of this plan of examination, I have here a few objects exhibiting iridescent colours, which, by trial, will be found to give the following results:—

The crest of this humming bird, *Chrysolampis mosquitus*, which, to the unaided eye, appears resplendent with all shades of red, orange, yellow, or green, according to the angle of the incident light, appears, when examined by the mirror, of one unvarying red tint, disappearing when the object is moved, but absolutely unchanging in tint. Such an object, therefore, I should describe as "iridescent red;" all else regarding its colour may be inferred. Again, the breast, or gorget, of the same bird reflects all shades of orange, yellow, or green to the eye alone ; with the mirror it is seen of a deep orange, which, as before, is unchanged in tints by any variation in position. Such an object I would describe as "iridescent orange." The gorget of another humming bird, *Calliphlox amethystina*, to the eye alone appears crimson, orange, yellow, or green ; with the mirror it is iridescent crimson only, spectroscopically a red of the 2nd order. Amongst insects, instances of iridescent species are numberless, the results of examination are just the same as in other iridescent bodies. This butterfly, *Morpho*, to the eye alone appears either greenish-blue, blue, or violet, as its inclination to the light varies ; examined with the mirror it appears green, and should be described as iridescent green, or iridescent bluish-green. This beetle, *Poropleura bacca*, appears any shade of red, yellow, or green to the eye alone ; with the mirror only iridescent red. In this extraordinary beetle, *Chrysochroa fulminans*, we have all the colours of the spectrum in their natural sequence, beginning with red at the tip of the wing case, and ending with violet higher up the elytron. These colours vary in an indescribable manner when attentively examined at different angles of incident light with the eye alone ; with the mirror the wing cases are seen to be coloured successively from base to tip iridescent green, yellow, orange, and red, and these tints remain unaltered by change of position of the object. This piece of *Haliotis* shell exhibits indescribable changes of colour with every movement, but the difficulty of description, though by no means removed, is immeasurably lessened by the use of the mirror. And the same with this specimen of iridescent iron ore, its colours, which vary to the unaided eye, remain unchanged when examined by the mirror. To simplify the description of iridescent objects, therefore, I would advocate the above method, and would describe the result of such examination by recording the colour observed by aid of the mirror, and prefixing the term "iridescent" to express the changing properties of the colour. Bearing in mind the unvarying nature of these changes, a far clearer idea may be formed of the appearance of these objects than from any attempted description of what is admittedly indescribable. Time and space are also economised by the omission of lengthy descriptions. The accuracy, and, therefore, the value of any description of colour, is always enhanced by mapping its spectrum ; more especially is this true in the case of iridescent colours. This is easily done, and by applying such map to a spectral chart, the order of the colour, and therefore its tint, is apparent. In examining many objects, chiefly birds or insects, by means of the mirror as above described, apparent exceptions are repeatedly met with to the fact stated above, that the colour is invariable in tint and disappears by inclination of the body. Such instances are no real exceptions, but are due to the reflecting plates being curved, or having pigmentary matter beneath them, or an opalescent medium above them. In this way some of the most extraordinary and beautiful colour effects it seems possible to conceive are produced. Some of them I hope to bring before your notice on a future occasion.

In examining objects with the perforated mirror a single light is necessary. The sun is of course the best, and the electric light probably almost as good. I frequently employ the limelight, but a good paraffin lamp may be used as a substitute. Ordinary gas is unsuitable. The light should be placed in front of the observer, its direct rays being prevented from falling on the objects by means of a book or partition of some kind resting on the table, and of such a height that the light can be seen above it. On placing the mirror to the eye the light may be reflected from the mirror on to the object, and the latter manipulated so as to reflect the ray back through the perforation in the mirror to the eye. The incidence is thus known to be normal, and the colour observed is the one to be recorded.

Notes on some Ancient Dyes. By Edward Schunck, Ph.D., F.R.S.

(Received May 4th, 1892.)

The fragments of ancient dyed fabrics which I have examined I owe to the kindness of Mr. R. D. Darbishire. They are specimens from a lot found by Mr. Flinders Petrie, in a tomb at Garob, Lower Egypt, supposed to date from 400–500 A.D. They were used apparently for filling the mummy cases where required, not strictly speaking as grave clothes. My object in examining them was to ascertain, if possible, what were the materials employed in producing the various colours seen on them. The fabrics examined consisted almost entirely of wool. Here and there in the warp of some of the specimens were threads, conspicuous for difference in colour, consisting of linen. The following colours could be distinguished :—blue, yellow, green, red, maroon, purple or claret, black. I will take them in the order named.

Blue.—The colour of the fabric was a dull medium blue. On treatment with hot caustic lye a great part of the wool dissolved. The residue, which was dark blue, having been filtered off, washed and dried, was treated with boiling aniline, to which it communicated a bright blue colour. The blue solution having been filtered boiling, deposited on cooling a quantity of blue crystalline scales, which, after being filtered off, washed with alcohol and dried, were found to consist of indigo blue. On being treated in a tube they gave a sublimate of regular crystals, blue by transmitted, copper-coloured by reflected, light ; they dissolved in concentrated sulphuric, giving a blue solution, and the solution in aniline showed the absorption spectrum of indigo blue. It is evident, therefore, that indigo in some form or other was the material used in dyeing this colour.

Yellow.—The colour of the patches dyed yellow was so evidently faded, and showed so little intensity, as to make it very uncertain whether analysis would lead to any precise result; the examination was therefore omitted.

Green.—Of the material dyed this colour, I had but a small quantity, but it was sufficient to allow of some conclusion regarding the means whereby the colour was produced. On being treated for some days with dilute hydrochloric acid it imparted to the latter a deep yellow colour. The portion left by the acid, after being washed and dried, yielded indigo blue on treatment with boiling aniline. It is probable, therefore, that the colour was produced by first dyeing the fabric with indigo, then treating with some mordant, such as alum, and, lastly, dyeing with some yellow colouring matter, most likely of vegetable origin. With the small quantity of material at my disposal, I found it impossible to ascertain the nature of the yellow colouring matter employed.

Red.—This was the most pronounced, and at the same time the most interesting, of the colours examined. The colour of the fabric was a full deep red. It might be called a Turkey red: the dye, in fact, proved on examination to be a kind of Turkey red as having the characteristic properties of that dye.

On being burnt, the fabric left a considerable quantity of ash, consisting of calcium sulphate, alumina, aluminium phosphate, ferric oxide, and silica. A large portion of this ash no doubt represents the mordant employed in producing the colour. On treatment with hot dilute hydrochloric acid the fabric lost its red colour and became yellow. After removal of the acid by washing with water, and pressing between blotting paper, treatment with boiling alcohol deprived the wool of the greater part of the yellow colour, a faint tinge only being left. The deep yellow alcoholic liquid obtained left on evaporation a reddish-brown amorphous residue. This, on being treated with a boiling solution of alum, dissolved in part, yielding a pink fluorescent liquid, which had exactly the same colour, and showed precisely the same absorption bands as a solution of purpurin from madder in alum liquor. On adding hydrochloric acid to the pink solution and heating, the colouring matter was precipitated in orange-coloured flocks, the liquid becoming almost colourless. The flocks after being filtered off and washed with water dissolved easily in boiling alcohol, yielding a yellow solution, which, on spontaneous evaporation, left a quantity of dark yellow needles arranged in rosettes. These needles dissolved in caustic alkali, giving a cherry-red solution, which showed the absorption bands of purpurin. The solution, on exposure to air and light, became colourless.

Some of the precipitated colouring matter, on being employed in the usual way for dyeing a bit of calico to which various mordants had been applied, yielded colours exactly like those obtained with purpurin from madder, *i.e.*, the alumina mordant gave a bright red, the iron mordant dull purple to black tints. The matter left undissolved, after repeated treatment with boiling alum liquor, was still highly coloured. It dissolved easily in alcohol, the solution leaving on evaporation a brown amorphous residue, which remained soft even after long standing. This residue consisted for the most part of fatty matter, but it also contained some colouring matter insoluble in alum liquor. That this colouring matter was alizarin seemed probable, since the colour which the mixture imparted to alkaline lye resembled that of an alkaline solution of impure alizarin.

These experiments lead to the conclusion that the red colour of the fabric was produced by dyeing with some kind of madder, either wild or cultivated, the fabric having been previously treated with a mixed aluminous and ferric mordant, and then probably oiled—that it was, in fact, really a kind of Turkey red.

Maroon.—The dull chestnut colour of this fabric presented a striking contrast to the bright red of the preceding. Its constitution was, however, similar. Having treated it in the same way as the other, I found that the colouring matter must have been derived from madder; fatty matter was also present, but the mordant contained a larger proportion of ferric oxide, a fact which sufficiently explains the brown tint of the dyed fabric.

Purple.—The fabric in which this colour was seen was made up of a pale yellow warp, and a weft of a dull purple or claret colour. The latter colour was found to be due to an intimate mixture of red and blue, for the threads, on examination under the microscope, were seen to consist partly of red, partly of blue fibres, the former predominating. The two sets of fibres had, of course, been mixed before spinning. The blue fibres were certainly dyed with indigo, the red probably with madder.

Black.—The colour of the black fabric, like that of the green, was a compound of two colours, one overlying the other. Under the microscope the individual threads appeared grey. On treatment with a mixture of alcohol and hydrochloric acid they changed colour, a yellow liquid being obtained, while the fabric itself now appeared blue, and after washing and drying yielded indigo by appropriate treatment. The yellow alcoholic liquid was found to contain purpurin. The colour may be supposed to have been produced in the following manner:—The woollen fabric having first been dyed blue was mordanted, to use a modern phrase, and then dyed with madder, the two colours together producing the effect of black.

On the action of Acetic Acid, with oxidising substances, on Indigo Blue. By Charles O'Neill, F.C.S.

(Received May 18th, 1892.)

If a quantity of very pure indigo blue in fine powder be placed in a glass or porcelain mortar, with 20 or 30 times its weight of mono-hydrated or glacial acetic acid, well mixed up, then crystals of permanganate of potash added in small portions, at intervals of a few minutes, with continual stirring and grinding, it will be found that chemical action is taking place, heat is evolved, the mixture thickens almost to a paste, and when the quantity of permanganate added is equal to about one-fourth part of the weight of indigo operated upon, the operation is finished. Examined under a pretty high power of the microscope, say with ⅛ inch objective, the contents of the mortar are found to consist of a mass of small prismatic crystals floating in a nearly colourless liquid; the crystals have a faintly yellow colour, and no indigo blue is visible. The thick mass of crystals may be drained on a filter, washed with strong acetic acid and then with water, until all soluble matters are removed, then dried very gradually in a warm place, where the temperature for the first few hours should not exceed 20° to 25° C.; after most of the water has evaporated, the temperature may be gradually increased up to 100° C., at which heat the dry product is permanent, and may be kept for years unchanged in a dry place.

Other oxidising agents may be used, but the only ones to be recommended are the di-oxide of lead, the red oxide of lead, either added directly or previously dissolved in strong acetic acid, and lastly, the higher oxides of manganese lower than the di-oxide. The two lead oxides act perfectly well, the only objection being that it is nearly impossible to remove traces of lead from the indigo preparation. The oxides of manganese which are between the mono-oxide and the di-oxide are quite suitable if of good quality; a necessary feature is that the specimen used must be perfectly soluble in dilute acetic acid to which sulphurous acid is added.

