PROCEEDINGS

OF THE

PHILOSOPHICAL SOCIETY OF GLASGOW.

VOL. IV.

MDCCCLV.—MDCCCLX.

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PROCEEDINGS

OF THE

PHILOSOPHICAL SOCIETY OF GLASGOW.

FIFTY-FOURTH SESSION.

Anderson's University Buildings, November 7, 1855.

THE Session of the Philosophical Society of Glasgow was opened this evening,—Dr. Allen Thomson, President, in the Chair.

The President delivered an address, in which he made a review of the proceedings at the recent meeting of the British Association in Glasgow.

Among other observations, he said, "The success of the meeting, which is universally acknowledged, was manifested not less by the number and distinction of the scientific men who attended and took a part in the proceedings, than by the extent and importance of the scientific memoirs brought forward and discussed.

"The total number of members enrolled at this meeting was 2,140, the largest attendance at any meeting of the Association since its commencement, with the exception of that at Newcastle in 1838.

"The sum of money received for tickets from members and associates amounted to £2,314; the whole of which, owing to the liberality of the private subscriptions in Glasgow for defraying the local expenses, has been handed over to the Association for application to scientific objects.

"The local subscription amounted to £1,450.

"The number of papers read and presented was 349, distributed through the several sections as follows:—

A. Mathematical and Physical Science,	55
B. Chemical Science,	62
C. Geology,	46
D. Zoology and Botany, 47, Subsection D, Physiology, 30,	77
E. Geography and Ethnology,	36
F. Statistics,	31
G. Mechanical Science,	42
Total,	349

being nearly an average of forty-three and a-half papers for each of the eight sections.

"The sectional meetings took place on six days, and of these meetings there were forty-two in all. They lasted on an average four hours, which gives an aggregate amount of time of 168 hours devoted to the reading and discussing the various communications. This time—equal to fourteen days of twelve hours each—would be equal to that passed in six or seven sessions of the meetings of the Glasgow Philosophical Society.

"There is good ground, therefore, for satisfaction in the result of the meeting, and we have reason to congratulate ourselves that science has prospered in the hospitable care of our city. To this success a variety of circumstances have no doubt contributed, among which may be mentioned, *first,* the attractions which Glasgow presents as one of the greatest seats of the successful application of scientific principles to important, useful, and practical objects; *second,* the increasing influence and continued improvement in the management of the British Association itself; and, *third,* the strenuous and well-directed efforts of those immediately charged with the arrangements for the meeting.

"In reflecting now, as it is natural for us to do, on the advantages that may have been derived from such a meeting, I doubt not that every one will be disposed to give a foremost place to the pleasure he has received, and the improving influence he has experienced from seeing the interesting countenances, hearing the eloquent and learned discourses, and making the acquaintance of many eminent men whose names may have been long known to him as the most distinguished in their several departments. In some instances this is perhaps a gratification of mere curiosity; in others it is positively useful in enabling us to appreciate more justly, and to enjoy more fully the writings of authors whom we have not previously seen.

"Not less marked than the feeling now alluded to is the consciousness, which every cultivator of science must be aware of, that he has received a great and fresh stimulus to exertion from the example of the many bright ornaments of science who are congregated together at the Association meetings. We are pleased to witness the respect which is paid by those highest in social rank to the distinction of scientific attainments; and we are glad also to perceive that many of those whose social position might have made them regardless of science, have attained to considerable eminence in various of its branches; but it is still more satisfactory to find, that, in this great republic of science, obscurity in social rank is no bar to fame, and scientific distinction is in proportion only to the value of the contribution which is brought forward by any of its members.

"Whatever may be thought of the frequency of the meetings of the Association in general, it cannot be held by any one who has witnessed our recent assemblage, that an interval of fifteen years was too short a period before the repetition of the meeting in Glasgow took place. Not only has a sufficient number of fresh votaries of science appeared in the field since the time of the first visit, but in the hands of these and of the veterans, science and its applications to useful arts have not slumbered in this town or its vicinity, but have been advanced here as elsewhere with increasing rapidity. The sketch which I shall lay before you of the principal communications brought before the several Sectional meetings, will show that the value of the scientific facts and importance of the principles discussed at this meeting, do not yield to any of those which have preceded it. Great and striking novelties or discoveries in science do not arise in regular periodic succession; but valuable research, and great vigour, and fruitfulness of suggestion, may with justice be said to have characterized the proceedings at every one of the Sectional meetings.

"Before entering upon an enumeration of the scientific business brought forward at the Sections, it is proper for me to allude shortly to the general interest which was given to the meeting by the manner in which the office of president was filled by the Duke of Argyll. All those, I am sure, who heard the eloquent and learned addresses delivered by that accomplished nobleman, must have been struck with the masterly sketch in which, at the first public meeting, he brought rapidly before them, in language equally elegant and descriptive, a history of the progress of science in the period between the first and the second meetings of the British Association in Glasgow; and the citizens of Glasgow, and of the west of Scotland, feel some degree of pride, that from among themselves had arisen one whose grace and learning were calculated to add lustre to such an assemblage of the most celebrated scientific men of this and other countries."

The President then gave a short account of the more important papers brought before the several Sections, having been kindly furnished with the necessary materials by the Presidents or Secretaries of the several Sections.

He then continued—

"After these, the greater and essential features of the meeting, I need do no more than allude to the various minor arrangements and accessory circumstances which contributed to its success.

"The very suitable accommodation provided by the College for the various Sectional meetings—the unequalled halls which the town so liberally offered for the public assemblies, among which I must not pass over the M'Lellan Galleries—the elegant and sumptuous entertainment of the Lord Provost to the office-bearers of the Association—the two highly instructive and deeply interesting lectures by Professor Carpenter and Colonel Rawlinson—the Conversational meetings, Claudet's stereopticon, and Duboscq and Nachet's exhibition of photographic pictures and minute objects by means of the electric light—the photographic exhibition in Messrs. Wylie and Lochhead's gallery—the interesting specimens of ancient boats or canoes—the unrivalled collection of fossils of the coal formation, and of some other strata, together with the series illustrating the manufacture of iron, glass, pottery, and various other products of Glasgow industry—the excursions, particularly that to Arran—the marine vivaria, prepared by Dr. Miles and Dr. Paterson, in which a set of plants and animals were exhibited which many of the associates of the meeting had never before seen alive; and, lastly, the extreme liberality with which the different public institutions, and a large number of the most interesting private manufactories were opened to the Association,—these various circumstances could not but add, in an eminent degree, to the pleasant occupation and instruction which the meeting was calculated to afford to persons of every variety of scientific taste."

On the motion of Mr. Provan, seconded by Mr. Murray of Monkland, a vote of thanks was given to the President for his address.

Mr. William Church, Accountant, was elected a member, having been proposed at the concluding meeting of last Session.

Mr. Cockey, the Treasurer, called the attention of the Society to the alterations which had been made during the recess in the Hall, by which its appearance and comfort had been greatly improved. He stated that the alterations had incurred an expense of about £60, and moved that the Society grant that sum to the Council to defray the cost.

The first vote on this motion was taken, and the Society agreed accordingly to grant £60 from the funds.

Mr. Dawson and Mr. Bell were requested to audit the Treasurer's Accounts.

The following books and maps were presented to the Society, for which thanks were voted to the donors:—

Physical and Geological Map of India, by S. B. Greenough, F.R.S., &c., presented to the Society on behalf of the Executors of that gentleman, by Robert Hutton, Esq. of Putney Park, Surrey, F.G.S.

Transactions of Royal Scottish Society of Arts, vol. iv., Part III.

Proceedings of Liverpool Literary and Philosophical Society, No. 9.

Memoirs of Literary and Philosophical Society of Manchester, vols. xi. and xii.

Transactions of Historic Society of Lancashire and Cheshire, vol. vii.

Proceedings of Royal Society of Edinburgh, 1854-55.

"Drawings of the Machinery of the Arabia and La Plata Steam-Ships." By Mr. David Kirkaldy.

The Society then proceeded to the Fifty-fourth Annual Election of office-bearers.

On the motion of Mr. Robert Blackie, seconded by Mr. Bryce, the following were elected:—

President.

DR. ALLEN THOMSON.

Vice-Presidents.

MR. ALEXANDER HARVEY. | MR. W. J. MACQUORN RANKINE.

Librarian.

MR. WILLIAM GOURLIE.

Treasurer.

MR. WILLIAM COCKEY.

Joint-Secretaries.

MR. ALEXANDER HASTIE, M.P. | MR. WILLIAM KEDDIE.

The Society then proceeded to elect twelve Councillors by ballot. Mr. Mathieson and Mr. M'Harg were requested to act as scrutineers of the votes.

The scrutineers having retired to examine the vote-papers,

The President and Dr. Miles exhibited and described several rare marine productions.

The scrutineers having given in their Report, the following were found to be elected Members of

Council.

MR. WALTER CRUM.	DR. JOHN STRANG.
DR. THOMAS ANDERSON.	MR. ROBERT BLACKIE.
MR. JOHN CONDIE.	MR. WILLIAM RAMSAY.
MR. WILLIAM MURRAY.	MR. WALTER NEILSON.
PROFESSOR WM. THOMSON.	MR. ROBERT HART.
MR. JAMES R. NAPIER.	MR. JAMES COUPER.

The second vote was taken on the proposed grant of £60 to defray the expense of improving the Hall, and this grant was finally agreed to.

Mr. W. J. Macquorn Rankine brought forward the following motion, of which notice was given at last meeting:—

"That a Memorial be presented to the Lords of Her Majesty's Treasury, praying that the Ordnance Survey of the improvable parts of the counties of Lanark, Renfrew, and Dumbarton, be engraved and published [in addition to the scale already in progress] on the scale of six inches to one mile; and that a committee be appointed to communicate with the Commissioners of Supply of the said counties, the Town Council of Glasgow, and other public bodies, with reference to the attainment of the above object."

Mr. Bryce seconded the motion.

Mr. Hastie suggested the insertion of the words, "in addition to the scale already in progress"—with which amendment the motion was agreed to.

The following committee was appointed:—Mr. Hastie, M.P.; Mr. Walter Crum; Mr. Alexander Harvey; Mr. James Bryce, jun.; Mr. William Ramsay; Mr. W. J. Macquorn Rankine, Convener.

November, 21, 1855.—*The* President *in the Chair.*

Mr. David M'Kinlay, Pollokshields; Mr. Richard Brown, North Woodside Ironworks; Mr. William Fraser, New Bridge Street; Mr. Alexander Russell, Writer, 4 South Hanover Street; and Mr. Alexander Harvey, jun., Machine Maker, were elected members.

Mr. Cockey gave in a Report on the state of the Library, from which it appeared that the number of volumes is at present 2,421.

Dr. Anderson laid on the table copies of the printed *Proceedings* of the Society.

Mr. Cockey, the Treasurer, gave in the following abstract of his Account for Session 1854–1855:—

	Dr.	£	s.	d.	£	s.	d.
1854. Nov. 1.	—To Cash in Union and Savings Banks,	£89	15	8			
1855. Nov. 1.	— Interest on Bank Accounts,........	3	9	11			
					£93	5	7
	— Entries of 31 new Members, at 21s. each, ...	£32	11	0			
	— 9 Annual Payments from Original Members, at 5s. each,............	2	5	0			
	— 245 Annual Payments, at 15s. each,	183	15	0			
					218	11	0
	— Rent from Sabbath School Teachers, for use of Hall, ...				3	0	0
					£314	16	7

1854.	Cr.						
Nov. 1.—By New Books,	£61	10	4			
— Subscription to Ray Society,	1	1	0			
— Do. to Palæontographical Society,	1	1	0			
— Binding,	6	0	0			
				£69	12	4
— Stationery,				1	9	9
— Printing Circulars, &c.,				13	0	0
— Rent of Hall,	£15	0	0			
— Fire Insurance,	3	11	0			
— Gas,	1	6	7			
— Cleaning the Hall and petty charges,	0	11	4			
— Rent of Merchants' Hall for Lecture,	2	17	6			
				23	6	5
— Salary to Librarian,	45	11	0			
— Fee to Officer of Andersonian University,	4	0	0			
— Delivering Circulars,	7	15	2			
				57	6	2
— New Black Boards and Mountings,				4	8	3
— Alterations and Repairs in the Hall,				61	10	1
— Balance—						
Cash in Union Bank,	82	3	10			
Do. in Treasurer's hand,	1	19	9			
				84	3	7
				£314	16	7

THE PHILOSOPHICAL SOCIETY'S EXHIBITION FUND.