The amount of oxygen required is 1 at. to 1 mol. of indigo. When the operation is successfully carried on with permanganate of potash the reduction of the permanganic acid to manganous acetate is complete, no manganic acetates being formed; under certain conditions of temperature and dilution abundant crystals of manganous acetate are visible in the finished mixture. They are perfect rhomboids; these crystals are more frequently visible when using a manganic oxide as the converting agent, the manganous acetate being but sparingly soluble in strong acetic acid.

Sometimes the operation with permanganate does not go well, the minimum quantity does not complete the operation, more has to be added, and the already formed manganous acetate is converted into a manganic acetate, which, in the subsequent washings, is decomposed, and the indigo product would be contaminated with manganic oxides if it were not treated before the final washings with dilute acetic acid, containing sulphurous acid, which completely removes the impurity.

The indigo blue used should be of a high degree of purity; with commercial indigo of the best sorts, the crystals are formed pretty well, but it is vain to expect to obtain in any clear or certain manner the products of decomposition to be presently described. No commercial indigo that I have ever had in my hands contained more than 75 % of indigo blue, and the 25 % of matters not indigo blue are unconquerable impediments in the way of getting a good product. The indigo precipitate obtained by oxidising the dissolved indigo contained in a reduction vat is very suitable for these experiments, but such a precipitate made from commercial indigo is never pure indigo blue; very good specimens may shew 92 % indigo blue, hardly ever a higher percentage. The nearest approach to pure indigo blue suitable for the treatment described is obtained by the reduction of pure crystalline indigotine, obtained by sublimation, or better by solution from boiling aniline. Such a product may contain 99 % indigo blue, and will give nearly the calculated quantitative results in these experiments. It would have been very desirable to act at once upon the pure indigo blue from aniline, but its crystalline condition impedes the complete action of the acids and oxidising agents; with the calculated amount of oxidising matters only a small portion of the crystalline indigotine is acted upon. If the quantity of permanganate be increased to eight or ten times the calculated quantity, the crystals are finally acted upon, although not completely, with evolution of heat. The solution in which the action takes place is a saturated solution of higher oxides of manganese, secondary reactions have taken place, the yield is much smaller than with the amorphous or very finely crystalline precipitated indigo, and it does not shew quite the same results.

The product made, as described, from precipitated indigo, viewed in bulk has a greyish, greenish, or blueish colour; in thin layers it is nearly white, with a yellow tinge; it is no doubt either white or a very pale yellow; the various shades that various preparations shew are owing to the presence of small quantities of indigo blue unacted upon. In the method of preparation it will have been observed that two practically insoluble bodies are used to produce a third insoluble body. It is curious how this third body should assume the crystalline form, but it does so, and envelopes a portion of blue in the crystals which cannot be reached by the agents employed, unless used in such excess as to exercise a destructive action upon the product itself. The oxy-aceto-indigotin, as the preparation may be named for the present, does not admit of purification by any process of dissolution and recrystallising; for practical purposes it is insoluble in all menstrua that I have tried. In some directions it possesses considerable stability; mineral acids, unless concentrated, have no action upon it; a mixture of permanganate and sulphuric acid, which destroys indigo rapidly, has no action upon it, and may be used to free a product from uncombined indigo; chromic acid, chlorine, etc., in dilute solutions, have no action upon it; it is very readily decomposed by alkalies. I cannot claim to know the real composition or constitution of this new and interesting body; it contains no indigo blue, no isatine and no acetic acid. Combustions of the purest and most successful preparations were made again and again; in those thought best the C was to the H as 20 to 15, never as 20 : 16, as it was thought the ratio should be; but as I had never a pure product to analyse, and as the tendency of the impurity was to reduce the proportion of hydrogen to carbon, I have for the present adopted the ratio of C_{20} to H_{16}, and believe the following equation represents the chemical change:—

$$\underset{\textit{Indigo.}}{C_{16}H_{10}N_2O_2} + O + \underset{\textit{Acetic Acid.}}{2(C_2H_4O_2)} = H_2O + C_{20}H_{16}N_2O_6.$$

The assumption of the separation of the elements of water during the reaction is deduced rather from theoretical considerations of the behaviour of the compound than from any very reliable observations in practice, but I think there is no doubt the excess of acetic acid beomes diluted, and is no longer able to act as the monohydrated acid acts. The calculated yield is 145%, as much as 140% has been got, and often 125% and 130%. The decompositions of the oxy-aceto-indigotin are numerous, and some very complex. I only propose to consider four or five of those which can be followed most easily; and, to trace the changes which take place, will assume a structure for the body which has no other pretensions than as forming a sort of working hypothesis to illustrate the changes. The supposed structure is as follows :—

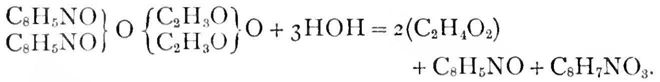
$$C_{20}H_{16}N_2O_6 = \left.\begin{matrix}C_8H_5NO\\ C_8H_5NO\end{matrix}\right\} O \left\{\begin{matrix}C_2H_3O\\ C_2H_3O\end{matrix}\right\} O.$$

I am not going to attempt defending this arrangement as a rational arrangement. I know nothing about the constitution of the body, I have never read about any similar body, and that acetic anhydride should exist in it seems very improbable.

Decomposition by steaming and boiling with water. The addition of the elements of water to the oxy-aceto-indigotin, which is effected by boiling it in water or steaming it, splits it up and produces two molecules of acetic acid, one of isatin, and half a molecule of indigo blue. The calculated percentage is acetic acid (mono-hydrated) 31·6, isatin 34·5, and indigo blue 38·7, making 104·8; these quantities have been obtained many times; the percentage of acetic acid is very regular, but the percentage of indigo and isatin are subject to a perturbation not yet clearly understood; not in every case, but in most cases, there is production of a small quantity of a fourth substance, very little soluble in water, but easily soluble in chloroform, from which it separates in lustrous yellow or golden coloured crystals. It is apparently the same substance which is formed by the direct oxidation of indigo in air, it has not been obtained in sufficient quantity to be examined; it may amount to as much as 8 or 10% of the weight of aceto product, but generally much less. It is believed to result from the interaction of indigo and isatin at the moment of their formation, and to be a substance intermediate in composition between indigo and isatin. The length of time required to split up the aceto body depends upon the size and perhaps hardness of the crystals. It commences immediately, and may be completed in twenty minutes, or it may take several hours boiling or steaming; it is effected more rapidly and completely in sealed tubes heated to 150° C.

Decomposition by dry heat. Heated in a tube retort the aceto-product suffers little change until the temperature rises to 130° or 140° C.; it then gives off acetic acid, and continues to do so until a temperature of 180° C. is reached, the acetic acid when collected is found to be the monohydrate, and crystallises readily upon cooling. The residuum in the retort is a complex substance, yielding no isatin to water or alkalies, contains a strong dark red colouring matter, but is mostly a pitchy matter, very soluble in chloroform, which leaves indigo insoluble, usually, in a crystalline state, but in less quantity than indicated by theory. In the hot air bath at 180° C. acetic acid is expelled quickly, partial fusion takes place, and chloroform dissolves out only a red pitchy matter, leaving indigo; but if the heat be lower, say at 140° to 150° C., and the operation stopped when the loss of acid is about 18 or 20% instead of 31%, and then treated with cold chloroform, there is dissolved with the pitchy matter a notable quantity of the oxy-aceto body. This chloroform solution soon decomposes upon standing, depositing indigo blue, and is found to contain isatin. If calico be dipped in the chloroform solution, it is found after standing, or steaming and washing, to be stained of a light blue colour, which is permanent, and, in fact, is an indigo dye.

Decomposition with soda hydrate. If to a mixture of the oxy-aceto-indigotin with water there be added a sufficient quantity of soda hydrate, and the mixture left in the cold for a time, complete decomposition takes place. There is formation of indigo blue, no isatine, or only a trace, is produced, two molecules of acetate of soda and the sodium salt of a new acid, and other substances. The reaction may be expressed in this way, using H instead of Na for greater clearness.



$$\left.\begin{matrix}C_8H_5NO\\C_8H_5NO\end{matrix}\right\}O\left\{\begin{matrix}C_2H_3O\\C_2H_3O\end{matrix}\right\}O + 3HOH = 2(C_2H_4O_2) + C_8H_5NO + C_8H_7NO_3.$$

or shorter

$$C_8H_5NO + 2(HO) = C_8H_7NO_3.$$

This acid is precipitated from its soda solution by mineral acids, and the yield is about 25 % of the weight of the aceto body. It is sufficiently soluble in boiling water to obtain it in well-defined crystals. Cold water only retains one part of the acid in one thousand ; it is very soluble in strong or dilute alcohol. At first I thought I had obtained the true isatic acid, which has not yet been isolated, but upon combining it with bases I found it to be a polybasic acid of a high molecular weight. The formula above deduced must be multiplied by four, and comes $C_{32}H_{28}N_4O_{12}$; molecular weight 660. The acid crystallises from water and dilute alcohol in fine yellowish coloured needles ; it can be made quite white by treatment with animal charcoal ; it has a distinct acid reaction to litmus. Its melting point is about 190° C., when it begins to decompose, giving off, among other things, aniline, which can be readily recognised. It forms at least two salts with soda. The neutral salt $C_{32}H_{26}Na_2N_4O_{12}$ is very soluble in water, does not crystallise, but dries up to a gummy looking mass; the acid salt $C_{32}H_{27}NaN_4O_{12}$ is less soluble in water, and crystallises pretty well from its hot solution. The silver and lead salts are insoluble in water, but the copper and some other metallic salts are soluble and crystallisable.

Decomposition with strong acetic acid. When the oxy-aceto-body is heated along with mono-hydrated acetic acid, another kind of decomposition takes place, the whole is broken up, indigo blue is seen in suspension, and, upon cooling, bright yellow crystals are deposited. It is difficult to separate these crystals from the indigo in a pure state, and I have had recourse to the device of taking the mixture of yellow crystals and destroying the indigo with a mixture of permanganate and dilute sulphuric acid, which has no action upon the yellow crystals. Combustion gives a ratio of C to H as 16 : 7, or a little under; no doubt the H found in this is more than should be, and I consider that the formula will be C_8H_3NO, or a multiple of it. The reaction producing these two bodies, indigo and the yellow crystals, is probably quite internal to the molecule of the oxy-aceto-indigotin body, and merely a re-arrangement of its elements under the constraining influence of heat in a medium non-hydrating, as

$$\left\{\begin{matrix}C_8H_5NO\\C_8H_5NO\end{matrix}\right\}O\left\{\begin{matrix}C_2H_3O\\C_2H_3O\end{matrix}\right\}O = 2(C_2H_4O_2) + C_8H_5NO + C_8H_3NO.$$

The oxidised indigo nucleus is supposed to lose its attached oxygen and two of hydrogen from one of the half molecules, which form water and convert the acetyl rest into two of acetic acid. This yellow body has not been closely examined.

Annual Meeting, April 26th, 1892.

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

Mr. THOMAS EWAN, B.Sc. (Vict.), Ph.D. (Munich), of the Owens College, Manchester, was elected an ordinary member.

The following gentlemen were elected honorary members :—

Capt. W. DE ABNEY, R.E., F.R.S., S. Kensington ; E. F. AMAGAT, Paris ; PAUL F. AUG. ASCHERSON, Berlin ; ADOLF VON BAEYER, Professor of Chemistry, Munich ; LUDWIG BOLTZMANN, Professor of Physics, Munich ; FRANCESCO BRIOSCHI, Naples ; Dr. ANTON DOHRN, Zoological Station, Naples ; W. T. THISLETON DYER, F.R.S., Director, Botanical Gardens, Kew ; GASTON DARBOUX, Professor to the Faculty of Sciences, Paris ; THOMAS ALVA EDISON, Electrician, Menlo Park, New York ; CH. FRIEDEL, Professor to the Faculty of Sciences, Paris ; CARL GEGENBAUER, Professor of Anatomy, Heidelberg ; Professor F. W. GIBBS, Yale, U.S.A. ; W. G. HILL, Washington ; CH. HERMITE, Paris ; Sir JOSEPH D. HOOKER, F.R.S., Sunningdale ; Professor FELIX KLEIN, Göttingen ; AUGUST KUNDT, Professor of Physics, Berlin ; A. LADENBURG, Professor of Chemistry, Breslau ; ALFRED MARSHALL, Professor of Political Economy, Cambridge ; CARL LUDWIG, Professor of Physiology, Leipsic ; E. MASCART, Professor at the Collége de France, Paris ; VICTOR MEYER, Professor of Chemistry, Heidelberg ; J. C. DE MARIGNAC, Geneva ; H. MOISSAN, Professor at the École Supérieure de Pharmacie, Paris ; H. POINCARÉ, Professor to the Faculty of

Sciences, Paris; W. H. PERKIN, F.R.S., Sudbury, Harrow; G. H. QUINCKE, Prof. of Physics, Heidelberg; C. LIEBERMANN, Professor of Chemistry, Berlin; F. RAOULT, Professor to the Faculty of Sciences, Grenoble; J. VAN'T HOFF, Professor of Chemistry, Amsterdam; GRAF VON SOLMS LAUBACH, Professor of Botany, Strassburg; the MARQUIS DE SAPORTA, Aix-en-Provence; OSBERT SALVIN, F.R.S., Haslemere; EMIL DU BOIS REYMOND, Professor of Physiology, Berlin; THEODOR CURTIUS, Professor of Chemistry, Kiel; ALPHONSE DE CANDOLLE, Professor of Botany, Geneva; R. BOWDLER SHARPE; GENERAL FRANCIS A. WALKER, Professor of Political Economy, Boston, U.S.A.; G. WIEDEMANN, Prof. of Physics, Leipsic; Prof. MAX FÜRBRINGER, Amsterdam.

The Annual Report of the Council was presented, and it was moved by the Ven. ARCHDEACON ANSON, M.A., seconded by Mr. JOSEPH CORBETT, and resolved:—"That the Annual Report be adopted, and printed in the Society's *Memoirs and Proceedings*."

It was moved by Mr. J. J. ASHWORTH, seconded by Mr. JOHN ANGELL, F.C.S., and resolved:—"That the system of electing Associates of the 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.—ARTHUR SCHUSTER, Ph.D., F.R.S., F.R.A.S.

Vice-Presidents.—EDWARD SCHUNCK, Ph.D., F.R.S., F.C.S.; OSBORNE REYNOLDS, M.A., LL.D., F.R.S., &c.; JAMES BOTTOMLEY, B.A., D.Sc., F.C.S.; JAMES COSMO MELVILL, M.A., F.L.S.

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

Treasurer.—CHARLES BAILEY, F.L.S.

Librarian.—FRANCIS NICHOLSON, F.Z.S.

Other Members of the Council.—HAROLD B. DIXON,

M.A., F.R.S.; ALEXANDER HODGKINSON, M.B., B.Sc.; JOHN BOYD; JOHN F. W. TATHAM, M.A., M.D.; Alderman JOSEPH THOMPSON; CHARLES O'NEILL, F.C.S.

Ordinary Meeting, April 26th, 1892.

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

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

Mr. CHARLES BAILEY exhibited a Japanese botanical text-book on timber trees, with thin specimens of the woods cut in three directions, pasted in, as an illustration of Japanese progress in technical education.

Dr. SCHUNCK exhibited a specimen of woollen cloth of Egyptian production in the fifth century, and read a letter from Professor Beaumont describing it as an illustration of coarse reed manufacture, and stating that the fringe had apparently been added to the fabric. This was disputed by Mr. J. J. ASHWORTH, who contended that the fringe was an integral part of the fabric, which was similar to a "rep" cloth of the present day, except that the fringe was a continuation of the weft instead of the warp.

[*Microscopical and Natural History Section.*]

Annual Meeting, April 11th, 1892.

The President of the Section, ALEX. HODGKINSON, M.B., B.SC., in the Chair.

Mr. P. CAMERON exhibited some nests of Indian *Hymenoptera.*

Mr. T. SINGTON gave a description of some remarkable geological formations he had observed in the Island of Arran, and showed a number of rock specimens.

Mr. HYDE exhibited a fruit of *Aralia Sieboldii.*

After some discussion, the following resolution was adopted unanimously :—

"That this meeting recommends that a list of Natural "History books in the Library be printed for the use of the "members and associates of the section, and that Messrs. "BAILEY, MELVILL, NICHOLSON, and SINGTON be ap- "appointed a sub-committee to carry out this resolution."

The Annual Report of the Council, and the Treasurer's financial statement, were presented and adopted.

The following gentlemen were elected Officers and Council for the ensuing session :—

President.—R. E. CUNLIFFE.

Vice-Presidents.—ALEX. HODGKINSON, M.B., B.SC.; P. CAMERON, F.E.S.; J. C. MELVILL, M.A., F.L.S.

Secretary.—THEODORE SINGTON.

Treasurer.—MARK STIRRUP, F.G.S.

Council.—CHARLES BAILEY, F.L.S.; JOHN BOYD; H. C. CHADWICK; E. PYEMONT-COLLETT; R. D. DARBISHIRE, B.A., F.G.S.; F. NICHOLSON, F.Z.S.; W. R. SCOWCROFT; T. ROGERS.

Annual Report of the Council, 1st April, 1892.

The number of members on the roll on the 31st March, 1892, is 128 against 133 at the corresponding period in 1891. The number of new members admitted during the year has been 7, while 8 members have resigned. The Society has lost 4 of its members by death, viz.:—Sir Thomas Sowler; Mr. Edmund Salis Schwabe, B.A.; Dr. W. C. Henry, F.R.S.; and Mr. Oliver Heywood. It has also lost five of its honorary members by death:—Baron Emile de Laveleye; Dr. Ferdinand Römer; Sir George Airey; John Couch Adams, F.R.S.; and Prof. Hermann Kopp.

The receipts and expenditure of the past session are set forth in detail in the accompanying balance sheets, and the total balance in favour of the Society, on the 31st March, 1892, stands at £171. 0s. 9d., as represented by the cash lying in the hands of the Society's bankers. The amount at the corresponding period of the previous session was £353. 0s. 3d.

The diminution in the Society's funds is, in the main, explained by the fact recorded in the last annual report, that no payment had been made in the session 1890-91 for printing and binding the Society's *Memoirs*, &c., whereas this year's payments include two years' charges, viz., £265. 16s. 3d. More than the normal expenditure has been incurred during the session now closed for repairs to building and furniture, and for cleaning carpets, curtains, and the like. Some additional shelving for the increasing library has been put up in the cloak-room, but this accommodation by no means provides for what is needed in this direction.

The number of societies using the building for their meetings remains the same as last year. One of these societies dissolved in November last, viz., the Manchester Scientific Students Association, whose books of minutes have been presented to the Society. Arrangements have been made with the Manchester Architects Association for the use of the rooms for the meetings of that organisation.

The Council recommends the continuance of the system of electing associates of Sections by the usual resolution.

The Librarian reports that there is a continued steady increase in the number of volumes received from other Societies, and that an addition has been made to the number of periodicals purchased by the Society.

Amongst other works added during the year are authors and compilers' presentation copies, as follows :—

Alexander Buchan. "The Meteorological Results of the Challenger Expedition."

Frank Vincent. "Around and About South America."
,, "Norsk, Lapp and Finn."
,, "In and Out of Central America."
,, "Through and Through the Tropics."

Sanford Fleming. "Time Reckoning for the 20th Century."

Wm. Sharp, M.D., F.R.S. "The Repetition of the Same Dose."

Joseph Prestwich, F.R.S. "On the Age, Formation, and Drift Stages of the Darent Valley."

Charles Bailey, F.L.S. "Review of the Work of the Leeuwenhoek Microscopical Club, 1867-1891."

Charles Bailey, F.L.S. "Catalogue of the Type Fossils in the Woodwardian Museum."

H. Resal. "Exposition de la Théorie Des Surfaces."

S. C. de L. Michele Rajna. "Sul Metodo Grafico Nel Calcolo Delle Eclissi Solari."

S. C. de Michele Rajna. "Estratta dai Rendiconti del R. Istituto Lombardo."

O. A. L. Pihl. "The Stellar Cluster χ Persei."

G. DEWALQUE. "Prodrome d'une Description Geologique de la Belgique."

RUSSO-JEWISH COMMITTEE. "The Persecution of the Jews in Russia."

HAZELL'S "Annual," 1891.

W. G. FARLOW & A. B. SEYMOUR. "A Provisional Host-Index of the Fungi of the United States." Part 3.

W. H. BAILEY. "Outside the Class-room. Thoughts for Young Engineers."

E. L. HICKS. "The Collection of Ancient Marbles at Leeds."

AGNES M. CLERKE. "The System of the Stars."

MRS. DAVID CHADWICK. "Thomas Sopwith, with Excerpts from his Diary."

ARTHUR WM. WATERS. "Some Meterological Conditions of Davos."

R. INGHAM CLARK. "Notes on Varnish and Fossil Resins."

AUSTRALIAN MUSEUM. "Descriptive Catalogue of the Nests and Eggs of Birds found breeding in Australia and Tasmania." No. 12.

PEDRO MONTT. "Exposition of the Illegal Acts of Ex-President Balmaceda."

MICHAEL FOSTER, F.R.S., &c. "A Text Book of Physiology." Vol. IV.

HENRY WILDE, F.R.S. "On the Causes of the Phenomena of Terrestrial Magnetism."

ARTHUR CAYLEY, F.R.S., &c. "Collected Mathematical Papers." Vol. IV.

SIR H. E. ROSCOE, F.R.S., & C. SCHORLEMMER, F.R.S. "Treatise on Chemistry." Vol. III., part 6.

A valued addition to the Society's property is the bronze bust of the late Dr. R. Angus Smith, F.R.S., presented by the president, Dr. Schunck.

As recorded in the Report for 1889-90 Professor Osborne Reynolds, F.R.S., at the request of the Council, undertook the writing of a Memorial Volume on the life and work of the late Dr. James Prescott Joule. This is now complete, and has been passing through the press during the past session. The Editor reports that partly in consequence of the locking-up of type in this work, and partly owing to other circumstances over which he has had no control, there has been unusual delay in the publication of the *Memoirs and Proceedings* for the session. The Council trusts that in consideration of these circumstances the members will excuse any inconvenience which may have resulted. Two volumes will be issued to the members for this session, viz., Vol. V. of the *Memoirs and Proceedings*, and the "Memoir of James Prescott Joule," forming Vol. VI. of the *Memoirs and Proceedings.*

The number of papers presented during the session has again been satisfactory evidence of the continued activity of the Society in carrying on the work contemplated by its eminent and public-spirited founders, one hundred and ten years ago. During the session 22 papers, recording the results of original research or observation, have been read at its meetings, and of these 9, after careful consideration by the Council, have been passed for publication in full as *Memoirs*, some are still under consideration, and of the remainder abstracts have been or will be printed in the *Proceedings.*

EDMUND SALIS SCHWABE, B.A., was born November 17th, 1841, and christened in the Middleton Parish Church by the present Bishop of Chichester. He was educated at Overslade School, near Rugby, and at University College School, London. In 1858 he entered at University College, London, and took his B.A. degree at the London University, with honours in mathematics, in 1860. In 1861 he became a partner in the firm of Messrs. Salis Schwabe and Co., calico printers, of Rhodes and Manchester. In 1865 he married Sophia Jekyll, who died in 1870, leaving one daughter. He took a great interest in New College, late of London, now of Oxford, and in Owens College, Manchester; he was an auditor of the former, and contributed to the funds of both institutions. He was elected a member of the Society in 1881, but did not contribute to its *Memoirs* or *Proceedings*. He died at the Windsor Hotel, Montreal, August 4th, 1891.