1855.			
May 15.—To Balance, per Deposit Receipt from Corporation of Glasgow,	£619	16	8
— Interest to this date,	27	18	0
	£647	14	8

GLASGOW, 10*th November*, 1855.—We have examined the Treasurer's Account, and compared the same with the Vouchers, and find there are in the Union Bank of Scotland Eighty-Two Pounds 3s. 10d., and in the hands of the Treasurer One Pound 19s. 9d.—together, Eighty-Four Pounds 3s. 7d.—at the Society's credit at this date.

The Treasurer has also exhibited to us a Voucher which he holds for money lent to the Corporation of the City of Glasgow from the proceeds of the Philosophical Society's Exhibition in 1846, with Interest thereon to 15th May last, being Six Hundred and Forty-Seven Pounds 14s. 8d.

THOMAS DAWSON.
MATTHEW P. BELL.

REPORT BY THE TREASURER, NOVEMBER 9, 1855.

The Furniture and other moveable property of the Society remain nearly the same as last year, the additions consisting of New Gas Fittings, Twelve New Seats, a Register Grate and Fender, and additions to the Library, which will appear in a supplementary list.

The number of Members at commencement of Session 1854-5 was		259
New Members admitted during the Session,		34
		293
From this there fall to be deducted from Roll at commencement of present Session,—		
Resigned by letter,	3	
In Arrear two years, and held as resigned,	12	
Placed on Non-Resident List,	3	
Left Glasgow for places unknown,	6	
New Members elected but not come forward,	2	
Dead,	4	
	—	30
On List for 1855-56,		263

Of the above 263, there are 29 Members in Arrear of Dues one year.

December 5, 1855.—*The* PRESIDENT *in the Chair.*

The following gentlemen were elected members:—Mr. Charles Wilson, School of Design, Bath Crescent; Mr. James Long, A.M., 44 St. George's Road; Rev. C. P. Miles, A.M., M.D., 14 Buckingham Terrace; Mr. Alex. Grant, Mile-End; Mr. William Whyte, Queen Street; Mr. Hugh Heugh Maclure, Civil Engineer, 8 Prince's Square, Buchanan Street; Mr. Robert Davidson, Chemist, Printworks, Busby; Mr. Thomas M'Guffie, Builder, 125 North Montrose Street; Mr. John Taylor, jun., Cochrane Street.

The Committee on the Ordnance Survey presented a draft of a Memorial to the Lords of Her Majesty's Treasury, which, on the motion of Mr. Hastie, was approved of. It was agreed that copies of the Memorial should be sent to the Clerks of Commissioners of Supply of the Counties of Lanark, Dumbarton, and Renfrew.

"*To the Right Honourable the Lords Commissioners of Her Majesty's Treasury.*

"The Memorial of THE PHILOSOPHICAL SOCIETY OF GLASGOW, Sheweth—

"That your Memorialists have learned that the Ordnance Survey of various parts of Scotland, and amongst others of the Counties of Lanark, Renfrew, and Dumbarton, is now being laid down and lithographed, with a view to publication, on the scale of one two-thousand five-hundredth part of the natural dimensions, or 25·344 inches to one mile.

"That your Memorialists are fully sensible of the advantages of this scale, as being the most suitable for all purposes connected with the transfer and improvement of landed property, the execution of public works, and various other purposes.

"That your Memorialists nevertheless beg leave to represent, that the said scale, from not exposing to the eye more than a very limited extent of country at one view, and for other reasons, is too large for the preliminary planning of public works, and the choosing of the most economical and otherwise suitable sites and lines for them—purposes of the highest importance to the national prosperity, and for which the most advantageous scale is, the smallest which is consistent with showing all roads, buildings, and other important objects distinctly in their natural proportions, without exaggeration of dimensions, or the use of conventional representations of such objects.

"That the scale which best fulfils these conditions has been well ascertained, by the experience of scientific and practical men, to be one which is either exactly or approximately one ten-thousandth part of the natural dimensions; for example, six inches to one mile, which is one ten thousand five hundred and sixtieth part of the natural dimensions.

"That your Memorialists understand that the plans of certain parts of Scotland are now being engraved and published on the scale of six inches to one mile, or thereabouts, and that the process of making reduced copies of the survey on this scale is neither difficult nor expensive.

"Your Memorialists therefore beg leave respectfully to represent to your Lordships, that it would be a great advantage to the district of which your Memorialists are the chief scientific Society, as well as to the country at large, if the plans of the Counties of Lanark, Renfrew, and Dumbarton, besides being published on the large scale employed for the original laying down of the survey, were also reduced to, and engraved and published upon a scale either of six inches to one mile, or of one ten-thousandth part of the natural dimensions; such reduced plans exhibiting the levels of the ground in figures, and also by means of lines, either of equal elevation (commonly called contour lines), or of greatest and least declivity (or ridge and valley lines), according as may be consonant to the practice adopted for other districts."

"*To the Clerk to the Commissioners of Supply of the County of* ———.

"SIR,—I am directed by the Council of the Philosophical Society of Glasgow, to transmit to you the enclosed copy of a Memorial which has been presented to the Lords of Her Majesty's Treasury by that Society.

"The Council of the Philosophical Society consider that the subject of the Memorial is one well worthy of the attention of the Commissioners, and that, should the Commissioners see fit to make a similar representation to the Lords of Her Majesty's Treasury, an important benefit to the County may be secured.—I have, &c.,

"*Secretary of the Philosophical Society of Glasgow.*"

Lanark, Renfrew, Dumbarton.

Copy to the Town Clerks of Glasgow, substituting "Town Council" for "Commissioners of Supply," and "District surrounding Glasgow" for "County."

The President exhibited specimens of Clio Borealis, and several other recent Pteropods, along with a specimen of Conularia quadrisulcata, the only fossil species of Pteropod found in the coal formation.

Mr. W. J. Macquorn Rankine brought under the notice of the Society an instance communicated to him by Mr. William Smith Dixon, of the spontaneous fracture of a mass of cast iron during a sudden reduction of temperature. The block, which was cast at the Govan ironworks, consisted of nine tons of metal, and split right down the centre during a late hail-storm, when the temperature of the atmosphere fell eight degrees in the course of five minutes.

Mr. Condie mentioned that the block, which was a fine specimen of iron, had been cooled by exposure to the open air for two or three days, and the surface became wet with sleet during the hail-shower. He remembered that some years ago, a mass of iron, thirty tons in weight, after being finished, was laid on a waggon at Greenock, where it broke to pieces from the effect of a sudden rise of temperature during a thaw.

Mr. Walter Neilson ascribed the fracture of iron in both instances to the effect of contraction.

Mr. Crum referred to an example where fracture had taken place without any change of temperature, and was probably caused by irregular annealing and unequal tension.

Professor William Thomson suggested, that Mr. Condie should make experiments on iron of different textures, and bring the results under the notice of the Society.

Mr. James Napier read a paper "On the Principles of Practical Metallurgy."

December 19, 1855.—*The* PRESIDENT *in the Chair.*

The following were elected members, viz.:—Mr. John H. Lindsay, 282 Bath Street; Mr. Walter Paterson, merchant, 8 Claremont Terrace; Mr. John Kirsop, hatter, 98 Argyle Street; Mr. Andrew Craig, Engineer, Shotts Iron Works, Motherwell.

Mr. Hastie read a letter from the Clerk of Her Majesty's Treasury, acknowledging receipt of the Society's Memorial on the Ordnance Survey; also, letters acknowledging receipt of copies of the same from the Clerks to the Commissioners of Supply for Lanarkshire and Renfrewshire.

Dr. Rowney read a paper "On the Chemistry of Oils and Fats, and their Economic Uses."

Mr. Ure exhibited a Model Apparatus for Collecting Rubbish carried down Sewers.

January 9, 1856.—MR. HARVEY, Vice-President, *in the Chair.*

The following gentlemen were elected members, viz.:—Mr. James Goldie, 23 St. Vincent Crescent; Mr. Thomas M. Whyte, 36 Elmbank Crescent; Dr. James G. Wilson, 143 Hope Street; Mr. Robert Pollock, Merchant, 41 Eglinton Street; Mr. A. Bertram, Editor of *Glasgow Daily News*, 92 South Portland Street; Mr. D. A. B. Murray, Merchant, 14 York Street; Mr. John Weild, Marine Surveyor, Thornliebank, and 91 Buchanan Street; Mr. James M'Clelland, jun., Accountant, 128 Ingram Street; Mr. David Stewart, Accountant, 4 South Hanover Street; Mr. J. S. Fleming, Writer, 10 Miller Street; Mr. Alex. Macnie, Writer, 36 Miller Street.

A letter from the Clerk to the Commissioners of Supply for the County of Dumbarton was read, acknowledging receipt of a copy of the Society's Memorial on the Ordnance Survey.

Mr. James Napier read a paper "On Metallurgy amongst the Ancient Hebrews." From a comparison of the processes at present in use for obtaining and purifying gold and silver ores, with the notices of the methods practised in ancient times, occurring in the Holy Scriptures and other writings of antiquity, Mr. Napier came to the conclusion, that all the requirements for perfectly purifying gold and silver were known to the

Hebrews and the ancients generally. By a similar mode of inquiry, he showed their acquaintance also with copper, tin, bronze, lead, and iron. (Mr. Napier's paper was subsequently expanded, and published in the form of a treatise on "The Ancient Workers and Artificers in Metal, from references in the Old Testament and other Ancient Writings.")

Mr. James Paterson described a method of obtaining cool water for the city in summer from Loch Katrine.

Abstract of a Paper read by MR. JAMES PATERSON, *pointing out means whereby the Water from Loch Katrine might be obtained at a temperature differing little from that of spring water, at all seasons of the year.*

ON examining the plans publicly exhibited for introducing the water from Loch Katrine into this city, I observed, with regret, that there appeared to be no provision made to obtain, and to prevent, the water flowing into the city during the summer months, from reaching us at a summer temperature, when at such a season cool water is so refreshing and desirable.

Being aware that it is a well established fact, that as we descend from the surface towards the bottom of a lake, the difference in the temperature of water between the summer and winter gradually decreases until you reach the depth (in our Scotch lakes, according to Jardine), of 120 feet, when the temperature continues constant during all seasons, the idea struck me that it would be a great boon to the citizens of Glasgow, should effectual means be devised, whereby the water from Loch Katrine could at all times be obtained of a regular temperature.

In turning this matter over in my mind, I feel satisfied, that were a malleable iron tube of sufficient area constructed, to fit the mouth of the tunnel, and made watertight by means of vulcanized india rubber rings, or otherwise, and of sufficient length to reach down to the required depth in the loch, water of the desired uniform temperature would always be secured, as the water would be withdrawn from the loch at the depth to which the tube reached. And as the water in this loch is said to be always of a comparatively low temperature (even in the heat of summer), the water might be withdrawn with the desired effect, at a much less depth than I have indicated above. Besides, by the use of such a tube, we would not only avoid the surface water with all its impurities, but would also provide against the regular purity of the water being disturbed, by the surface soil drawn into the lake on the occasion of any flood or thunder-storm.

Water thus obtained, if allowed to flow into the reservoir, as indicated in the plans, would so be neutralized. An alteration here would also be necessary, so that the water, instead of flowing directly from the tunnel into the reservoir, might be conveyed by pipes along the bottom, upon the same level as, and to within a short distance of, the exit pipes for supplying the city, so that the water might pass directly through from the tunnel into the distribution pipes, and thus secure a constant supply of fresh cool water to the inhabitants. This could not be the case, if allowed to flow direct from the mouth of the tunnel, and mingle with the mass of water in the reservoir.

Having submitted these suggestions to the Water Commissioners, they were, by them, communicated to Mr. Bateman, and I am happy to think that they have so far met his approval, as, in a communication I had from him, he states that he has made provision for carrying the water in pipes from the tunnel, along the bottom of the reservoir, to the exit pipes.

January 23, 1856.—*The* President *in the Chair.*

The following gentlemen were elected members:—Mr. George Innes, Bombay Army, Edinbarnet, near Glasgow; Mr. George Thomson, Engineer, Clydebank Foundry; Mr. Robert M'Connel, Founder, 18 Renfield Street; Mr. Wm. G. Wilson, Engineer, 49 West George Street.