Dr. WILLIAM CHARLES HENRY was at the time of his death the oldest member of the Society, having been elected on October 31st, 1828. He was the representative of a family connected with it for three generations, his grandfather, Mr. Thomas Henry, F.R.S., a native of Wrexham, who settled in Manchester as an apothecary, and subsequently achieved distinction as a chemist, besides laying the foundations of the wealth of his descendants, having been one of its founders, and, with Dr. Barnes, one of its first secretaries. The Society possesses a portrait of him. His son, William Henry, M.D., F.R.S., also for many years a member of the Society and an eminent chemist, whose bust, by Chantrey, is also in the possession of the Society, married Mary Bayley, aunt of Mr. T. B. Potter, M.P., and his son, known during his residence in Manchester as Dr. Charles Henry, was born in Manchester on March 31st, 1804. His early education was received at various schools and under various teachers, including the Rev. William Johns, Dr. Dalton, and the Rev. J. J. Taylor. In November, 1824, he matriculated at Edinburgh University, and graduated M.D. in 1827. He at one time contemplated a residence at Cambridge, but, though he was admitted to Caius College, he did not remain there long. During the winter of 1827-8 Dr. Henry was at Paris, walking hospitals and attending the lectures at the Sorbonne. On his return to England he was elected physician to the Manchester Royal Infirmary, a post he held from 1828 until May, 1835, when he resigned in order to continue his studies in the chemical laboratories on the Continent. He spent a year at Berlin, working at mineral analysis with Henry Rose, and a short time at Giessen under Liebig. He published papers on "The Physiology of the Nervous System," 1833; "A Critical and Experimental Inquiry into the Relations subsisting between Nerves and Muscles," 1831; "Remarks on the Atomic Constitution of Elastic Fluids," 1834; "Experiments on the Action of Metals in determining Gaseous Combination," 1835; and "Experiments on Gaseous Interference," 1836. His separately published books were his graduation thesis, "De Tuberculorum Origine," 1827, a "Memoir of the Very Rev. Richard Dawes, Dean of Hereford," 1867, and "Memoirs of the Life and Scientific Researches of John Dalton," issued by the Cavendish Society in 1854. Dr. Henry was one of Dalton's most intimate friends, and to him the philosopher bequeathed his scientific remains, subsequently presented to the Manchester Literary and Philosophical Society by Dr. Henry. Dr. Henry acted as Dr. Dalton's literary executor. He was elected a Fellow of the Royal Society in 1834. He was also a Fellow of the Geological and Chemical Societies, a corresponding member of the Royal Academy of Sciences at Turin, and a magistrate for Herefordshire. Dr. Henry left Manchester about half a century ago, and has since lived at Ledbury. He married, in 1832, Margaret, daughter of Mr. Thomas Allan, F.R.S., a distinguished mineralogist. He had two sons. Mrs. Henry died early in 1890, after a married life of almost 58 years. Dr. Henry himself died at his residence, Haffield, Ledbury, of influenza, on January 7th, 1892. To our *Memoirs* he contributed a paper on the "Life and Writings" of his father, read before the Society in 1837 (Vol. VI., Second Series), and a biographical notice of Peter Ewart (Vol. VII., Second Series). He was prominently associated with the movement in 1837 for providing Manchester with the white marble statue of Dalton, by Chantrey, and was the last surviving trustee of the statue. He was a liberal donor to the Society's centenary fund, out of which the house in 36, George Street was extended, and also a liberal subscriber to the fund for the white marble statue of Joule now being executed by Mr. Alfred Gilbert, A.R.A.

EMILE DE LAVELEYE was born at Bruges, April 5th,

1822. He studied at Bruges, Paris, and Ghent. In 1848 he turned his attention to the study of economics, which henceforth became his special pursuit. From 1864 until his death he held the chair of Political Economy in the University of Liége. No man ever lived with a greater absorbing capacity for facts and ideas bearing on his favourite science. An omniverous reader, and a frequent contributor to English, French, and American periodicals, he also published a French translation of the Memoirs of Sir Robert Peel, and was the author of a long series of original volumes on various subjects, several of which have been translated into English. His purely economic writings were chiefly on agriculture and the currency question; but he also published volumes on education, on free-trade, on various questions of European politics, on socialism, on the land question, on Italy and the Balkans (countries in the fortunes of which he took a very special interest), on the primitive forms of property, on forms of government, and on the democracy. The purely literary side of his nature was illustrated by translations of the Niebelungen and the Eddas, a treatise on Provençal literature, and a history of the Frankish kings. The combination of literary feeling with observant power, sharpened by his interest in economic problems, is exemplified in the volumes in which he records his impressions as a traveller in various parts of Europe. By his death it may be said that the world has lost one of its most humane economists. In his hands Political Economy was anything but a dismal science. A Liberal of the broadest type, he was prepared to become a Socialist all out if he could have satisfied himself that any form of Socialism would make the general condition of mankind better and happier. It was this spirit of sympathy which led him to urge in his earlier volumes on the agriculture of Holland, Belgium, Lombardy, and Switzerland that the personal interest of the small peasant proprietor more than counterbalanced the economy of a division of labour on a wholesale scale on large farms cultivated by hired labour. It was the same spirit which led him to exclaim, "O coton! je te maudis au nom de l'art et au nom de l'hygiène!" when commenting in his letters from Italy on the replacement of the picturesque costumes of bygone times by the monotonous uniformity of cheap machine-made fabrics. But his scientific faculties were also strong and his learning profound. He insisted on the importance of historical inquiry. Facts could not lie. By the test of the past in economics we ought to be able to detect the weaknesses of mere dogmas and increase our understanding of theories. All this explains Laveleye's unwearying advocacy of bimetallism for a quarter of a century. It cannot be doubted that his earlier inclination towards monometallism was a result of the Californian and Australian gold discoveries, which suggested that the yellow metal would become a sufficiently abundant, cheap, and elastic currency. But as he himself has told us, he had already fought under the banner of M. de Parieu, "the apostle of that grand and fruitful idea of monetary union which he had the good fortune to realize in 1865 in creating the Latin Union," and his loyalty to the ideal of a Universal Monetary Union, with the teachings of Wolowski, finally "cured" him of "unhealthy inclinations towards monometallism." Like Sir Louis Mallet, he regarded bimetallism as a necessary part of Free Trade. Before Prince Bismarck brought in his famous Tariff Bill, Laveleye predicted that unless England took measures to stop the demonetisation of silver she would witness a revival of Protectionism in Germany and throughout the world. It was from the dying hand of his master, Wolowski, that he received the message, "My strength is forsaking me, but do you continue to defend our cause, which is the truth." If he sometimes despaired of Free Trade, it was because what he regarded as the selfish prejudices of England with regard to bimetallism led him to think that the world was not yet good enough for Free Trade. Yet he had a strong English feeling. He was a member of the Royal Academy of Belgium, a corresponding member of the Institute of France, and of the Accademia dei Lincei of Rome, and had been invested with the orders of Leopold, the Legion of Honour, the Crown of Italy, Charles the Third of Spain, the Crown of Oak, St. James, Christ of Portugal, and others. He was elected an honorary member of the Manchester Literary and Philosophical Society in 1887. A few weeks before his death the rank of "Baron" was conferred on him by the King of the Belgians. He died at the Chateau de Doyon, Namur, on January 2, 1892, and an international movement has been initiated for the erection of a statue to his memory.

SIR THOMAS SOWLER was born in 1818 and died on April 4, 1891, at his residence in Victoria Park, Manchester. He was the son of Mr. Thomas Sowler, a Manchester bookseller, who established the *Manchester Courier* in 1825. On leaving the Manchester Grammar School, where he was educated, Sir Thomas, with his brother, Mr. John Sowler, who died before him, took an active part in the management of the newspaper, of which he became the sole proprietor in 1871. He took a leading part in promoting the modern Volunteer movement in Manchester from its inception, when he joined as a gunner in the Artillery Brigade, rising to the rank of lieutenant-colonel, which position he resigned in 1874. Later he was made honorary colonel, and retained that appointment until his death. He also took a prominent part in the foundation of the Manchester Free Library system. For many years he was secretary to the Manchester Natural History Society until its transference to Owens College. He held prominent positions also in connection with the promotion of music in Manchester, and with the Manchester Jubilee Exhibition of 1887. The honour of knighthood was conferred on him by Her Majesty on January 1, 1890. He was a Justice of the Peace for Manchester, and in 1866 married a daughter of the late Mr. James Yates. The Sowler family originally came from Durham, where they carried on the business of printers in the early part of last century, the old anthem books in use at Durham Cathedral up to 1845 having been printed by the great-grandfather of Sir Thomas.

JAMES NASMYTH, a notice of whose death was omitted from the report for 1890-1, was born on August 19th, 1808. He was the son of Alexander Nasmyth, the celebrated Scottish painter. In his youth he knew many of the literary men of Edinburgh, Sir Walter Scott among others. At the age of 13, he attended scientific lectures at the Edinburgh School of Arts, at the same time making model steam engines for sale. In 1827, he made for the Scottish Society of Arts a road steam carriage. At the age of 21 he went to London, and was engaged by Henry Maudsley, the engineer, as his private assistant. He received as wages, 10s. per week. He made the acquaintanceship of Henry Brougham, a friend of his father's, who offered to introduce him to men of science in London. Nasmyth replied that the man he most wished to know was Michael Faraday. Brougham accordingly gave him a letter of introduction. Nasmyth says in his "Autobiography," "Not long after Faraday called and found me working beside Maudsley. He expressed himself delighted to find me in so enviable position. This most pleasant and memorable meeting with the great philosopher initiated a friendship which I had the good fortune to continue to the close of his life." Nasmyth left Maudsley's in 1831, and returned to Edinburgh, where he spent three years in making the engineer's tools for his future foundry. At the age of 26 he began business for himself on a flat in Dale Street, Manchester, with a capital of £63, being encouraged and supported in his enterprise by the Brothers Grant, then residing in Mosley Street, Manchester, the originals of Dickens's Cheeryble Bros. Owing to a difference with the tenant below him, he left this flat at the end of two years, and removed to Patricroft, where he built the Bridgewater Foundry. In 1839 he received an order for forging the paddle shaft for the steamship *Great Britain*, but as no forge hammer then in use was capable of forging a shaft 30in. in diameter, he invented the steam hammer to overcome the difficulty. He married, in 1840, Anne Hartrop, daughter of the manager of some ironworks near Barnsley, belonging to Earl Fitzwilliam. In 1842 he made some steam hammers for the French Government, and travelled through France and Italy. In 1843 he visited St. Petersburg, Stockholm, and Dannemora. He used to transact his business in the morning and devote the afternoon to seeing the country. In 1843 he applied the principle of the steam hammer to a pile driver, which is so ingeniously arranged that the whole weight of the machine, in addition to the force of the blow, acts on the top of the pile. In addition to mechanical engineering, he also took a great interest in astronomy. He made for himself a 20-inch reflecting telescope, with which he carried out some interesting researches on the moon, and in June, 1860, discovered the willow-leaf pattern on the sun's surface. He gave a lecture on the moon before the British Association at Edinburgh in 1850. In 1856 he retired from business. He became a member of the Society on August 11th, 1837, and in 1862 was elected an honorary member, on his removal from Manchester. He spent the last 35 years of his life at Penshurst, in Kent, and died of old age at Bailey's Hotel, South Kensington, on May 7th, 1890. To the Society's *Memoirs*, he contributed the following:—"Remarks on the origin of the Babylonian or Arrow-headed character," in 1842 [Vol. IV., 2nd series]; "On the structure of the luminous envelope of the sun," in 1861 [Vol. I., 3rd series]; "On the planet Mars," in 1863 [Vol. II., 3rd series]; and "On War Rockets," in 1868 [Vol. IV., 3rd series]. His models of Lunar Craters, prepared in plaster from his own telescopic observations, photographed and engraved, are still the finest illustrations of the moon's surface.

The Society has this year to deplore the loss in the same month of the two most distinguished English Astronomers of the age. GEORGE BIDDELL AIRY was born at Alnwick on July 27th, 1801, and graduated at Cambridge as Senior Wrangler in 1823. Although he partially maintained himself already as an undergraduate by giving private lessons, his scientific work was begun before he took his degree, and he was appointed Lucasian Professor of Mathematics in 1826, and transferred to the Plumian Professorship of Astronomy in 1828. In a limited space it is impossible to give an adequate account of Airy's accomplishments, but it must not pass without notice that he was the first in England to treat astronomy as a high branch of science, and to enforce its practice in this sense in the Observatory at Cambridge. In his report on the progress of astronomy for the British Association in 1832, he says:—"In those parts of astronomy, requiring only method and judgment, with very little science in the persons employed, we have done much. . . . Our principal progress has been made in the lowest parts of astronomy, while to the higher branches of the science we have not added anything. . . . An observer conceives he has done everything when he has made an observation." In this Airy made a radical change, both at Cambridge and afterwards at Greenwich, when he became Astronomer

Royal in 1835, but the details must be sought elsewhere. In mathematics Airy was a prolific, clear and profound writer. We are now in some danger of underrating his work by comparing it with that of the succeeding generation of brilliant men, with whom his great age made him contemporary; but it is probable that later generations will recognise him as the forerunner of the men who have revolutionised mathematical science in this century. An accidental fall at his country house resulted in internal complications, which necessitated a severe surgical operation. From this he never completely rallied, and he died on January 2nd, 1892, in his ninety-first year. Sir George Airy was elected an honorary member of the Society on April 18th, 1843.

JOHN COUCH ADAMS was born at Lidcot, near Launceston, on June 5th, 1819, and graduated at Cambridge as Senior Wrangler in 1843. Already, in 1841, while still an undergraduate, Adams had determined to attempt the explanation of the irregularities of the planet Uranus in its path, irregularities which were not accounted for by the attraction of known planets. The story of the successful, simultaneous, and independent solution of this problem by Adams and Leverrier, and the consequent discovery of the planet Neptune, is well known, and need not be retold here. This discovery has, by its pre-eminence, swamped in the general mind the steady and unremitting scientific work which only terminated with his death. For one year Adams held the Professorship of Mathematics at St. Andrews, but returned to Cambridge in 1859 as Lowndean Professor of Astronomy and Geometry. As professor, his lectures were prepared and written with extraordinary care, which indeed distinguished all his work. Besides the works which he published on the Theory of the Moon and of the November Meteors, which are perhaps the best known, Adams was

Director of the Observatory at Cambridge from 1861 to his death, and work of the greatest value appears in the Annual Reports. He was never very anxious to publish, and an impression exists that there is much valuable work ready for the printer's hands. Adams was elected an honorary member of this Society on April 20th, 1847. On Airy's retirement, in 1881, the post of Astronomer Royal was offered to him, but declined on the score of age. For a long time he had been in failing health, and unable to do his usual work, and his death, January 21st, 1892, was not unexpected.

By the death of HERMANN KOPP the Society has also lost one of its most illustrious honorary members. Born in 1817, he entered upon his scientific studies at Heidelberg in his eighteenth year, devoting himself especially to chemistry and physics. Three years later he passed over to Marburg and took his degree, with a dissertation entitled, "De oxydorum densitatis calculo reperiendæ modo." Soon after this we find him engaged at Giessen, under Liebig, carrying out investigations in the borderland of chemistry and physics, whilst interesting himself with kindred problems in meteorology and crystallography. The dissertation mentioned above affords, however, an indication of the main direction of his thought, and though occasionally drawn into other channels he pursued with great eagerness and diligence the study of the relations between the physical and chemical properties of bodies. His observations on the boiling points of liquids, on the expansion of liquids by heat, on the changes of volume during the passage from the solid to the liquid condition, on the capacity for heat and the connection which he showed to exist between such properties and the chemical nature of the substance, rank amongst the most important generalisations in the whole region of chemistry. And the fact that by his 30th year he had completed his history of chemistry, stamps him at once as a remarkable man. The value of his work and writings was soon recognised; he became in succession extraordinary and (when Liebig went to Munich) ordinary professor at Giessen. Twenty years afterwards (1863) he was appointed professor at Heidelberg, where he remained to the last. The agreeable surroundings of Heidelberg, and the daily intercourse with such men as Bunsen, Kirchkoff, Helmholtz, and Kuno Fischer were more to him than the further advancements of position which were repeatedly placed in his way. "Schon Bunsen allein hält mich in Heidelberg fest" was his sufficient reply to all such temptations, and with Bunsen he was almost daily to be seen at such times as he allowed himself to be released from his lecture room or his study. His experimental researches, especially in the earlier years, were so extensive that it is difficult to conceive how he found the opportunity for any considerable literary work. We need only give the titles of the more important of his writings, however, to indicate his immense activity in this direction :—

(1) "Geschichte der Chemie," 4 vols., 1843-1847 ;

(2) "Beiträge zur Geschichte der Chemie," 1869-75 ;
"Entwickelung der Chemie in der neueren Zeit," 1873;
"Die Alchemie in älterer und neuerer Zeit."

These latter works may be regarded as supplementary to the first, and were meant to furnish the basis of a history of Chemistry on even a more complete and exhaustive scale than the original work.

(3) "Einleitung in die Krystallographie."

(4) Coadjutator from 1849 in the "Jahresbericht der Chemie," and from 1851 in Liebig's Annalen, and in Graham Otto's Physical and Theoretical Chemistry.

(5) Several pamphlets of very great interest, amongst which are :—

"Sonst und Jetzt in der Chemie."

"Aurea catena Homeri," a present to Liebig on his 80th birthday.

"Aus der Molecularwelt" a present to Bunsen on his 70th birthday.

As an investigator Kopp carries us forward far in advance of his time, and places before us themes of the highest interest in the chemistry of to-day; and as a writer he carries us backward to the very dawn of chemistry and alike, throughout all his work, with the same characteristic clearness and accuracy of detail. Beloved by his colleagues, he was none the less so by those who had the privilege to be reckoned his students, amongst whom unvarying kindliness and great-hearted humility will ever be associated with the name of Kopp.

OLIVER HEYWOOD was born on the 9th of September, 1825. Though not himself a literary or scientific worker he was closely connected with the Literary and Philosophical Society, being the grandson of its founder, Dr. Percival, and belonging to a family several of whose members held the office of Treasurer between the years 1791 and 1850. He was educated for some time at St. Domingo House, Liverpool, by Mr. Carl Volker, several of his school-fellows at this establishment eventually becoming prominent public men; and subsequently at Eton. On leaving school he entered upon business life in the bank bearing his family name, and remained in this capacity until 1874, when the business was transferred to the Manchester and Salford Bank, of which he became a director. In 1888 he was made High Sheriff of Lancashire, and the freedom of the City of Manchester was conferred upon him. It is for his generous and active support of all educational and philanthropic causes that he will be best remembered. He was for many years president of the Manchester Mechanics' Institute, and bore a prominent part in the transactions by which it was converted into the Technical School. In 1849 he was nominated among the trustees of the Manchester Grammar School, and for many years he continued to serve its interests, contributing largely to the improvement of its educational apparatus, to the erection of new buildings and to the increasing of its facilities for physical training. In 1870 he became a member of the first Manchester School board: he did not, however, continue on the subsequent Boards. The restoration and preservation of Chetham Hospital were due to his benevolence. But perhaps his greatest services to education were those in connection with Owens College, to which he remained a constant and liberal friend, and of which he was a life governor. He was elected a member of the Society on March 22nd, 1864, and died at his residence, Claremont, Pendleton, on March 17th, 1892. He was a liberal donor to the Society's Centenary Fund, and also to the Joule Memorial Fund, of which latter he was the treasurer.

C. FERDINAND VON RÖMER was born at Hildersheim, in Hanover, on January 5, 1818. His father was a Councillor of the Hanover High Court of Justice. He received his early education in the Evangelical Gymnasium of Hildersheim, and subsequently studied at Göttingen, Heidelberg, and Berlin, receiving his degree of Doctor of Philosophy at the University of Berlin in 1842. While studying at Berlin, he engaged in investigations on the older rocks of Western Germany, and in 1844 published the results. In 1845 he proceeded to America and engaged specially in the investigation of the Palæozoic and Cretaceous rocks of Texas, publishing the results in papers which give a comprehensive view of the geology of Texas after his return to Europe in 1847 and while engaged at Bonn as a private tutor. In 1855 he was appointed Professor of Geology, Palæontology, and Mineralogy in the University of Breslau. Thenceforth his original researches were mainly on the geology of Silesia, on which subject he published three quarto volumes in 1870, for which he received the honour of knighthood and the appointment of Geheimer Bergrath of Silesia. He also made tours in England, Belgium, Poland, Austria, Sweden, Norway, Russia, Turkey, and Spain. He died at Breslau on December 14, 1891. The special feature of Römer's career was the wide range of his work in geology and palæontology. He gave attention to nearly every system, from the earliest to the latest rocks, but his most important contributions to science are considered to be those relating to the Devonian system, his investigations into which ranged from Devonshire to Constantinople. His writings on palæontology were extensive and important, and he added many new genera to this science. He also contributed to the literature of mineralogy. He was elected an honorary member of the Society on April 19, 1887. A movement has been started for a memorial of him in the form of a marble bust, to be placed in the Mineralogical Museum at Breslau.

MANCHESTER LITERARY AND

Charles Bailey, Treasurer, in Account with the Society,

Dr.

Statement of the Account.