Professor William Thomson read papers "On the Effects of Mechanical Strain on the Electric Conductivity of Metals."

"On the Effect of Magnetization on the Electric Conductivity of Iron."

February 6, 1856.—*The* President *in the Chair.*

Dr. Anderson described the Manufacture of Aluminium.

Mr. J. Finlay read a paper "On the Practice and Difficulties of Ventilation."

February 20, 1856.—*The* President *in the Chair.*

Dr. Alexander M'Fie Smith, Govan, and Mr. Walter M'Lellan were elected members.

The President read a paper "On the Different Forms of the Gills, or Branchial Apparatus, in Vertebrate Animals;" and exhibited specimens of Fœtal Skates and Sharks, together with the Menobranchus, Siredon, and other Animals.

Professor W. J. Macquorn Rankine exhibited a collection of full-sized drawings of the fractures of railway axles.

Mr. Alex. Harvey exhibited and described Mr. Kennedy's Water Meter.

There was presented to the Society, in name of His Royal Highness Prince Albert, a Copy of the Natural History of Deeside and Braemar, by the late Dr. M'Gilvray, printed by command of Her Majesty. The Librarian was instructed to acknowledge receipt of the work to the Publishers, in terms of a request to that effect. It was agreed that the work should not be allowed to be taken out of the Library.

March 5, 1856.—*The* PRESIDENT *in the Chair.*

Mr. Robert Blackie presented to the Library the Supplementary Volume of the *Imperial Dictionary*, for which the thanks of the Society were voted to Messrs. Blackie, the Publishers.

Dr. Anderson read a paper "On Bone Oil and its Products."

Professor Macquorn Rankine described some experiments on the Pressure sustained by Structures of Brickwork, with reference to Factory Chimneys.

On the Stability of Factory Chimneys. By W. J. MACQUORN RANKINE, LL.D., F.R.SS. L. & E.

CHIMNEYS are exposed to the lateral pressure of the wind, which, without sensible error in practice, may be assumed to be horizontal, and of uniform intensity at all heights above the ground.

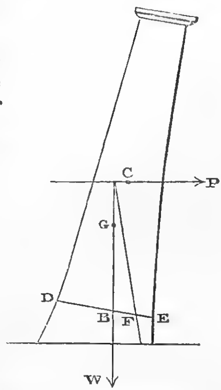
The surface exposed to the pressure of the wind by such structures is usually either flat, or cylindrical, or conical, and differing very little from the cylindrical form. Octagonal chimneys, which are occasionally erected, may be treated as sensibly circular in plan. The inclination of the surface of a tower or chimney to the vertical is seldom sufficient to be worth taking into account in determining the pressure of the wind against it.

The greatest intensity of the pressure of the wind against a flat surface directly opposed to it, hitherto observed in Britain, has been 55 lbs. per square foot; and this result (which is given on the authority of Dr. Nichol) has been verified by the effects of certain violent storms in destroying factory chimneys and other structures.

In any other climate, before designing a structure intended to resist the lateral pressure of wind, the greatest intensity of that pressure should be ascertained either by direct experiment, or by observation of the effects of the wind on previous structures.

The total pressure of the wind against the side of a cylinder is about one-half of the total pressure against a diametral plane of that cylinder.

Let the figure represent a chimney, square or circular, and let it be required to determine the conditions of stability of a given bed-joint, D E.



Let S denote the area of a diametral vertical section of the part of the chimney above the given joint, and p the greatest intensity of pressure of the wind against a flat surface. Then the total pressure of the wind against the chimney will be sensibly

$$\left.\begin{array}{l} P = p\,S \text{ for a square chimney;} \\ P = p\,\frac{S}{2} \text{ for a round chimney;} \end{array}\right\} \ldots(1.)$$

and its resultant may, without appreciable error, be assumed to act in a horizontal line through the *centre of gravity of the vertical diametral section,* C. Let H denote the height of that centre above the joint D E, then the moment of the pressure is

$$\left.\begin{array}{l} H\,P = H\,p\,S \text{ for a square chimney;} \\ H\,P = \frac{H\,p\,S}{2} \text{ for a round chimney;} \end{array}\right\} \ldots\ldots\ldots\ldots(2.)$$

and to this the least *moment of stability* of the portion of the chimney above the joint D E, should be equal.

For a chimney whose axis is vertical, the moment of stability is the same in all directions. But few chimneys have their axes exactly vertical; and the least moment of stability is obviously that which opposes a lateral pressure acting in that direction toward which the chimney leans.

Let G be the *centre of gravity of the part of the chimney* which is above the joint D E, and B a point in the joint D E vertically below it; and let the line D E = t represent the diameter of that joint which traverses the point B. Let q' represent the ratio which the deviation of B from the middle of the diameter D E bears to the length t of that diameter.

Let F be the limiting position of the centre of resistance of the joint D E, nearest the edge of that joint towards which the axis of the chimney leans, and let q denote the ratio which the deviation of that centre from the middle of the diameter D E bears to the length t of that diameter.

Then the least moment of stability is denoted by

$$W \cdot \overline{BF} = (q - q') W t, \qquad (3.)$$

The value of the co-efficient q is determined by considering the manner in which chimneys are observed to give way to the pressure of the wind. This is generally observed to commence by the opening of one of the bed-joints, such as D E, at the windward side of the chimney. A crack thus begins, which extends itself in a zig-zag form diagonally downwards along both sides of the chimney, tending to separate it into two parts, an upper leeward part, and a lower windward part, divided from each other by a fissure extending obliquely downwards from windward to leeward. The final destruction of the chimney takes place, either by the horizontal shifting of the upper division until it loses its support from below, or by the crushing of a portion of the brickwork at the leeward side, from the too great concentration of pressure on it, or by both those causes combined; and in either case the upper portion of the structure falls in a shower of fragments, partly into the interior of the portion left standing, and partly on the ground beside its base.

It is obvious that in order that the stability of a chimney may be secure, no bed-joint ought to tend to open at its windward edge; that is to say, there ought to be some pressure at every point of each bed-joint, except the extreme windward edge, where the intensity may diminish to nothing; and this condition is fulfilled with sufficient accuracy for practical purposes, by assuming the pressure to be an uniformly varying pressure, and so limiting the position of the centre of pressure F, that the intensity at the leeward edge E shall be double of the mean intensity.

Chimneys in general consist of a hollow shell of brickwork, whose thickness is small as compared with its diameter; and in that case it is sufficiently accurate for practical purposes to give to q the following values:—

$$\left.\begin{array}{ll}\text{For square chimneys,} & q = \tfrac{1}{3}; \\ \text{For round chimneys,} & q = \tfrac{1}{4}.\end{array}\right\} \qquad (4.)$$

The following general equation, between the moment of stability and the moment of the external pressure, expresses the condition of stability of a chimney:—

$$H P = (q - q') W t, \qquad (5.)$$

This becomes, when applied to square chimneys,

$$\mathrm{H}\,p\,\mathrm{S} = (\tfrac{1}{3} - q')\,\mathrm{W}\,t;$$

and when applied to round chimneys,

$$\frac{\mathrm{H}\,p\,\mathrm{S}}{2} = (\tfrac{1}{4} - q')\,\mathrm{W}\,t. \quad \ldots\ldots\ldots\ldots (6.)$$

The following approximate formulæ, deduced from these equations, are useful in practice.

Let B be the *mean* thickness of brickwork above the joint D E under consideration, and b the thickness to which that brickwork would be reduced if it were spread out flat upon an area equal to the external area of the chimney. That reduced thickness is given with sufficient accuracy by the formula,

$$b = \mathrm{B}\left(1 - \frac{\mathrm{B}}{t}\right); \quad \ldots\ldots\ldots\ldots (7.)$$

but in most cases the difference between b and B may be neglected.

Let w be the weight of a cubic foot of brickwork; being from 112 lbs. to 120 lbs. Then we have very nearly,

$$\left.\begin{array}{ll}\text{For square chimneys,} & \mathrm{W} = 4\,w\,b\,\mathrm{S};\\ \text{For round chimneys,} & \mathrm{W} = 3{\cdot}14\,w\,b\,\mathrm{S};\end{array}\right\} \ldots\ldots\ldots\ldots (8.)$$

which values being substituted in the equations 6, give the following formulæ:—

$$\left.\begin{array}{ll}\text{For square chimneys,} & \mathrm{H}\,p = \left(\frac{4}{3} - 4\,q'\right) w\,b\,t;\\ \text{For round chimneys,} & \mathrm{H}\,p = (1{\cdot}57 - 6{\cdot}28\,q')\,w\,b\,t.\end{array}\right\} \ldots (9.)$$

These formulæ serve two purposes; *first*, when the greatest intensity of the pressure of the wind, p, and the external form and dimensions of a proposed chimney are given, to find the mean reduced thickness of brickwork, b, required above each bed-joint, in order to insure stability; and, *secondly*, when the dimensions and form, and the thickness of the brickwork of a chimney are given, to find the greatest intensity of pressure of wind which it will sustain with safety.

The shell of a chimney consists of a series of divisions, one above another, the thickness being uniform in each division, but diminishing upwards from division to division. The bed-joints between the divisions, where the thickness of brickwork changes (including the bed-joint at the base of the chimney), have obviously less stability than the intermediate bed-joints; hence it is only to the former set of joints that it is necessary to apply the formulæ. Those formulæ have been applied to the great chimney of the works of Messrs. Tennant and Company at St. Rollox, near Glasgow, which was erected from the designs of Messrs. Gordon and Hill, and is, with the exception of the spire of Strasbourg, the Great Pyramid, and the spire of St. Stephen's at Vienna, the most lofty building in the world, being 436 feet high above the ground, and 450 feet high above the foundation; and it has been found that the stability of that chimney is suited exactly to the maximum pressure of wind already mentioned, of 55 lbs. per square foot.

March 19, 1856.—*The* PRESIDENT *in the Chair.*

Dr. Decimus Hodgson was elected a member.

Mr. Bryce described some recent Observations on the Granite of the Island of Arran.

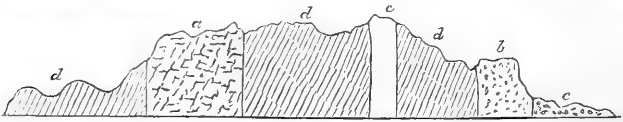
Notice of the Discovery of a New Granite Tract in Arran.
By JAMES BRYCE, M.A., F.G.S.

THE northern and southern halves of this celebrated island are remarkably distinct in their physical features and geological structure. The former, bounded southwards by a line running almost due east and west from Brodick bay to Iorsa water-foot, consists of a mass of peaked and rugged mountains, intersected by deep and wild glens, which diverge from a centre, and open seaward on a narrow belt of low land. The southern half consists of a rolling table-land, bleak and unpicturesque inland, but breaking rapidly down seaward into a coast border of great romantic beauty. The general elevation of this portion is from 500 to 800 feet; and the irregular ridges which traverse it, most usually in a direction nearly east and west, do not rise above 1,100 or 1,400 feet. The northern portion, on the other hand, rises into mountains passing 2,000 feet, and culminates in the south summit of Goatfell, having an altitude of 2,875 feet, while many of the peaks reach a height very little less. The rocks constituting this mountain group are granite and the old slates; the latter flanked on the north and east by sandstones and limestones of Devonian and carboniferous age. The entire southern plateau is composed of sandstone, broken through and overlaid by various trap rocks, chiefly greenstone and porphyry. The whole of this sandstone we refer to the age of the coal formation, on the ground that limestone, with true carboniferous fossils, occurs in repeated alternation with it, and that there is an entire absence of fossils of New-Red types; we cannot see that there is any evidence for separating a portion of it, as has hitherto been done, from the sandstones underlying, as even a rudimentary development of the New-Red system.

Now, this remarkable difference in physical aspect, as well as the extraordinary variety of geological phenomena which the island exhibits, alike arise from a single peculiarity often overlooked by those who have undertaken to describe it. This consists in the *abnormal position* of the granite nucleus. Granite usually forms an anticlinal axis to the rocks amid which it rises; these being symmetrically disposed on opposite sides of it. But in Arran it is not so; the granite has been protruded *close to the outer* or eastern *border* of the slate rocks, so as to come almost into contact on one side with the newer sedimentary strata. So near is it, that the slate band between it and these strata, on the hill side west of Corrie, is only a few yards in thickness; and it is even probable that in some places it is in contact with the sandstone. The protrusion of so large a body of igneous rock by plutonic fires, along the line of junction of the old slates and secondary formations, and its elevation to so great a height in a space so limited, have produced all those varied and interesting phenomena which have given so much celebrity to Arran, and rendered it such an admirable field of study.