		1891-2.							1890-91.			
1892—March 31st:	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.
To Cash in hand, 1st April, 1891				353	0	3				277	5	
To Members' Contributions :—												
Old Members, 1889-90, 9 Subscriptions at 42s.	13	18	0									
,, 1890-91, 25 ,, ,, ...	52	10	0									
,, 1891-92, 92 ,, ,, ...	193	4	0									
,, 1892-93, 3 ,, ,, ...	6	6	0									
New Members, 1889-90, 1 Admission Fees at 42s. ..	2	2	0									
,, 1890-91, 1 ,, ,, ,, ..	2	2	0									
,, 1891-92, 2 ,, ,, ,, ..	4	4	0									
,, 1889-90, 1 Subscription ,, ..	2	2	0									
,, 1890-91, 2 ,, ,, ..	4	4	0									
,, 1891-92, 4 , ,, ..	8	8	0									
				294	0	0				263	11	
To Library Subscriptions :—												
One Natural History Associate, 1891-92, at 10s.				0	10	0				0	10	
To Contributions from Sections :—												
Microscopical and Natural History Section, 1890-91 ..	5	5	0				0	0	0			
,, ,, ,, ,, 1891-92 ..	5	5	0				0	0	0			
Physical and Mathematical Section 1890-91 ..	2	2	0				0	0	0			
				12	12	0				0	0	
To Use of the Society's Rooms :—												
Manchester Geological Society to 31st March, 1891 ..	30	0	0				0	0	0			
,, ,, ,, ,, 1892 ..	30	0	0				0	0	0			
Manchester Medical Society to 30th September, 1891 ..	25	0	0				25	0	0			
Manchester Photographic Society to 30th Sept., 1891 ..	30	0	0				25	0	0			
Manchester Scientific Students' Asso. to Nov., 1891 ..	6	0	0				9	0	0			
				121	0	0				59	0	
To Sales of the Society's Publications, 1891-92				2	6	5				2	0	
To Natural History Fund, 1891-2 :—												
Dividends on £1225, Great Western Railway Co. Stock ..				59	14	4				59	14	
To Bank Interest, less Bank Postages, 1891-92				4	12	10				6	18	
To Joule Memorial Committee for Postages, &c.				0	0	0				5	1	1
To Donation: Rev. Thomas P. Kirkman, M.A...				5	0	0				0	0	
,, Mr. Wm. Brockbank, F.G.S., &c.				10	0	0				0	0	
				£862	15	10				£674	0	11

1892.—April 1. To Cash in Williams, Deacon, Manchester and Salford Bank, Limited £171 0 9

PHILOSOPHICAL SOCIETY.

from 1st April, 1891, to 31st March, 1892, with a Comparative for the Session 1890-91.

Cr.

	1891-92.		1890-91.	
1892—March 31st :—	£ s. d.	£ s. d.	£ s. d.	£ s. d.
By Charges on Property :—				
Chief Rent (Income Tax deducted)	12 12 0		12 12 0	
Income Tax on Chief Rent	0 6 3		0 6 3	
Insurance against Fire	13 17 6		13 17 6	
Repairs to Building, Gas, and Furniture	21 17 1		4 8 2	
New Book-shelves in Cloak Room	5 12 0	54 4 10	0 0 0	31 3 11
By House Expenditure :—				
Coal, Gas, Water, Wood, &c.	34 12 2		34 6 5	
Tea, Coffee, &c., at Meetings	11 7 8		12 7 1	
Cleaning, Cleaning Carpets, Sweeping Chimneys, &c.	12 15 11	58 15 9	5 9 1	52 2 7
By Administrative Charges :—				
Clerk and Housekeeper	62 8 0		62 8 0	
Postages and Carriage of Parcels	28 18 8		26 8 6	
Stationery, Receipts, and Engrossing	2 17 9		6 2 4	
Printing Circulars, Reports, and Lists of Members	21 4 6		0 0 0	
Distributing 'Memoirs,' Address Wrappers, &c.	7 17 9	123 6 8	0 0 0	94 18 10
By Publishing :—				
Honorarium for editing the Society's publications	50 0 0		50 0 0	
Printing 'Memoirs and Proceedings' from 14th September, 1889, to 21st August, 1891	225 1 9		0 0 0	
Binding 'Memoirs and Proceedings'	19 10 0		0 0 0	
Wood Engraving and Lithography	24 12 7	319 4 4	30 2 6	80 2 6
By Library :—				
Binding Books in Library	1 13 0		0 0 0	
Books and Periodicals	30 14 8		19 15 5	
Preparing New Catalogue and re-arranging Library (on a/c.)	40 0 0		0 0 0	
Assistant in Library	15 0 0		10 0 0	
Catalogue Boxes, Slips, &c.	2 3 0		0 0 0	
Palæontographical Society for the years 1891 and 1892	2 2 0		0 0 0	
Ray Society for the years 1891 and 1892	2 2 0		0 0 0	
Zoological Record, Vol. 27	1 0 0	94 14 8	1 0 0	30 15 5
By Natural History Fund :—				
Natural History Books and Periodicals	18 6 7		21 18 11	
Grant to Microscopical and Natural History Section	0 0 0		0 0 0	
Plates for Natural History Papers in 'Memoirs'	23 2 3	41 8 10	9 18 6	31 17 5
By Balance 31st March, 1892		171 0 9		353 0 3
		£862 15 10		£674 0 11

NOTE.—The Accounts (of which the above is a summary) have been audited, and found correct, 12th April, 1892, by Mr. Samuel Okell, F.R.A.S., and Mr. Charles O'Neill, F.C.S., &c.

Summary Balance Sheet, Session 1891-92.

		£ s. d.	£ s. d.
General Account :—			
Balance in favour of this Account, 1st April, 1891		114 2 6	
Receipts during the Session, 1891-92 :—			
Subscriptions, Admission Fees, Sections, &c.	£307 2 0		
Donations from members	15 0 0		
Use of the Society's rooms	121 0 0		
Sale of the Society's publications	2 6 5		
Bank Interest	4 12 10		
		450 1 3	
		564 3 9	
Expenditure during the Session, 1891-92 :—			
Charges on Property	54 4 10		
House Expenditure	58 15 9		
Administrative Charges	123 6 8		
Publishing	319 4 4		
Library	94 14 8		
		650 6 3	
Balance against this Account, 31st March, 1892			86 2 6
Compounders' Fund :—			
Balance in favour of this Account, 1st April, 1891		177 10 0	
Balance in favour of this Account, 31st March, 1892			177 10 0
Natural History Fund :—			
Balance in favour of this Account, 1st April, 1891	£61 7 9		
Dividends on Great Western Railway Co.'s Stock during the Session 1891-92	59 14 4		
		121 2 1	
Expenditure during the Session 1891-92 :—			
Natural History Books and Periodicals	£18 6 7		
Drawing, engraving, and printing plates on Natural History subjects	23 2 3		
		41 8 10	
Balance in favour of this Account, 31st March, 1892			79 13 3
			257 3 3
Less balance, as above, against the General Account			86 2 6
Cash in Williams, Deacon, and Manchester and Salford Bank, Limited, 31st March, 1892			£171 0 9

Annual Report of the Council of the Microscopical and Natural History Section.

The meetings have been held as usual, monthly, throughout the session, and the attendance and interest have been fully maintained. Considering the small number of members and associates this is encouraging, but the Council feels that if the section is to be kept up to its old standard, there must be an infusion of new blood, and, therefore, appeals to all to make an effort to make known the advantages which the section can offer to all naturalists in this neighbourhood, so as to induce them to enrol themselves as members or associates.

During this session four members and two associates have resigned, one member has died, and one member and one associate have been elected.

Amongst those members who have resigned is the section's former president, Professor W. C. WILLIAMSON, LL.D., F.R.S. He has left the neighbourhood and gone to reside in London, and, therefore, is unable any longer to attend the meetings. One of the earliest members of the section, he has always been its good friend, and his contributions to its discussions have been always highly appreciated. He will be missed very much, but the Council hopes that his health may be spared to him to enable him to continue his valuable scientific researches.

It will be noticed from the statement of accounts that a number of valuable books are still being added to the library, such as the "British Hieracia," Fowler's "Coleoptera," and the *Journal de Conchyliologie.* The Library also now contains a complete set of the "Challenger Reports." Various scientific periodicals are regularly taken in, and, from time to time, as occasion offers, other important works will no doubt be purchased. Students will do well to acquaint themselves with the valuable works of reference now on the shelves, and to avail themselves of them by joining the section.

The following is a list of members and associates of the section :—

Members :—J. J. ASHWORTH, CHARLES BAILEY, F.L.S., JOHN BOYD, HENRY BROGDEN, ALFRED BROWN, M.D., SAMUEL COTTAM, F.R.A.S., EDWARD COWARD, R. ELLIS CUNLIFFE, R. D. DARBISHIRE, B.A., F.G.S., HASTINGS C. DENT, F.L.S., WILLIAM KING DEANE, FREDERICK JAMES FARADAY, F.L.S., EDWARD HALKYARD, CHARLES JAMES HEYWOOD, ALEX. HODGKINSON, B.Sc., M.B., Sir HENRY HOYLE HOWORTH, F.S.A., M.P., A. MILNES MARSHALL, M.A., M.D., D.Sc., F.R.S., J. COSMO MELVILL, M.A., F.L.S., J. E. MORGAN, M.D., M.A., FRANCIS NICHOLSON, F.Z.S., J. F. W. TATHAM, M.A., M.D.

Associates :—W. BLACKBURN, F.R.M.S., E. J. BLES, M.B., PETER CAMERON, F.E.S., H. C. CHADWICK, E. PYEMONT-COLLETT, F.E.S., PETER CUNLIFFE, F. R. CURTIS, H. L. EARL, B.A., JOHN RAY HARDY, ARNOLD U. HENN, HENRY HYDE, LESLIE JONES, M.D., H. L. KNOOP, THOMAS ROGERS, W. R. SCOWCROFT, THEODORE SINGTON, GEORGE NASH SKIPP, MARK STIRRUP, F.G.S., WM. LADD TORRANCE, EDWARD WARD, F.R.M.S., R. WHEELER.

Mark Stirrup, Treasurer, in account with the Microscopical and Natural History Section of the Manchester Literary and Philosophical Society.

Dr. *Session 1891-92.* **Cr.**

Date		£	s.	d.
1891.				
April.	To Balance in Manchester and Salford Bank (St. Ann's St. Branch)	104	9	7
Dec. 20.	To Bank Interest	1	9	10
	,, Subscriptions and Arrears from April 14th, 1891, to April 7th, 1892..........	18	10	0
		£124	9	5
	To Balance to Credit of Section........	102	4	3

Date		£	s.	d.
1891.				
April 28.	By G. F. C. Dawson, Returned Subscription, overpaid ..	0	10	0
July 3.	,, F. J. Hanbury, "British Hieracia." Parts 5—8....	1	4	0
Aug. 14.	,, J. E. Cornish, "Fowler's Coleoptera," Parts 48—49, and "Naturalist," April-June	0	9	7
Nov. 12.	,, West, Newman, and Co., "Journal of Botany," 1891....................	0	12	0
1892.				
Jan. 19.	,, Chas. Simms and Co., Circulars and Cards	1	10	6
,, 21.	,, A. Brothers and Co., 100 Prints of Plate, Cameron	0	15	0
Feb. 5.	,, H. Crosse, "Journal de Conchyliologie," 1891—1892, 2 years............	1	9	3
,, 12.	,, D. Douglas, "Annals of Scot. Nat. Hist.," 1892..	0	7	6
,, 26.	,, J. E. Cornish, "Challenger Reports," "Deep Sea Deposits," and "Coleoptera," 50—53	2	13	5
,, ,,	,, M. C. Cooke, "British Desmids"	2	0	0
Mar. 22.	,, Sectional Subscription	5	5	0
April 1.	,, C. Hargreaves— Teas ....2 17 4 Postages, &c. ..1 3 1	4	0	5
4.	,, C. Simms & Co., Receipt Book and Circulars	1	4	0
5.	,, J. E. Cornish, "Naturalist," July to March	0	4	6
7.	,, Cash in hands of Treasurer	1	14	3
	By Balance in Manchester and Salford Bank (St. Ann's Street)	100	10	0
		£124	9	5

April 7th, 1892,
Examined and found correct,
(*Signed*) HENRY HYDE,
W. R. SCOWCROFT.

The Microscopical and Natural History Section of the Manchester Literary and Philosophical Society in account with the Parent Society for Grant from the Natural History Fund.

Dr. *April 16th, 1891, to April 7th, 1892.* **Cr.**

Date		£	s.	d.
1891.				
April 16.	To Balance of Grant unexpended	33	16	1
		£33	16	1
	To Balance of Grant unexpended	25	6	1

Date		£	s.	d.
1891.				
July 3.	By "British Hieracia," Parts 5—8	1	4	0
Aug. 14.	,, "Fowler's Coleoptera," Parts 48—53	1	5	0
1892.				
Feb. 5.	,, "Journal de Conchyliologie;" 1891—1892	1	9	3
26.	,, Challenger Reports—"Deep Sea Deposits"..	1	16	9
,,	,, Cooke's "British Desmids"	2	0	0
Jan. 21.	,, A. Brothers and Co., 100 Prints	0	15	0
	,, Balance	25	6	1
		£33	16	1

O

THE COUNCIL AND MEMBERS.

APRIL 21, 1892.

President.

ARTHUR SCHUSTER, PH.D., F.R.S., F.R.A.S.

Vice-Presidents.

EDWARD SCHUNCK, PH.D., F.R.S., F.C.S.
OSBORNE REYNOLDS, M.A., LL.D. F.R.S.
JAMES BOTTOMLEY, B.A., D.SC., F.C.S.
JAMES COSMO MELVILL, M.A., F.L.S.

Secretaries.

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

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CHARLES BAILEY, F.L.S.

Librarian.

FRANCIS NICHOLSON, F.Z.S.

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JOHN BOYD.
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ALEXANDER HODGKINSON, M.B., B.SC.
J. W. F. TATHAM, B.A., M.D.
Alderman JOSEPH THOMPSON.
CHARLES O'NEILL, F.C.S.

Honorary Members.

Date of Election.	
1892, April 26.	Abney, Capt. W. de, R.E., F.R.S. *S. Kensington.*
1892, April 26.	Amagat, E. F. *Paris.*
1887, April 19.	Armstrong, Sir Wm. George, C.B., D.C.L., LL.D. *Newcastle-on-Tyne.*
1892, April 26.	Ascherson, Paul F. Aug. *Berlin.*
1892, April 26.	Baeyer, Adolf von, Professor of Chemistry. *Munich.*
1886, Feb. 9.	Baker, Sir Benjamin, LL.D., M. Inst C.E. 2, *Queen's Square Place, Westminster, S.W.*
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.*
1892, April 26.	Boltzmann, Ludwig, Professor of Physics. *Munich.*
1892, April 26.	Brioschi, Francesco. *Naples.*
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 at the Univ. of Heidelberg. *Heidelberg.*
1892, April 26.	Candolle, Alphonse de, Professor of Botany. *Geneva.*
1888, April 17.	Cannizzaro, S., Prof. of Chemistry. *University of Rome.*
1889, April 30.	Carruthers, William, Pres. L.S., F.R.S. Keeper of Botanical Dept., British Museum.
1859, Jan. 25.	Cayley, Arthur, M.A., LL.D., D.C.L., V.P.R.A.S., F.C.P.S., Sadlerian Prof. of Pure Maths. in the Univ. of Cambridge, Cor. Mem. Inst. Fr. (Acad. Sci.), &c. *Garden House, Cambridge.*
1886, Oct. 30.	Clifton, Robert Bellamy, M.A., F.R.S., F.R.A.S., Prof. of Natural Philosophy, Oxford. *New Museum, Oxford.*
1899, 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. *Ecole Polytechnique, Paris.*
1892, April 26.	Curtius, Theodor, Professor of Chemistry. *Kiel.*
1892, April 26.	Darboux, Gaston, Professor to the Faculty of Sciences. *Paris.*
1886, Feb. 9.	Dawson, Sir John William, C.M.G., M.A., F.R.S., LL.D., F.G.S. *McGill College, Montreal.*
1888, April 17.	Dewalque, Gustave, Professor of Geology. *University of Liège.*
1892, April 26.	Dohrn, Dr. Anton, Zoological Station. *Naples.*
1892, April 26.	Dyer, W. T. Thisleton, F.R.S., Director, Botanical Gardens. *Kew.*

Date of Election	
1892, April 26.	Edison, Thomas Alva, Electrician. *Menlo Park, New York.*
1889, April 30.	Farlow, W. G., Professor of Botany. *Harvard College, Cambridge, Mass., U.S.A.*
1889, April 30.	Flower, William Henry, C.B., LL.D., F.R.S. Director of Nat. Hist. Dept., British Museum.
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., Professor to the Faculty of Sciences. *Paris.*
1892, April 26.	Fürbringer, Prof. Max. *Amsterdam.*
1892, April 26.	Gegenbauer, Carl, Professor of Anatomy. *Heidelberg.*
1892, April 26.	Gibbs, Professor F. W. *Yale, U.S.A.*
1886, Feb. 9.	Helmholtz, Geheimrath Herman von, LL.D., For. Mem. R.S. Präsident der Physikalisch-technischen Reichsanstalt. *Berlin.*
1889, April 30.	Hertz, H., Professor of Physics. *Bonn.*
1892, April 26.	Hermite, Ch. *Paris.*
1892, April 26.	Hill, W. G. *Washington.*
1848, Jan. 25.	Hind, John Russell, LL.D., F.R.S., F.R.A.S., Superintendent of the Nautical Almanac. Cor. Mem. Inst. Fr. (Acad. Sci.) 3, *Cambridge Park Gardens, Twickenham.*
1881, April 17.	Hittorf, Johann Wilhelm, Professor of Physics. *Polytechnicum, Münster.*
1866, Jan. 23.	Hofman, A.W., Ph.D., M.D., LL D., F.R.S., Cor. Mem. Inst. Fr. (Acad. Sci.), &c. 10, *Dorotheenstrasse, Berlin.*
1892, April 26.	Hoff, J. Van't, Professor of Chemistry. *Amsterdam.*
1892, April 26.	Hooker, Sir Joseph D., F.R.S. *Sunningdale.*
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.*
1872, April 30.	Huxley, Thomas Henry, M.D., Ph.D., LL.D., D.C.L., P.P.R.S., Hon. Prof. of Biology in Royal School of Mines, Cor. Mem. Inst. Fr. (Acad. Sci.), &c. 4, *Marlborough Place, Abbey Road, N.W.*
1852, Oct. 16.	Kirkman, Rev. Thomas Penyngton, M.A., F.R.S., *Croft Rectory, near Warrington.*
1892, April 26.	Klein, Professor Felix. *Göttingen.*
1892, April 26.	Kundt, August, Professor of Physics. *Berlin.*
1892, April 26.	Ladenburg, A., Professor of Chemistry. *Breslau.*
1887, April 19.	Langley Prof. S. P., *Smithsonian Institution, Washington, U.S.*

Date of Election.	
1892, April 26.	Laubach, Graf von Solms, Professor of Botany. *Strassburg.*
1892, April 26.	Liebermann, C., Professor of Chemistry. *Berlin.*
1887, April 19.	Lockyer, Norman, F.R.S., Cor. 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, E.C.*
1892, April 26.	Ludwig, Carl, Professor of Physiology. *Leipsic.*
1892, April 26.	Marignac, J. C. de. *Geneva.*
1892, April 26.	Marshall, Alfred, Professor of Political Economy. *Cambridge.*
1892, April 26.	Mascart, E., Professor at the Collége de France. *Paris.*
1889, April 30.	Mendeléeff, D., Professor of Chemistry. *St. Petersburg.*
1889, April 30.	Meyer, Lothar, Professor of Chemistry. *Tübingen.*
1892, April 26.	Meyer, Victor, Professor of Chemistry. *Heidelberg.*
1892, April 26.	Moissan, H., Professor at the École Supérieure de Pharmacie. *Paris.*
1887, April 19.	Newcomb, Prof. Simon, For. Mem. R.S. *Johns Hopkins University, Baltimore, U.S.*
1844, April 30.	Owen, Sir Richard, K.C.B., M.D., LL.D., F.R.S., F.L.S., F.G.S., V.P.Z.S., F.R.C.S., Ireland, Hon. M.R.S.E., For. Assoc. Inst. Fr. (Acad. Sci.), &c. *Sheen Lodge, Richmond.*
1866, Feb. 9.	Pasteur, Louis, For. Mem. R.S., Membre de l'Institut. *Paris.*
1892, April 26.	Perkin, W. H., F.R.S. *Sudbury, Harrow.*
1851, April 29.	Playfair, Rt. Hon. Sir Lyon, K.C.B., LL.D., Ph.D., F.R.S., F.G.S., M.P., V.P.C.S., &c. 68, *Onslow Gardens, London, S.W.*
1892, April 26.	Poincaré, H., Professor to the Faculty of Sciences. *Paris.*
1866, Jan. 23.	Prestwich, Joseph, F.R.S., F.G.S., Cor. Mem. Inst. Fr. (Acad. Sci.) *Shoreham, near Sevenoaks.*
1892, April 26.	Quincke, G. H., Prof. of Physics. *Heidelberg.*
1866, Jan. 23.	Ramsay, Sir Andrew Crombie, LL.D., F.R.S., F.G.S., 15, *Cromwell Crescent, South Kensington, London.*
1892, April 26.	Raoult, F., Professor to the Faculty of Sciences. *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.*
1892, April 26.	Reymond, Emil du Bois, Professor of Physiology. *Berlin.*
1889, April 30.	Résal, Professor Henri, Membre de l'Institut. *Ecole Polytechnique, Paris.*

Date of Election.	
1889, April 30.	Roscher, Dr. Wilhelm, K. Geheimer Rath, and Professor of Political Economy. *Leipsic.*
1889, April 30.	Routh, Edward John, Sc.D., F.R.S. *Newnham Cottage, Cambridge.*
1872, April 30.	Sachs, Julius von, Ph.D. *Wurzburg.*
1889, April 30.	Salmon, Revd. 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.*
1892, April 26.	Saporta, the Marquis de. *Aix en-Provence.*
1892, April 26.	Sharpe, R. Bowdler.
1889, April 30.	Siemens, Dr. Ernest Werner von, Geheimer Rath. 94, *Markgrafenstrasse, Berlin.*
1869, Dec. 14.	Sorby, Henry Clifton, LL.D., F.R.S., F.G.S., &c. *Broomfield, Sheffield.*
1851, April 29.	Stokes, Sir George Gabriel, Bart., M.A., M.P., LL.D., D.C.L., Pres. R.S., Lucasian Professor of Mathem. Univ. Cambridge, F.C.P.S., Cor. Mem. Inst. Fr. (Acad. Sci.), &c. *Lensfield Cottage, Cambridge.*
1886, Feb. 9.	Strasburger, Professor. *Bonn.*
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.*
1851, April 22.	Thomson, Sir William, M.A., D.C.L., LL.D., F.R.S.S. L. and E. Prof. of Nat Phil. in Univ. of Glasgow. For Assoc. Inst. Fr. (Acad. Sci.), 2, *College, Glasgow.*
1872, April 30.	Trécul, A., Member of the Institute of France. *Paris.*
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.*
1868, April 28.	Tyndall, John, LL.D., M.D., D.C.L., Ph.D., F.R.S., F.C.S. *Hind Head House, Haslemere, London, W.*
1892, April 26.	Walker, General Francis A., Professor of Political Economy. *Boston, U.S.A.*
1892, April 26.	Wiedemann, G., Prof. of Physics. *Liepsic.*
1889, April 30.	Williamson, Alexander William, Ph.D., LL.D., For. Sec. R.S., Corr. Mem. Inst. Fr. (Acad. Sci.). *High Pitfold, Shottermill, Haslemere.*
1886, Feb. 9.	Young, Prof. C. A. *Princeton College, N.J., U.S.*
1888, April 17.	Zirkel, Ferdinand, Professor of Mineralogy. *University of Leipsic.*

Corresponding Members.