Such being the remarkable position of the granite in the northern mountains, it is not perhaps more than was to be expected, that in its protrusion from beneath sedimentary formations already deposited before it was raised to the day, this granite should also pierce through and appear as an intrusive rock among them. Yet its occurrence in such a situation long escaped notice, and was not observed till 1837, when Mr. Ramsay, in his careful survey of the island, discovered it amid sandstones of carboniferous age on the west side of Glen Cloy. M. Neckar, however, was the first to describe the district, which he named Ploverfield, in 1839. This granitic outburst, and the interesting attendant phenomena, are well and fully described in Mr. Ramsay's admirable *Guide*, and need not now be further referred to. Our own inquiries have given a very considerable extension to the Ploverfield granite; and in the summer of 1855, we were so fortunate as to discover another tract of granite, overlooked by all previous observers.

Driving along the lower portion of the String road towards Shiskin, with a party of friends on an excursion to King's Cove, I noticed an extensive talus of blocks reaching from the base of a high cliff on the left, to wtihin a few hundred yards of the road. These struck me as very unlike the blocks of sandstone, which strew the surface all along on that side; and going up to the boundary of the talus, I found that it was composed of granite blocks. I then also perceived that the cliff itself was formed of granite; and it struck me as remarkable that on a route so frequented as this, the occurrence of the granite had so long remained unnoticed. On an early subsequent visit, I determined the limits of the tract to which the rock is confined. The annexed ideal section, from east to west, between Corriegills and Mauchrie water, represents the position and relations of this granite tract, as well as that of Ploverfield, the horizontal extent of the sandstone being of course much contracted:—



(*a*) *Granite of Ploverfield;* (*b*) *new granite tract at Craig-Dhu;* (*c*) *old red sandstone of Mauchrie water;* (*d*) *sandstone with beds of limestone, the whole of carboniferous age;* (*e*) *eruptive rocks of Doir-nan-Each, the highest hill in the west district of the south section of the island, chiefly porphyry and highly hornblendic basalts.*

The granite tract now to be described lies on the south side of the Shiskin road, nearly opposite the farm house of Glaister. Here the hill, whose base is skirted by the road all the way down from the "String," overhangs the valley of Mauchrie water in a steep cliff called Craigmore, Craig-Dhu, or The Corby's Rock. This cliff is the outer edge of a small plateau or table land, cut off from the higher ground behind, towards Doir-nan-Each, by a deep hollow which completely isolates it. The summit is 700 to 800 feet above the valley, and is more than a quarter of a mile long, by one to one and a-half furlongs broad. It descends steeply towards Shiskin on the south-west, and slopes gradually north-east towards Moniquail. The summit and sides of this plateau are formed of fine-grained granite, very similar to that of Ploverfield. The base of the cliff towards Mauchrie water is covered by a long talus of granite blocks and smaller fragments, reaching to within 200 or 300 yards of the road, and appearing even at that distance of very different aspect from fallen masses of sandstone.

The granite here seems to rise either through the old red sandstone, or at the junction of this rock with the carboniferous strata. The granite is nowhere seen *in situ* at a low level; the talus before mentioned obscures the rocks along the base of the hill, and the ground by the roadside, and along the valley, is deeply covered with alluvium. At one spot only could we detect any rock *in situ*. Immediately below the bridge, by which the road crosses a small stream, the water runs over a projecting mass, which seems to be either a serpentine, a greenstone with much felspar, or an iron-shot claystone. But at a high level on the west, south, and east sides of the plateau, the granite is seen to rise through a coarse conglomerate; and numerous contacts are observable. These are highly interesting, and clearly indicate the intrusion of the granite subsequently to the formation of the conglomerate. The base of this conglomerate is a coarse sand, and the imbedded fragments sandstone, quartz, and granite. The base is highly indurated, and assumes a porphyritic structure; the sandstone is rendered crystalline, and the quartz has been fused, and often converted into a substance resembling porcellanite. The fragments of granite are of an elliptic form, less rounded than the quartz, and are exactly like the adjoining mass of granite in structure and component parts. Whence have these granite fragments been derived? From the body of fine granite among the northern mountains, or from the adjoining mass itself? Mineral structure does not enable us to determine—the two rocks are so similar. If from the former source, then we must conclude that the granite of the interior was elevated so as to be exposed to disintegrating causes, while the conglomerate was forming; in which case granite fragments ought to occur abundantly in the sandstone conglomerates; but this is not found anywhere in Arran;—a fact noticed by all observers. Even here the fragments occur only in close proximity to the granite itself. Must we not then rather suppose that pieces of the granite adjoining, when this rock was erupted in a fluid or semi-fluid state, were injected among the outer strata of the conglomerate, also fused by the contact, and so became imbedded in these strata only?

Granite, then, occurs in Arran in three disconnected tracts, and the question remains, are these of three distinct ages, or were they erupted simultaneously, so as to pierce through the three formations during one and the same period of disturbance? The latter is by far the most probable supposition, because we find; *first,* that while the granite of the nucleus, that is, of the interior mountains, everywhere pierces through, and alters the enveloping slate-band; this slate-band, in some places where it is very narrow, *has also altered the old red sandstone in contact with it,* having been itself in fusion from contact with the molten granite; and, *secondly,* that the actual position of the old red sandstone and carboniferous limestone along the Corrie shore, indicates great upheaval and disturbance by protruding masses of granite advancing in that direction from the nucleus. The entire series of sedimentary strata in Arran was therefore deposited prior to the intrusion and elevation of the granitic masses; and the Craig-Dhu and Ploverfield tracts were most probably formed simultaneously with that of the northern mountains. This question will be found discussed at greater length in the second edition of a pamphlet on *The Geology of Clydesdale and the Clyde Islands.*

The President made a communication illustrative of the Osteology of the Higher Apes, and exhibited various specimens, among which was the skeleton of a young Chimpanzee recently prepared.

A copy of the Census of Ireland for 1851 was presented to the Library by Mr. Hastie, M.P., for which the thanks of the Society were voted.

April 2, 1856.—William Murray, Esq., *in the Chair.*

Mr. Thomas Boyd and Mr. Thomas Watson were elected members.

Dr. Taylor, Andersonian University, read a paper "On the Nature and Causes of Waterspouts."

Dr. Taylor also exhibited a new method of Illuminating the Magic Lantern.

April 16, 1856.—*The* President *in the Chair.*

Mr. William Mackenzie was elected a member.

The President announced that, in compliance with an invitation from the Council, Professor Henry D. Rogers, of Boston, United States, had consented to deliver a Lecture to the Society on the evening of the 30th instant, and that it was proposed that the meeting should be held in one of the public halls of the city—admission for the members and their friends being by ticket. The Society approved of this proposal.

Mr. Bryce presented the Report of the Committee on the Low Temperatures of the Winter of 1854-5.

Report on the Low Temperatures of the Spring Months of the Year 1855. By James Bryce, M.A., F.G.S.

The Report now laid before the Society has been prepared in conformity with a resolution passed at the close of last session. A Committee was then appointed, "consisting of Dr. Thomas Anderson, Professor of Chemistry; Mr. James Bryce, High School; Mr. Thomas R. Gardner, optician; Mr. Robert Hart, Cessnock Park, Govan; and Mr. James King, Windsor Terrace—Mr. Bryce, Convener"—with instructions "to make inquiries as widely as possible respecting the low temperatures of the spring months of the present year, and report to the Society next session." The Committee soon after entered on the inquiry. In reply to a circular distributed as widely as possible during the summer, returns were in due course received from a considerable number of places, widely separated over the country. On these, and the facts collected by the members of the Committee, the present Report is founded. The author desires to acknowledge his special obligations to Mr. Gardner and Mr. Hart, for the valuable aid which they have rendered. Much information was also obtained by the kind co-operation of Mr. Clark of the Botanic Garden.

It is matter of regret that the Report now presented cannot lay claim to much scientific value. The instruments whose indications are given were not compared with one another, or with any common standard, so as to give precisely correspondent results. When the inquiry was undertaken, no combined system of observations in regard to Scottish meteorology had yet been instituted; and the Committee had, therefore, no choice but to make use of such information as they could draw from the registers of isolated observers, employing instruments, probably good enough in their construction, but without that value in their indications which is given by inter-comparison, and the application of a uniform plan of reduction. Happily, however, such a combined system has now been established; and any future Report having reference to years subsequent to the present will possess a true scientific value. In September last, at the meeting of the British Association in this city, a Meteorological Society for Scotland was organized; in connection with which, and at suitably selected stations, there will soon be a great many observers recording their observations simultaneously at the critical hours, by means of instruments of the best construction, and previously compared with a standard. The discussion and comparison of these, under the able superintendence of Mr. Keith Johnston and Dr. Stark, will, doubtless, in a few years, make us acquainted with many important laws; while the publication, from time to time, of the continuous and combined records of all the phenomena, will render unnecessary such an inquiry as that entered upon by your Committee. This Report, indeed, can only be regarded as a feeble attempt to supply the want of such a society—to foreshadow the advantages which will result from its labours, and to fix a sort of rudely measured approximate base, with which to compare inquiries and observations in years to come.

The spring months of 1855 were distinguished from those of many preceding years by a continued low temperature. During the month of December, 1854, and the early part of January following, the weather was mild and open, with slight frost on a few days only, and winds varying, at Glasgow, through the quadrant, from S.W. to N.W. Here, on the 12th January, the wind went about E., and a slight frost was first experienced on the night of the 12th-13th. The change of weather was almost simultaneous at the other stations from which we have returns, and which range from Stornoway, the Orkneys, Elgin, and Aberdeen, to Kirkcudbright. Frost, at first slight, set in between the 10th and 14th

January, and continued of extreme severity till the end of February. From that date till the 6th of April, the temperatures were somewhat higher, but still very much lower than usual in the spring months. Partial thaws, with slight elevation of temperature, and very little rain occurred on the 19th and 20th January; on the 3d, 4th, 5th, and 24th February; and again on the 1st, 2d, 12th, and 13th March. With these exceptions, at Glasgow, and most of the other stations, there was continuous frost, with occasional slight snow-falls, throughout the period. The details will be seen in the accompanying tables. These do not, however, give the complete registers at all the stations. Our inquiries having been chiefly directed to the subject of temperature, complete registers were not asked for; and besides, their insertion would have made the tables very cumbrous. For the returns received we have to express our grateful thanks to the following gentlemen:—Alexander Smollett, Esq., M.P., Cameron House, near Bonhill, Dumbarton; Sir James Matheson, Bart., M.P., Stornoway Castle, and the Rev. James Gunn, minister of Cross, Stornoway; E. J. Bedford, Esq., R.N., Manor House, Oban; J. W. Melville, Esq., Mount Melville, and Alexander Watson Wemyss, Esq., Denbrae House, by St. Andrews; J. B. Neilson, Esq., Queen's Hill, Stewarton, Kirkcudbright; William Miller, Esq., Eastwood Hill, near Mearns, county of Renfrew; Professor Nichol, College Observatory, Queenston, Glasgow; Professor Ferguson, King's College, Aberdeen; Professor C. Piazzi Smyth, Edinburgh; Mr. George Berry, Dalvey Gardens, Morayshire; Mr. Clark, Botanic Garden, Glasgow; Professor Dickie, Queen's College, Belfast. Of the Committee, Mr. Robert Hart, Cessnock Park, Govan; Mr. Thomas R. Gardner, Ibroxholm, two miles west of Glasgow; and the author of this Report, have furnished their registers. That of the author is kept on the north-west boundary of the city, yet exposed to influences tending to elevate the temperature, as will be seen by the higher readings of the thermometer. The temperatures at Sandwick, Orkney, are taken from the well known register, published each month, for many years past, in *The Philosophical Magazine and Journal of Science* (vol. ix., 4th Series, January to June, 1855); those at Edinburgh and Orton Hall, near Peterborough, Yorkshire, from *The Scottish Gardener and Journal of Horticulture* (vol. iv., 1855),—the registers at these places being kept by Mr. Macnab of the Botanic Garden, and Mr. John Reid.