Date of Election.	
1860, April 17.	Ainsworth, Thomas. *Cleator Mills, near Egremont, Whitehaven.*
1870, March 8.	Cockle, The Hon. Sir James, M.A., F.R.S., F.R.A.S., F.C.P.S. 12, *St. Stephen's Road, Bayswater, London.*
1866, Jan. 23.	De Caligny, Anatole, Marquis, Corres. Mem. Acadd, Sc. Turin and Caen. Socc. Agr. Lyons, Sci. Cherbourg, Liège, &c.
1861, April 2.	Durand-Fardel, Max, M.D., Chev. of the Legion of Honour, &c. 36, *Rue de Lille, Paris.*
1849, April 17.	Girardin, J., Off. Legion of Honour, Corr. Mem. Instit. France, &c. *Lille.*
1850, April 30.	Harley, Rev. Robert, M.A., F.R.S., 4, *Wellington Square, Oxford.*
1882, Nov. 14.	Herford, Rev. Brooke. *Arlington Street, Boston, U.S.*
1862, Jan. 7.	Lancia di Brolo, Frederico, Duc, Inspector of Studies, &c. *Palermo.*
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.*
1869, Feb. 5.	Schönfield, Edward, Ph.D., Director of the Mannheim Observatory.

Ordinary Members.

Date of Election.	
1873, Jan. 7.	Allmann, Julius, 70, *Deansgate.*
1870, Dec. 13.	Angell, John, F.C.S., F.I.C. 6, *Beacons Field, Derby Road, Fallowfield, Manchester.*
1861, Jan. 22.	Anson, Ven. Archd. George Henry Greville, M.A., *Birch Rectory, Rusholme.*
1885, Nov. 17.	Armstrong, Thomas, F.R.M.S. *Brookfield, Urmston; Deansgate.*
1837, Aug. 11.	Ashton, Thomas. 36, *Charlotte Street.*
1881, Nov. 1.	Ashton, Thomas Gair, M.A., 36, *Charlotte Street.*
1887, Nov. 16.	Ashworth, J. Jackson. 39, *Spring Gardens, City.*
1865, Nov. 15.	Bailey, Charles, F.L.S. *Ashfield College Road, Whalley Range, Manchester.*
1888, Nov. 13.	Bailey, G. H., D.Sc. Ph.D. *The Owens College.*
1888, Feb. 7.	Bailey, Alderman W. H. *Summerfield, Eccles New Road.*
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. 65, *Mosley Street, City.*
1855, April 17.	Brockbank, William, F.G.S., F.L.S. *Chapel Walks.*
1861, April 2.	Brogden, Henry, F.G.S. *Hale Lodge, Altrincham.*
1844, Jan. 22.	Brooks, Sir William Cunliffe, Bart., M.A., M.P. *Bank,* 92, *King Street.*
1889, April 16.	Brooks, Herbert S. *Slade House, Levenshulme.*
1860, Jan. 23.	Brothers, Alfred, F.R.A.S. 12, *Swinton Avenue, Manchester.*
1886, April 6.	Brown, Alfred, M.A., M.B. *Claremont, Higher Broughton.*
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. *School Board Offices, Deansgate.*
1880, Oct. 15.	Budenberg, C. F., M.Sc. 23, *Demesne Road, Alexandra Road.*
1872, Nov. 12.	Burghardt, Charles Anthony, Ph.D. 35, *Fountain Street.*
1891, April 21.	Buxton John H., *Guardian Offices, Manchester.*
1854, April 18.	Christie, Richard Copley, M.A., Chancellor of the Diocese, *The Elms, Roehampton, S.W.*
1841, April 30.	Clay, Charles, M.D., Extr. L.R.C.P. (Lond.), M.R.C.S. (Edin.), *Tower Lodge, Poulton-le-Fylde, Lanc.*
1884, Nov. 4.	Corbett, Joseph. 9, *Albert Square.*
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.*
1849, Jan. 25.	Crowther, Joseph Stretch. *Endsleigh, Alderley Edge.*
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., F.G.S., 26, *George Street.*
1878, Nov. 26.	Davis, Joseph. *Engineer's Offices, Lancashire and Yorkshire Railway, Hunt's Bank.*
1861, Dec. 10.	Deane, William King. *Almondbury Place, Chester Road.*
1879, Mar. 18.	Dent, Hastings Charles, F.L.S., F.R.G.S. 20, *Thurloe Square, London, S.W.*
1878. Feb. 8.	Dixon, Harold B., M.A., F.R.S., Professor of Chemistry, *The Owens College.*
1892, April 26.	Ewan, Thomas, B.Sc. (Vict.), Ph.D. (Munich). *The Owens College, Manchester.*
1883, Oct. 2.	Faraday, Frederick James, F.L.S., F.S.S. *Ramsay Lodge, Slade Lane, Levenshulme.*
1886, Feb. 9.	Gee, W. W. Haldane, B.Sc. *Technical School, Princess Street, Manchester.*
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.*
1875, Feb. 9.	Gwyther, R. F., M.A., Fielden Lecturer in Mathematics, Owens College. *The Owens College.*
1889, Nov. 12.	Hadley, H. E. *The Owens College.*
1889, Nov. 12.	Hall, Charles John, Mus. Doc. *Hawkesmoor, Southport.*
1890, Feb. 18.	Harker, Thomas. *Brook House, Fallowfield.*
1890, Jan. 7.	Harrison, Fred., M.A. *The Grammar School.*
1862, Nov. 4.	Hart, Peter. *Messrs. Tennants & Co., Mill Street, Clayton N., Manchester.*
1873, Dec. 16.	Heelis, James, 71, *Princess Street.*
1890, Mar. 4.	Henderson, H. A. *Eastbourne House, Chorlton Road.*
1890, Nov. 4.	Heenan, R. H., Engineer, M.I.C.E., M.I.M.E. *Manor House, Wilmslow Park, Wilmslow.*
1889, Jan. 8.	Heywood, Charles J. *Chaseley, Pendleton.*
1891, Nov. 3.	Halkyard, Edward. *The Firs, Knutsford.*
1891, Nov. 3.	Hare, Arthur W., M.B., F.R C.S.E., F.R.S.E., Professor of Surgery. *The Owens College, Manchester.*
1833, April 26.	Heywood, James, F.R.S., F.G.S., F.S.A. 26, *Kensington Palace Gardens, London, W.*
1884, Jan. 8.	Hodgkinson, Alexander, M.B., B.Sc. 18, *St. John Street.*
1882, Oct. 17.	Holt, Henry. *The Cedars, Didsbury.*
1873, Dec. 2.	Howorth, Henry H., F.S.A., M.P. *Bentcliffe House, Eccles.*

Date of Election.

1889, Oct. 15. Hoyle, W. E., M.A., Keeper of the Manchester Museum. 25, *Brunswick Road, Withington.*

1884 Jan. 8. Hurst, Charles Herbert, 151, *High Street, C.-on-M., Manchester.*

1870, Nov. 1. Johnson, William H., B.Sc. 26, *Lever Street.*

1878, Nov. 26. Jones, Francis, F.R.S.E., F.C.S. *Grammar School.*

1890, Jan. 7. Joseland, H. L., B.A. *The Grammar School*

1891, Nov. 17. Joyce, Samuel, Electrical Engineer, *Technical School, Princess Street, Manchester.*

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.*

1890, Nov. 4. Langdon, Maurice Julius, Ph.D., Chemist. *Sunbury, Victoria Park.*

1863, Dec. 15. Leake, Robert, M.P. *The Dales, Whitefield.*

1884. April 15. Leech, Daniel John, Professor, M.D. *The Owens College.*

1850, April 30. Leese, Joseph. *Messrs. S. & E. Leese, Fylde Road Mill, Preston.*

1892, Feb. 23. Lloyd, Canon Julius, M.A. *Moorfield, Kersal.*

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, M.D., F.R.C.P., Lond., Professor of Forensic Med., The Owens College. 16, *St. John Street.*

1879, Dec. 2. Marshall, Arthur Milnes, M.A., M.D., D.Sc., F.R.S., Professor of Zoology, Owens College. *The Owens College.*

1864, Nov. 1. Mather, William, M.P. *Iron Works, Salford.*

1873, Mar. 18. Melvill, James Cosmo, M.A., F.L.S. *Kersal Cottage, Prestwich.*

1879, Dec. 30 Miller, John Bell, M.E., Assistant Lecturer in Engineering, Owens College. *The Owens College.*

1881, Oct. 18. Mond, Ludwig, F.C.S. *Winnington Hall, Northwich.*

1861, Oct. 29. Morgan, John Edward, M.D., M.A., F.R.C.P., Lond., F.R. Med. and Chir. S., Professor of Medicine in the Victoria University. *The Hut, Tabley, Knutsford.*

1889, April 16. Moultrie, George W. *Bank of England, King Street.*

1873, Mar. 4. Nicholson, Francis, F.Z.S. 62, *Fountain Street.*

Date of Election.	
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.*
1861, Jan. 22.	O'Neill, Charles, F.C.S., Corr., Mem. Ind. Soc. Mulhouse. 14, *Cecil Street, Greenheys.*
1844, April 30.	Ormerod, Henry Mere, F.G.S. 5, *Clarence Street.*
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1861, April 30.	Parlane, James. *Rusholme.*
1876, Nov. 28.	Parry, Thomas, F.S.S. *Grafton House, Ashton-under-Lyne.*
1885, Nov. 17.	Phillips, Henry Harcourt, F.C.S. 183, *Moss Lane East, Manchester.*
1854, Jan. 24.	Pochin, Henry Davis, F.C.S, *Bodnant Hall, Conway.*
1854, Feb. 7.	Ramsbottom, John, M. Inst. C.E. *Fernhill, Alderley Edge.*
1859, April 16.	Ransome, Arthur, M.A., M.D., Cantab., F.R.S., M.R.C.S. 1. *St. Peter's Square.*
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, the 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.*
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1851, April 29.	Sandeman, Archibald, M.A. *Garry Cottage, near Perth.*
1870, Dec. 13.	Schorlemmer, Carl, LL.D., F.R.S., F.C.S. *The Owens College.*
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. *The Owens College.*
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1890, Nov. 4.	Sidebotham, Edward, *Earlsdene, Bowdon.*
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1890, Nov. 4.	Taylor, Walter, A.M.I.C.E. *The Hollies, Flixton.*
1884, Mar. 18.	Thompson, Alderman Joseph. *Riversdale, Wilmslow.*

Date of Election.	
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1865, Feb. 21.	Worthington, Thomas, F.R.I.B.A. 46, *Brown Street.*

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