One unavoidable defect of the tabulated results has been already alluded to—the want, namely, of previous inter-comparison of the instruments. Another arises from the circumstance that some of the columns give the maxima and minima temperatures, and others those at the hours now usually regarded as the *mean hours*. The numbers in these columns are, therefore, only comparable in a very general way; they do, however, indicate to us that the lowest morning and evening temperatures occurred on the days of minima at most of the stations, and that the changes during the period were in a great measure correspondent. Setting in on various days between the 9th and 14th January, the frost was fully established at all the stations by the middle of the month, and till the end of February the weather continued of extreme severity. The whole of March and the first week of April exhibited somewhat higher, but still very low general temperatures; and it was not till the 6th April that genial weather was experienced, with rain and westerly breezes. The period, therefore, comprised from eighty to eighty-five days, one of very unusual continuance, in these islands, of temperatures so low and widely experienced. It appears from all the returns, on comparing the indications at high and low adjoining stations, that the cold was more intense at the lower station. The minima, as is usual in such cases, occurred towards the close of the period of greatest severity of the frost, that is, towards the end of February. During the entire period, the wind remained almost constantly in the northern semicircle of the horizon, ranging through 135° between E. and N.W. Stornoway alone presents an exception, especially in January, the wind being from the south quarter during twenty-five days, and from the north during the last four days only. The wind was almost always so light that it was often difficult to know the exact point from which it proceeded. The barometric column was at its maximum at the setting in of the frost, at all the stations. The heights are given in the following table :—

January	11	12	13	14	15
Glasgow,......................	...	30·65	30·65	...	...
Bonhill,........................	...	30·70	30·69	...	...
Stornoway, ...	30·45	30·45	30·45	30·40	30·45
Sandwick,.....................	...	30·58	30·54	...	...
Boston, ...	...	30·22	...	...	...
Chiswick,.....................	...	30·543	...	...	...

The minimum at Glasgow was 29·714, and occurred on the 25th February, with snow-fall and wind at N.E. At the other stations the minima were nearly correspondent, being towards the close of the month. The heights corresponding to the lowest temperature on Feb. 17th were 30·004 and 29·964, at Glasgow. At the other stations the height of the mercury at the times of lowest temperatures was also intermediate between the maximum and minimum, as will be seen by reference to the tables. In no case does the minimum temperature correspond with a maximum of pressure, or *vice versâ*. We have no data, however, in our returns, for separating the effects of the dry air and aqueous vapour.

In the following table the minima temperatures are brought together for the sake of easier comparison. Those temperatures only are given which reach 20° F., or under. The elevation of several of the stations above the sea level is annexed:—

MINIMA TEMPERATURES, FEBRUARY, 1855.

Days—	10	12	13	14	15	16	17	18	19	20	21	22	23	Elev. of Stn.
														Feet.
Glasgow—Bot. Garden,	...	...	...	...	7°	...	...	...	...	...	...	...	...	106
Observatory,............	...	...	...	...	18°	10°7	8·5	...	...	...	...	...	...	179½
Govan,..................	...	...	18°	18°	14·5	10	7	9°5	...	...	...	12°	9°	28
Ibroxholm,..............	...	...	...	...	16	12	9	10	19	20	16	14	15	36
Lansdn. Cres., 9 A.M.,..	...	...	20	20	20	14	11	...	...	...	19	15	...	85
Eastwood-hill,..........	...	...	...	...	...	12	11	...	...	...	15	...	...	150
Bonhill,................	...	...	...	17	15	11	16	15	...	17	14	...	...	...
Oban,...................	...	...	...	19	19	19	...	...	...	...	...	18	...	12
Stornoway,..............	...	...	...	18	...	17	...	...	19	20	15	14	12	65
Sandwick, 8½ P.M.,.....	...	...	...	...	20	...	...	...	...	...	...	20	...	...
Dalvey,.................	...	...	...	...	...	—4	...	...	...	...	...	...	...	...
Aberdeen—King's Col.,	...	...	...	...	...	—2½	...	...	...	...	...	...	...	30?
Marischal,..	...	...	...	...	...	—1	...	...	...	...	...	...	...	50?
St. Andrews,............	...	...	..	...	18	17	...	17	...	...	...	...	...	328
Edinburgh,..............	...	...	13	14	5	10	...	15	...	15	18	...	...	50
Stewarton,..............	...	...	...	...	13	13	10	...	...	...	...	...	...	160
Orton,..................	13°	2	7	10	18	16	12	...	...	8	8	20	5	...
Boston,.................	...	...	...	...	...	...	...	12	...	...	...	11	...	...
Chiswick,...............	1	...	0	17	10	19	2	3	20	8	10	...	...	...
Belfast,................	...	...	...	18	13	19	20	17	...	...	...	...	...	50

At Orton, on February 1st and 27th, the temperature was 4°; on the 5th, 1°; on the 9th, 6°; on the 12th, 2°; on the 26th and 28th, 0°. Here, therefore, and at Chiswick, near London, the temperatures were lower than at any other of the stations, except those in Aberdeen and Moray shires. The yearly volume, issued from the Radcliffe Observatory by Mr. Manuel J. Johnson, and the Records of the Meteorological Society of England, show that at Oxford and various stations throughout England, the temperatures of the period were considerably below the mean of twenty-five years. The minima of February at Oxford were 7°·5 and 9°·5 on the 16th and 17th, exactly coinciding with the epochs of lowest temperature at almost all our stations—minimum at Huggate, Yorkshire, 13° on 18th February; at Torquay, 27°, day not named. The prevailing low temperatures over so wide an area are very remarkable, and probably much lower than any experienced for even a much longer period than twenty-five years. There was more or less snow at all the stations during the month of February; and with the trifling exceptions of the partial thaws already mentioned, the frost was persistent. About Glasgow, as well as at most of the stations, the depth of snow was inconsiderable—in high and in sheltered situations, about three to four inches; but completely wanting in those having southern exposure. Severe drifts occurred in Orkney, Moray, and Aberdeen shires; and at Orton and in Moray the snow for some weeks was nine inches deep. The mean temperature of the month at Chiswick was 28°·01; mean of twenty-nine years previous, 39°·07; mean of February, 1854, 37°·67. Regarding this month the Rev. C. Clouston of Sandwick has the following remarks:—

"Mean temperature of this month, ...	31°·64
Mean temperature of February for twenty-eight years previous,	38 ·24
Mean temperature of February, 1854, ...	39 ·22
Average quantity of rain in February for fourteen years previous,	3 ·39
Quantity this month, ...	1 ·32

The mean temperature of this month is lower than that of any month for the last twenty-eight years, except February, 1838, when it was 31°·31, and when there was snow during all the month, and for three weeks previously. This month it lay from the 11th till the last day; and the drift on the 23d and 24th formed high wreaths in many places, rendering the roads impassable to vehicles." We believe, however, that the severe weather in spring, 1838, here alluded to, was by no means so general as that of 1855. In 1838, however, Loch Lomond was completely frozen over, as on the 16th February, 1855. On the 17th it was visited by large parties from Glasgow, to enjoy and to witness the amusements of skating and curling upon this "Queen of Scottish Lakes." On the authority of Mr. Miller of Eastwood, we can state that on one occasion, prior to 1838, and also within this century, Loch Lomond was completely frozen and rendered passable. This was probably in the winter of 1813-14.

The mean temperature of March at Chiswick was 37°·61; mean of March for the last twenty-nine years, 42°·24; mean of March, 1854, 42°·54. Average amount of rain in March, 1·33 inch. At Sandwick, the mean of this month was 36°·61; mean for twenty-eight years, 40°·53; mean temperature of March, 1854, 45°·14—the highest during the whole period of twenty-eight years. The mean temperatures of March, 1837 and 1839, were 36°·54 and 36°·33 respectively, almost the same as that of March, 1855. The temperatures of April and May, 1855, were also from 3° to 4° below the means for twenty-eight years previous. Average quantity of rain for fourteen years, 2·52 inches.—Generally, as regards all the elements, the Oban, Stornoway, and Orkney stations, manifest the effects of oceanic influences, and the characters of a more insular climate, than is found at any of the others.

The fall of rain, as already remarked, was very inconsiderable during the period, owing to the steadiness of the frosty weather. The returns do not embrace this element except from a few of the stations; and these are brought together in the following Table. For the sake of comparison, we insert the amounts at Sandwick, Boston, and Chiswick, and add also the month of May. The melted snow is included in the Govan, Ibroxholm, and, we presume, in the other returns also :—

TABLE OF RAIN-FALL.

1855.	GOVAN.	IBROXH.	EASTWD.	BONHL.	STORNY.	SANDK.	BOSTON.	CHISWK.
January, ...	0·73	0·75	0·40	1·50	3·00	3·26	0·43	0·10
February,...............	0·68	0·60	0·05	1·80	1·50	1·32	2·18	1·35
March,..................	1·74	1·54	2·20	...	...	3·58	1·35	1·75
April, ...	1·38	1·26	1·10	...	...	2·89	0·23	0·26
May, ...	1·60	1·48	1·60	...	...	1·38	1·26	1·94
	6·13	5·63	5·35	...	...	12·43	5·45	5·40

Regarding the rain-fall at Eastwood-hill, Mr. Miller observes, that it is " not only much less than at Glasgow, but much less than in any other part of Scotland that he has heard of. In the corresponding months of 1854, the fall was 12·20 inches, or about two and a-half times as much."

The following Table shows the monthly average of these several months for a long series of years, and is inserted here for the sake of comparison with the foregoing Table, as showing the superior dryness of the early part of the year 1855 :—

TABLE OF AVERAGE RAIN-FALLS.

	JANUARY.	FEBRUARY.	MARCH.	APRIL.	MAY.
Glasgow—twelve years, ...	3·75	3·04	1·45	1·53	2·02
Sandwick—fourteen years,.......	4·38	3·39	2·52	1·83	1·68
Boston—nine years,................	1·53	1·02	1·31	1·43	1·20
Chiswick—twenty-nine years,...	1·74	1·54	1·33	1·59	1·85

Very few observations on which any dependence can be placed have been received in regard to the penetration of the frost of 1855 downwards into the soil. It was certainly considerable in many places; for in ground with a northerly aspect in the neighbourhood of Glasgow, ten days to a fortnight elapsed after the breaking up of the frost on the 6th of April, before the plough or spade could be employed to open up the soil; and farming operations were in consequence much delayed. With the arrival, however, of the genial weather, vegetation advanced with amazing rapidity; and the hay and other crops were very little, if at all, later than usual. Neither was the long drought followed by any unusual fall of rain.

The penetration of the frost would depend much on the nature of the soil. The following estimate has been formed by a skilful farmer and highly intelligent man in the Lewis, a friend of the Rev. James Gunn, whose kindness we have already acknowledged, and by whom this information also is sent to us:—

1. Into moss on which heath grows, the frost penetrated .	6 inches.
2. Moss on which no heath grows, ...	9 —
3. Arable land in field or garden, ...	12 —

In comparison to these, the frost of 1856 did not penetrate above one-fourth the depth. Mr. Miller of Eastwood makes the same estimate for arable land about Glasgow, viz., 12 inches.

As bearing on this point, Professor C. Piazzi Smyth has been so good as to furnish us with a copy of the register of the deep soil thermometers kept by him, and examined and entered weekly. We subjoin (see Table) the record of only two of these, t_4 and t_5, respectively at three feet and one-tenth of a foot in the soil—the others at six, twelve, and twenty-four feet being too deep for our purpose. Of the latter, Professor Smyth says, in a letter to us on September 8, 1855—"They are still suffering under last winter's cold, so slowly does the wave of annual temperature travel downward through the soil."

The indications given in the appended Table, drawn up from data kindly furnished by Professor C. P. Smyth, correspond with those of the other Tables. The thermometer t_5, one-tenth of an inch under the surface, read lowest on the 19th February; t_4 at three feet, on the 26th, or ten days after; and the readings generally are the lowest at or soon after the time of greatest cold,—a considerable rise taking place between the 2d and 9th of April—the 6th of that month, as already remarked, having been the day on which the frost finally broke up. The monthly means are given for four months of 1855 and the four previous years, in order to place the contrasts of temperature in a more striking light. The means for 1851-4 are taken from the Tables given in the last published or eleventh volume of the *Edinburgh Astronomical Observations.* These Tables embrace the entire series of observations of the Earth-thermometers since 1838, carefully reduced, and accompanied by descriptive and explanatory matter from the pen of Professor Forbes, and a brief statement of some of the results by Her Majesty's Astronomer for Scotland. A full exposition of the significancy of these Tables, by either of the distinguished physicists above mentioned, would be a great boon to the scientific world.

The influence of this severe season on trees and shrubs is remarkable. The following particulars have been kindly furnished by Professor Dickie of Queen's College, Belfast, being extracted from a paper by him on the subject, now passing through the press :—

In inland situations in Aberdeenshire, where there was a considerable covering of snow in February, all the young plants of *araucaria imbricata* were uninjured, except such as had branches protruding above the snow. Near the coast line, the effects on whin and broom were most conspicuous, for two reasons—the plants attain large size, and the covering of snow is less. Bushy plants, browsed by cattle, were uninjured, owing to the covering of snow. The effects were more conspicuous on these than on any other wild plants. They were generally killed in exposed places nearly to the ground. In the summer, new shoots were pushed out from below. Species of rosa, rubus, and salix, growing along with them, were uninjured. Sections of stems of whin and broom killed by the frost were examined under the microscope, but no change in the tissues could be detected. The only difference between them and sections of living ones was the existence of brown stains near the ducts; but this difference was not constant. There seems no way of accounting for the different effect of the frost, but by some original difference in constitution among plants. A great many exotic trees, and shrubs, were either materially injured or totally destroyed; but it would be rash to say that this indicates their inability to resist low temperatures under any circumstances. In every instance it was observed that the destruction was greater in low than in high situations, and this even in the same garden. This was seen in places not more than 100 yards apart, and differing only twenty feet in elevation. Dr. Dickie, rightly, we think, attributes this to accumulation of the heavier, colder, and damper air in such localities. After giving many striking examples from Aberdeenshire, the following is recorded from Belfast. The loss there was less, partly because the minimum temperature was greater than in Aberdeenshire, exceeding it by 14° to 17° F., and partly from the site of the garden being high and well drained. Among twenty plants destroyed, there were nine species of the pine tribe, one heath, and two other shrubs, which, in a locality three miles north-east, one mile from the sea, and 450 feet above its level, stood wholly uninjured. The Belfast garden varies from 50 to 75 feet above mean tide level. Dr. Dickie gives full details in this important paper regarding the plants destroyed in Aberdeenshire and at Belfast; and calls attention to the great value of observations and records on this subject, as affecting the naturalization of certain plants in our climate, and the knowledge which in a few years they would give us regarding the plants which might be expected to survive such changes of temperature in particular districts. Much ultimate disappointment, both to the buyer and seller of exotics, would thus be avoided.*

On the same subject, the following interesting particulars have been kindly furnished by Mr. Clark of the Glasgow Botanic Garden :—

"The following plants were destroyed in our garden by the severe frost of the spring of 1855 :—

"Thirty plants of Cupressus torulosus, which had stood out in the open border for some years. This fine coniferous plant was introduced from Nepâl in 1824, and has always been considered hardy.

"Cupressus funebris. This tree having been introduced from China in 1849, the stems had not attained the same degree of strength: though destroyed in Glasgow, it has survived in several other places.

"Prunus sinensis.

"Pinus microphylla and P. montezuma. Neither of these had been more than two years planted, and they were not sufficiently established to enable them to resist a degree of cold which they might have stood otherwise; microphylla has survived in many places.

"Libocedrus chilensis, destroyed also in most places. It was introduced from Chili in 1849.

"Many Portugal Laurels and Common Bays. In every instance where these were killed, they stood either under the shade of other tall trees, or in low damp situations, where the young wood of the previous year had not been sufficiently ripened, or exposed to the same amount of light and air as those standing in open situations."

"It was pleasing to observe," continues Mr. Clark, "that many exotics, not considered hardy, survived this most trying season (1855). Having been anxious to test the Rhododendrons of Dr. J. D. Hooker's Himalayan collection, I had some of them, previously kept in a cold frame, removed, before the winter set in, to an exposed situation. The following stood out without any protection and survived:—R. ciliatum and ciliatum-rosea, R. campylocarpum, R. lepidotum, niveum, R. glaucum, R. Wallichii. Also, R. barbatum safe, planted out two years previously. It is from northern India. In 1852 a plant of R. cinnamomea, a magnificent variety, introduced from Nepâl in 1820, was planted out, having been previously kept in the usual way in a greenhouse or conservatory, and sustained the frost uninjured. Cedrus deodara and Araucaria imbricata, quite safe, being in high dry situations.

* This paper has since been published, and will be found in *The Proceedings of the Botan. Soc. of Edin.*—*Scot. Gardener*, July, 1855.

The latter, however, does not thrive well in the neighbourhood of Glasgow, on account of the dampness and cold of the subsoil overlying our coal formation."

We have examined many scientific journals and transactions of learned Societies, in the hope of finding records of similar seasons of severity, with which to institute a comparison, and of perhaps catching some glimpse of a law of periodicity, or a return of such weather in cycles. But we have met with nothing worthy of bringing before the Society, excepting a few brief notices. One of these is from the pen of the celebrated Dr. Alexander Wilson, Professor of Astronomy in Glasgow University, whose theory of the solar spots, and the nature of the photosphere of the sun, has been generally adopted by astronomers. It is found in a short paper in *The Philosophical Transactions* for 1771, and refers to two days of January, 1768.

On the morning of Sunday, the 3d January, 1768, awaking early, he was surprised to find himself extremely cold in bed, and on putting out his arm to a table near his bed for a glass of water which stood there, and bringing it to his mouth, he found it was a mass of ice. Struck with an occurrence so extremely uncommon, he got up and dressed, and forthwith proceeded, with the aid of his son, to make various experiments, which he describes. We need here only give his record of the state of the thermometer on the two days mentioned. These are probably the lowest temperatures ever recorded as having occurred at Glasgow. The Observatory, where he resided, was in the eastern part of the College Park. The thermometer was properly protected.

Jan. 3, 1768.	10 h. a.m.,	5°	Jan. 3, 1768.	9 h. p.m.,	2°
—	11	7	—	9½	1
—	12	9	—	10	2
—	1 p.m.,	10	—	10½	2
—	2	11	—	11	2
—	3	9½	—	11½	1
—	3½	6½	—	12	0
—	4	3½	Jan. 4, —	12½ a.m.,	0½
—	4½	2	—	1	1
—	5	1½	—	2	0
—	6	1½	—	2½	3
—	6½	0½	—	3	6
—	7	—1	—	3½	7
—	7½	—0½	—	4	9
—	8	0½	—	4½	10
—	8½	1	—	5	12

The record extends no farther; and there seems to have been a sudden change of weather. On the forenoon of the 3d he laid a thermometer on the snow, in a shady place, and found that it fell in a very short time from 6° to —2°; and from this he inferred that before he began his observations there had been greater degrees of cold than those he had noticed. The depression was, no doubt, due to the increased radiation. This severe cold does not appear to have been general; for I find the greatest recorded cold at Liverpool, for January of that year, was 29° F. at noon; and at Middlewich, in Cheshire, at 8 A.M., 23° F.

In a paper in *The Manchester Memoirs*, vol. iv., 1793–6, Dr. Thomas Garnet brings together observations made at various places in England, and at Dumfries and Kirkmichael, in Scotland, for the years from 1768 to 1795. The lowest recorded temperatures of the period occurred at Chatham, in the last week of January, 1776. They range from 28° F. to $-3\frac{1}{2}$° F.; the latter being on the 31st, at the hours of 6, 7, and 8 A.M. In this paper the negative values are expressed by writing the figures *below* a *zero*. The winters of 1784 and 1786 seem also to have been characterized by low temperatures; also those of 1812-13, and 1813-14. At Dumfries, on Jan. 25, 1784, the thermometer stood at 8° F. early in the morning, and on the four previous days had ranged from 11° to 14°. The late John Templeton of Cranmore, near Belfast, a distinguished botanist, published in *The Belfast Magazine* for 1814 a paper, giving a list of the plants destroyed in the severe winter of 1813-14. The frost began in Nov., and on Dec. 29 the thermometer fell to 7° F.

The registers discussed by Mr. Glaisher in two papers in *The Phil. Trans.* (1849, part ii., and 1850, part ii.), run through seventy-nine years, and embrace 200,000 observations, made at Somerset House, Greenwich, Epping, and Lyndon in Rutlandshire. From these he has deduced, with that skill and sagacity which distinguish all his labours in this field, an approach to periodicity in the *mean annual temperatures* at Greenwich. The results are stated in Mr. Drew's admirable little work on Meteorology; where will also be found a plate giving the projected curve of temperature. So much as relates to our present purpose we give in Mr. Drew's words, p. 84:—"An inspection of the form assumed by this curve shows that, beginning with 1771, the years become gradually warmer till 1779, when the temperature in like manner declined, and a batch of cold years occurs, of which 1784 was the coldest. The heat then increased, but not in so great a degree, till 1794, when the extreme cold of that cycle, not so severe as before, was reached gradually in five years from that time. In periods varying from nine to fifteen years, throughout the whole series, we find the cycle of hot and cold years repeated." This is, we believe, the only attempt yet made in this country to grasp such a law of periodicity. Mr. Glaisher has also deduced a formula by which the mean annual temperature of any place may be found from that of Greenwich.

TABLE I.—SELECTION FROM THE REGISTERS AT THE PRINCIPAL STATIONS.

January, 1855.

January.	Stewrton.		Ibroxhm.		Gov.	Glasgow—Lansdowne Crescent.						Bonhill, Dumbarton.					Oban—Manr. Ho.			Stornoway.				Orkney, Sandwick.		Edin.	Orton.
	Thermom.		Thermom.		Ther.	Barometer.		Thermom.		Wind.		Barometer.		Thermom.		Wind.	Ther.		Wind.	Barom.	Ther.		Wind.	Ther.		Ther	Ther.
	9 A.M.	9 P.M.	Max.	Min.	Min.	9 A.M.	9 P.M.	9 A.M.	9 P.M.	9 A.M.	9 P.M.	10 A.M.	10 P.M.	Max.	Min.		Max.	Min.			Max.	Min		9¼ A.M.	8½ P.M.	Min.	Min.
1	45	44	43	41	45	29·800	29·850	43	42	W.	N.W.	29·80	30·00	45	42	W.N.W.	44	39	W.N.W.	29·80	42	40	S.W.	36·5	34·5	37	...
2	44	47	43	42	...	30·050	30·056	43½	47	S.W.	W.	30·09	30·12	50	44	W.	47	41	W.N.W.	29·75	42	41	S.W.	36	39	43	...
3	45	44	49	42	...	30·100	30·112	49	47	W.	W.	30·15	30·16	51	43	W.	47	41	W.	29·45	45	42	S.W.	46	46·5	43	...
4	45	46	48	42	...	30·040	29·880	43	45	W.S.W.	S.W.	30·08	29·84	50	45	W.N.W.	46	43	S.W.	29·40	46	44	S.W.	48	48·5	45	...
5	46	44	48	45	...	29·850	29·818	49	45	S.W.	W.	29·77	29·91	50	42	W.	47	42	S.W.	29·80	42	38	S.W.	40·5	42	43	...
6	43	45	46	44	...	30·018	30·190	45	47	W.	W.S.W.	30·14	30·22	50	42	S.W.	46	43	S.W.	29·85	45	40	S.W.	40·5	43	44	...
7	46	45	51	42	...	30·200	30·250	49	47	S.W.	W.S.W.	30·54	30·30	50	44	S.	47	46	S.S.W.	29·65	45	45	S.W.	48	46.5	46	...
8	46	45	49	47	...	30·212	30·104	47	46	S.W.	S.W.	30·23	30·07	49	35	W.	48	45	S.S.W.	30·10	32	28	S.	47·5	41·5	33	...
9	36	32	47	37	33	30·213	30·470	37	46	W.	N.E.	30·30	30·58	45	26	N.E.	48	38	W.	30·05	32	28	S.	37	38	22	...
10	26	34	42	26	26	30·520	30·480	29	33	S.W.	N.E.	30·58	30·52	45	30	W.	39	29	S.	30·35	44	40	S.	36	39·5	33	...
11	37	39	38	27	26·5	30·490	30·480	40	42	S.W.	W.	30·54	30·57	48	39	W.	46	39	S.	30·45	45	44	S.	48	41·5	39	...
12	41	39	45	38	37	30·630	30·650	42	42	E.	E.	30·68	30·70	44	30	N.W.	46	39	O.	30·45	38	36	S.	41·5	41·5	27	...
13	39	32	42	31	30	30·650	30·626	35	32	N.E.	E.N.E.	30·69	30·68	35	30	W.	37	30	O.	30·45	30	28	S.	43·5	34	30	...
14	35	32	34	28	27·5	30·600	30·600	31	31·5	N.W.	N.W.	30·63	30·64	39	24	W.	37	29	S.	30·40	40	35	S.	43	43	28	...
15	26	38	34	24	22	30·515	30·400	24·5	31	W.	W.S.W.	30·56	30·41	40	30	S.W.	41	29	var.	30·45	42	38	S.	44	38	34	4
16	36	30	37	25	26	30·280	30·250	34	33	N.E.	E	30·34	30·40	38	25	W.	40	30	N.N.E.	30·25	32	30	S.	37	38	31	6
17	32	28	37	27	25·5	30·375	30·436	31	29·5	E.N.E.	E.N.E.	30·50	30·51	35	21	N.W.	31	28	E.	30·20	30	30	S.	35	38	23	12
18	20	36	34	22	19	30·312	30·170	25	32	W.	W.	30·36	30·24	44	27	N.W.	37	23	E.	30·10	35	28	S.	39	44	33	4
19	36	37	39	24	24·5	30·175	30·100	37	36	N.	E.N.E.	30·20	30·18	44	33	E.N.E.	43	36	N.N.E.	30·05	40	39	S.	42	40	32	14
20	31	26	42	35	35	30·120	30·120	34	31	E.N.E.	E.	30·21	30·21	37	28	E.	38	35	S.E.	30·05	35	30	S.	38·5	37	29	6
21	31	35	37	27	26	30·086	30·058	32	32	E.N.E.	E.N.E.	30·18	30·12	38	33	E.	35	26	S.	29·95	30	24	S.	37	37	34	4
22	33	24	36	34	34	29·950	29·900	34	30	E.	E.S.E.	30·00	30·00	37	23	E.	36	33	E.	29·95	32	30	S.	38	35	22	4
23	22	24	36	23	22	30·000	30·100	25	29	E.	E.	30·11	30·26	33	23	N.E.	34	30	E.	30·00	30	30	S.	36	34	28	2
24	30	29	29	23	21	30·240	30·240	30	31	E.N.E.	E.	30·30	30·35	37	23	S.E.	33	25	S.E.	30·00	32	30	S.W.	35	34	32	4
25	34	30	33	24	22	30·262	30·220	25	32	N.E.	N.W.	30·35	30·23	38	28	W.N.W.	36	28	O.	29·95	30	28	S.W.	38	37	29	1
26	34	31	36	24	24	29·958	29·958	32·5	31	N.	N.E.	30·00	30·10	39	27	E.S.E.	37	33	E.N.E.	29·90	29	26	S.E.	33	34	30	0
27	31	31	36	30	29	30·100	30·150	32	30·5	N.E.	N.E.	30·22	30·30	37	21	E.	33	28	E.	29·85	29	27	N.	36	36	21	6
28	23	29	35	19	12·5	30·006	29·910	25	27	N.	E.N.E.	30·10	30·00	38	20	E.N.E.	35	23	E.	29·80	30	26	N.E.	33	35	23	0
29	22	31	36	19	18	29·875	29·832	25·5	27·5	E.	E.	29·98	29·90	36	20	N.W.	31	24	E.S.E.	29·70	25	25	N.	28	29	19	4
30	22	31	33	18	17·5	29·832	29·900	19	27	E.	E.	29·96	30·00	34	23	S.E.	30	22	E.S.E.	29·60	25	20	N.	29	30	22	1
31	26	31	31	19	20	29·886	29·880	25	26·5	E.	E.	29·98	30·02	32	27	E.N.E.	30	24	E.	29·70	23	19	O.	28	31	30	2

February, 1855.

TABLE I.—*Continued.*

February.	Strtn. Ther. 9 A.M.	Strtn. Ther. 9 P.M.	Ibro. Ther. Max.	Ibro. Ther. Min.	Govan. Ther. Max.	Govan. Ther. Min.	Glasgow—Lansdowne Crescent. Barometer. 9 A.M.	Barometer. 9 P.M.	Ther. 9 A.M.	Ther. 9 P.M.	Wind. 9 A.M.	Wind. 9 P.M.	Observatory. 1855. Min.	Observatory. 1856. Min.	Bonhill. Barometer. 10 A.M.	Barometer. 10 P.M.	Ther. Max.	Ther. Min.	Wind. —	Oban. Ther. Max.	Ther. Min.	Wind. —	Stornoway. Bar. —	Ther. Max.	Ther. Min.	Wind. —	Orkney, Sandwick. Barometer. 9¾ A.M.	Barometer. 8¾ P.M.	Edin. Th. Min.	Orton. Ther. Min.	Belfast. Ther. Min.	Aberdeen. Ther. Max.	Aberdeen. Ther. Min.
1	30	25	30	25	31	28	30·050	30·150	28·5	29	E.N.E.	E.	24	27	30·19	30·36	36	21	E.S.E.	31	25	E.N.E.	29·95	25	15	S.W.	35	35·5	15	4	27	36	18
2	28	34	35	21	34	19	30·220	30·150	25	28	E.	E.	25·4	30	30·38	30·28	36	27	E.	33	24	E.*b*.N.	30·05	22	19	S.E.	37·5	30	33	12	30	34	9
3	33	32	35	23	36	26	29·930	29·800	33	32	E.	E.	31·8	...	29·99	29·70	37	34	E.N.E.	39	29	E.	29·85	32	30	S.E.	35	35	32	?	30	36	25
4	35	35	37	35	38	34	29·750	29·760	36	36·5	E.	E.	...	26	29·50	29·60	39	38	E.S.E.	41	37	N.E.	29·30	32	32	E.	36·5	36	35	?	33	39	35
5	35	35	37	36	40	35	29·760	29·780	37	33	N.E.	E.N.E.	33	32·1	29·69	29·78	39	32	E.	40	35	E.N.E.	29·60	35	32	E.	36	35·5	33	1	39	39	35
6	35	33	36	34	40	33	29·800	29·812	36	34·5	E.N.E.	E.N.E.	33.2	38	29·83	30·04	41	34	E.	38	33	N.N.E.	29.70	32	30	E.	36·5	26	31	12	36	37	31
7	24	20	39	33	...	...	29 976	30·050	33·5	30	N.N.E.	E.N.E.	32	43	30·13	30·20	40	27	N.N.E.	36	33	N.E.	29·75	35	32	E.	35	33	26	4	37·4	40	31
8	29	27	37	28	48	28	30·150	30·050	29	27	E.	E.	25	39·8	30·32	30·28	34	26	E.	33	27	N.E.	29·70	32	30	E.	33·5	32·5	27	?	31	38	30
9	28	28	30	27	34	27	30·135	30·186	29	27	E.N.E.	E.N.E.	25·5	39·3	30·31	30·31	32	27	E.	31	26	E.	29·95	29	25	E.	31·5	32	28	6	30	33	31
10	32	25	31	29	34	29	30·062	29·865	29	26·5	E.	E.N.E.	27·6	...	30·20	29·98	37	25	E.N.E.	33	21	N.E.	30·10	30	23	E.	37·5	35	29	13	29	33	18
11	31	30	32	28	32	25	29 766	29·790	32	33	N.N.E.	E N.E.	...	30·2	29·87	29·85	38	22	E.	34	28	N.E.	29·60	28	24	E.	34·5	30	22	18	22	33	23
12	22	25	36	21	36	20	29·762	29·762	23	25	E.N.E.	E.N.E.	23·8	36	29·85	29·80	39	20	E.	33	23	N.E.	29·55	27	25	N.	33	29	16	2	30	37	23
13	23	31	35	18	36	15	29·750	29·750	20	23	N.E.	N.E.	20	35·5	29 73	29·70	37	23	E.N.E.	32	22	N.N.E.	29·50	25	20	N.E.	29	23	17	7	23	34	22
14	24	26	35	18	...	17	29·750	29·750	20	25	N.N.E.	N.N.E.	20·7	34·2	29·68	29·74	32	17	E.	28	19	Var.	29·40	30	18	S.	26	23	14	10	18	33	17
15	13	21	33	16	31	14·5	29·748	29·850	20	26	E.S E.	E.S.E.	18	43·1	29·90	30·12	31	15	E.S.E.	29	19	E.	29·30	30	25	N.	25	20	5	18	13	33	20
16	13	27	32	12	34	10	30·000	29·975	14	24	E.S.E.	S.E.	10·7	39·2	30·15	30·13	28	11	S.S.E.	29	19	S.E.	29·70	27	17	N.	31	28	10	16	19	39	—1
17	10	22	30	9	...	7	30·004	29·964	11	31	N.W.	W.	8·5	...	30·11	30·12	35	16	S.W.	34	21	S.S.E.	29·60	30	25	N.	35	34·5	25	12	20	23	4
18	24	29	32	10	...	9·5	29·936	29·994	23	32	W.N.W.	W.	...	32	30·12	30·18	33	15	N.N.E.	37	25	N.N.W.	29·65	35	29	N.	34·5	32	15	26	17	31	11
19	17	29	38	19	41	18	29·973	29·910	23·5	33·5	E.S.E.	S.E.	17·4	33	30·20	30·12	35	23	N.E.	37	24	Var.	29·65	25	19	S.	31·5	29	24	22	21·5	34	21
20	23	22	37	20	40	18·5	29·912	29 888	31	30·5	S.E.	S.E.	21·8	30·4	30·08	30·01	41	17	E.N.E.	36	30	S.	29·65	22	20	S.	28	24·5	15	8	22	39	22
21	13	23	36	16	40	15	29·904	29·900	19	26	N.	N.E.	16·7	35	30·03	30·08	34	14	E.	36	21	Var.	29·65	29	15	S.	31	27	18	8	27	34	22
22	12	28	32	14	35	12	29·910	29·900	15	27	E.S.E.	E.N.E.	12·8	31·3	30·08	30·02	35	20	E.S.E.	33	18	E.	29·65	25	14	S.	30	20	21	20	27	35	14
23	25	32	32	15	36	9	29·860	29·864	26·5	33	W.N.W.	W.*b*.S	26·8	33·5	30·00	30·08	39	22	W.	35	23	E.	29·40	32	12	N.	29·5	30	22	5	30	34	15
24	24	32	37	26	40	24	29·986	29·750	35	40	S.W.	S.S.W.	27·5	37·5	29·83	29·80	44	31	S.S.W.	39	30	W.S.W.	29·25	27	25	N.	28	32	30	14	24	37	20
25	31	33	39	30	45	30	29·714	29·720	32	30·5	N.N.E.	E.*b*.N.	30	...	29·51	29·64	37	31	W.	33	31	E.	29·15	30	20	N.	33	27·5	31	?	34	41	25
26	30	27	35	31	37	31	29·720	29·720	31	37	N.E.	W.	...	41	29·66	29·83	41	28	N.W.	35	30	N.E.	29·35	31	13	N.	30	32·5	26	0	34	35	19
27	34	34	38	31	39	30	29·732	29·710	32·5	33	W.N.W.	W.*b*.S.	29·5	44 2	29·80	29·78	43	33	S.E.	37	31	S.E.	29·30	32	19	N.	27	35·5	31	4	34	37	14
28	35	36	41	33	40	33	29·728	29·710	34	40	W.*b*.N.	S.S.W.	32·5	42·4	29·74	29·50	49	37	N.N.E.	44	31	N.W.	29·25	34	33	S.	38·5	36	35	0	37·4	40	23

March, 1855. TABLE I.—*Continued.*

March.	Stewarton. Thermom. 9 A.M.	Stewarton. Thermom. 9 P.M.	Ibroxhm. Thermom. Max.	Ibroxhm. Thermom. Min.	Govan. Thermom. Max.	Govan. Thermom. Min.	Glasgow—Lansdowne Crescent. Barometer. 9 A.M.	Glasgow—Lansdowne Crescent. Barometer. 9 P.M.	Glasgow—Lansdowne Crescent. Thermom. 9 A.M.	Glasgow—Lansdowne Crescent. Thermom. 9 P.M.	Glasgow—Lansdowne Crescent. Wind. 9 A.M.	Glasgow—Lansdowne Crescent. Wind. 9 P.M.	Oban. Thermom. Max.	Oban. Thermom. Min.	Oban. Wind. A.M.
1	40	39	45	36	45·5	37	29·700	29·720	40	39	S.W.	W.	43	39	S.W.
2	41	34	44	39	46	38	29·750	29·732	39	39	W.	S.	44	38	S.W.
3	35	36	45	32	47	30·5	29 690	29·640	33·5	35	W.	W.	41	34	N.W.
4	32	40	43	33	45	31	29·636	29·650	33	36	S.S.W.	S.	45	32	S.
5	37	42	44	38	46	37·5	29·638	29·664	40	43	S.W.	W.S.W.	46	31	S.
6	28	32	46	34	48	32	29 800	29·770	35·5	40	S.W.	S.	46	39	S.
7	30	40	47	30	48	31	29·866	30·000	32	40	E.	E.	46	32	O.
8	32	39	43	31	45	32	30·100	30·190	33·5	36	E.	E.	43	28	O.
9	29	35	42	29	45	23	30·014	29·910	32	37	E.	E.	40	32	S.E.
10	32	31	40	32	39	32	29·838	29·758	35	32	W.	S.S.W.	40	33	Var.
11	33	32	42	26	41	25·5	29·726	29·700	32	31	E.	E.*b*.N.	35	30	S.E.
12	36	39	37	32	42	33	29·675	29·700	34	40	S.S.W.	W.S.W.	46	33	W.
13	39	40	44	37	46	38	29·788	29·700	38	37	N.*b*.W.	N.	43	37	N.W.
14	31	30	42	27	45	32	29·664	29·675	31·5	36	E.	E.	44	32	Var.
15	34	36	42	26	43	32	29·700	29·656	32	35	E.	S.E.	39	29	S.E.
16	40	40	42	33	42	33	29·672	29·660	37	38	S.E	S.W.	46	37	S.E.
17	40	35	46	33	47	32	29·654	29·670	38	39	S.S.W.	S.W.	45	34	S.E.
18	39	39	47	34	48	33	29·682	29·680	38	40	W.	W.N.W.	43	35	N.*b*.W.
19	32	40	46	30	48	29	29·820	29·860	32	34	E.N.E.	N.E.	45	32	E.
20	36	35	44	33	48	32	29·870	29·778	35	35	E.N.E.	E.	46	34	E.
21	35	35	37	34	47	34·5	29·660	29·652	36	39	E.	E.*b*.N.	40	33	E.
22	33	30	33	32	43	32	29·600	29·650	32	30	N.E.	E.*b*.N.	40	33	E.
23	35	31	33	31	39	30	29·652	29·652	32	35	N.E.	E.*b*.N.	39	27	N.
24	24	33	38	31	38	26	29·648	29·650	32	39	N.*b*.E.	N.	39	29	N.
25	29	34	42	25	32	23	29·676	29·674	32	36	N.W.	N.W.	43	27	O.
26	29	36	44	29	46·5	28	29·662	29·666	35	38	N.E.	E.N.E.	45	30	W.
27	34	33	49	34	49	32	29·800	29·950	32	33	E.N.E.	E.	39	32	N.W.
28	33	40	48	26	44	24	30·200	30·350	27	30	N.	E.N.E.	40	26	N.E.
29	26	36	43	25	43	35·5	30·470	30·485	27	29	N.E.	N.E.	42	28	Var.
30	28	34	47	26	45	26	30·500	30·506	28	30	N.E.	N.E.	45	28	S.W.
31	27	38	47	26	48	25	30·458	30·400	28	34	N.E.	E.S.E.	44	29	W.

TABLE II.—INDICATIONS OF THE EARTH-THERMOMETERS AT EDINBURGH.

1855.	Thermometers. 3 Feet. t_4	Thermometers. 0·1 Ft. t_5	Thermometers. Air T.	Monthly Means. 1855. t_4	Monthly Means. 1855. t_5	Monthly Means. 1851. t_4	Monthly Means. 1852. t_4	Monthly Means. 1853. t_4	Monthly Means. 1854. t_4	Monthly Means. 1854. t_5
Jan. 1	41·67	39·6	44·1							
8	42·89	42·6	48·0							
15	42·34	34·0	34·9							
22	40·95	34·4	35·9	41·52	36·24	42·54	41·96	41·47	39·03	34·72
29	39·76	30·6	32·1							
Feb. 5	38·71	33·3	35·1							
12	38·33	30·5	33·2	37·74	30·82	41·76	41·50	38·68	39·96	39·85
19	37·29	29·1	34·4							
26	36·63	30·4	36·1							
Mar. 5	37·16	36·6	46·0							
12	37·80	34·4	40·7	37·76	35·22	41·45	40·93	38·77	42·00	40·27
19	38·07	35·5	47·0							
26	38·02	34·4	44·9							
Apr. 2	38·44	36·6	48·2							
9	39·82	42·6	53·3							
16	40·89	45·9	55·8	41·07	43·62	43·14	43·32	41·75	44·42	43·97
23	42·26	45·7	64·0							
30	43·95	47·3	63·1							

Mr. D. Mackain read "Notes of a short Sojourn in Portugal."

The President exhibited a portion of a plane tree, inclosing the lower end of the metacarpal bone, probably of the front leg of a large ox or other ruminant.

The President also exhibited several recent improvements in the Microscope, executed by M. Nachet of Paris.

April 30, 1856.

The members of the Society, together with a large number of ladies and gentlemen specially invited, met in the principal hall of the Corporation Picture Gallery. Professor Rogers delivered an Address descriptive of the physical geography, geology, and natural history of the United States.

May 14, 1856 (the concluding Meeting of the Session was held this evening).—Mr. Harvey, Vice-President, *in the Chair*.

Mr. William T. Wilson and Mr. Richard J. W. Macarthur were admitted members.

Mr. Walter Neilson read a paper "On Coal-mine Pumping Engines."

Mr. Mackain exhibited and described Gorman's Patent Pressure Water Meter.

Mr. Bryce made a communication on a plan in use at Oxford and Greenwich for the application of photography to meteorological observations, and invited support to a proposal for establishing similar observations in Glasgow. Specimens of the photographic records were exhibited, and a promise given to bring the subject more fully under the notice of the Society at a future period.

PROCEEDINGS

OF THE

PHILOSOPHICAL SOCIETY OF GLASGOW.

FIFTY-FIFTH SESSION.

November 5, 1856.

THE Fifty-fifth Session of the Philosophical Society of Glasgow was opened this evening,—Dr. Allen Thomson, President, in the Chair.

The President delivered an opening address, which he commenced with the following tribute to the memory of Mr. William Gourlie, one of the Society's Vice-Presidents, whose death occurred since the last meeting of the Society:—

"It is incumbent upon me to notice with the feelings it has produced in my own mind, and which I know to be shared by all the members of the Society, the melancholy loss which we have sustained since we last met, by the death of one of our Vice-Presidents. Mr. William Gourlie died in the latter part of June last, from the effects of a very painful and dreadful disease—a tumour of the upper jaw. He bore his sufferings, and met death with the calm fortitude and resignation which might have been expected in one who throughout life had shown himself so estimable a man, and so true a Christian. The circumstances of his being removed, in the prime of life, from domestic happiness and from social usefulness, are too melancholy to admit of my alluding to them further in this place.

"In Mr. Gourlie, Glasgow has lost one of its most upright and useful citizens, this Society has been deprived of one of its most valuable members, and many of us lament the departure of one of the kindest and worthiest of our friends.

"Mr. Gourlie entered the Philosophical Society in 1841, and took an active part, during the whole of his membership, in promoting its welfare. Deeply interested in many branches of science, and well versed in some, he was always ready to further any project calculated to advance its progress, and most zealous and judicious in the management of any business committed to his charge. No greater proof could be given of his zeal and energy, in the conduct of business, than was shown by what he effected as the most active of the local Secretaries of the recent meeting of the British Association in Glasgow. To his exertions on that occasion no small share of the acknowledged success of all the local arrangements was due, and it is too much to be feared that his labours in this work tended, in some degree, to hasten the attack of his fatal disease.

"Mr. Gourlie was an excellent practical botanist; he possessed a large collection of native and foreign plants in his dried herbarium. His cabinet contained many interesting specimens of fossil plants, and his collection of shells was also extensive and well arranged.

"As a citizen and magistrate of Glasgow, Mr. Gourlie occupied a high place. His exertions for the improvement of the people were dictated by a truly philosophic spirit; and there are many institutions in Glasgow which owe much to his active and judicious co-operation."

The President next referred to the death of one of the oldest members of the Society, Mr. James Lumsden, senior, of Yoker, who had been a member of the Society since 1815. For some years Mr. Lumsden's declining health had prevented him from taking any part in municipal affairs, but this would not make us forget how much in former times Glasgow owed to his exertions as its chief magistrate, and the respect which his public spirit, enlightened views, and great energy had secured for him from his fellow-citizens.

The President then took a rapid glance at the condition and prospects of different branches of physical science at the present time, as bearing upon the business of the Philosophical Society. As most encouraging for the prospects of science, he referred to the continued success of the meetings of the British Association—the extended usefulness of the objects brought under the attention of the Royal Societies of London and Edinburgh—the continuation, notwithstanding the exigencies of the war, of the annual grant of £1,000 from Government to the Royal Society for the encouragement of scientific objects—the Memorial to Parliament, by the Committee of the British Association, on the means of advancing science, and the introduction of scientific acquirement into the qualifications for the Indian service.

He referred next to the recent progress of various branches of science, more especially to some of the most recent advances in theoretical physics and practical mechanics, organic chemistry, microscopic research as applied to animal and vegetable structure, and the knowledge of the phenomena of life in the animal and vegetable kingdoms of nature.

He concluded by offering some remarks on the condition and prospects of the Philosophical Society, with suggestions for extending its usefulness and interest. With this view he suggested that, in addition to the original papers presented at the meetings, a series of reports should be prepared, by authors appointed for the purpose, on the present state and recent advancement of various branches of science, to be read at stated meetings of the Society throughout the session. He further suggested, that among the subjects engaging the attention of the Society, though not belonging immediately to physical science, might be comprehended a view of the relations subsisting between masters and workmen. Considering how many of the most influential members of the Society are engaged in manufacture, and give employment to very large numbers of workmen, it does seem most expedient that this Society should occasionally take into consideration the best means of improving the condition of the working classes. The gulf between the upper and lower classes is, in this country, already far too wide. Notwithstanding our boasted system of Scottish education, the most alarming ignorance and moral abasement prevail, and are steadily increasing. The influence of the Society might be employed in directing and assisting masters in their efforts to promote the moral and intellectual elevation of those employed by them, and thus to establish a closer intimacy between master and men, which might tend to diminish one of the greatest evils of our social condition—that which places the interests of the two classes in opposition to each other. With these views the President suggested the establishment of a section of the Society, whose duty it should be to report upon the statistics of labour and education among the working classes.

On the motion of Dr. Anderson, the thanks of the Society were given to the President for his address.

Mr. Dawson and Mr. Bell were requested to audit the Treasurer's Accounts.

November 19, 1856.—Dr. Allen Thomson *in the Chair.*

The following gentlemen were elected members:—Dr. W. B. M'Kinlay, 2 New Smithhills, Paisley; Mr. A. Hannay, Scotland Street, Glasgow; Mr. James M. Gale, C.E., 170 Buchanan Street; Mr. James Reid, Engineer, Hydepark Foundry, or 334 St. Vincent Street; Mr. James Boyd Thomson, F.S.A., Traffic Superintendent, E. and G. Railway, Glasgow; Mr. Wm. Tod, Engineer, Clyde Foundry; Mr. William Tait, Engineer, Scotland Street; Mr. Wm. L. E. M'Lean, Lancefield Forge; Mr. Edmund Hunt, Engineer, 109 Renfrew Street; Mr. Archibald Gilchrist, Engineer, 33 Anderston Quay; Mr. George Anderson, St. Rollox; Mr. John Ramsay, of Kildalton, Argyllshire.

Mr. Cockey, the Treasurer, gave in the following abstract of his Account for Session 1855–56:—

1855.	Dr.							
Nov. 1.—	To Cash in Union Bank,	£82	3	10				
—	„ in hands of Treasurer,	1	19	9				
					£84	3	7	
—	Entries of 42 new Members, at 21s. each,	44	2	0				
—	Annual Payments from 9 Original Members, at 5s.,	2	5	0				
—	Annual Payments from 266 Members, at 15s.,	199	10	0				
—	Payments from 6 Members in arrear,	3	10	0				
					249	7	0	
—	Sale of *Proceedings*,				0	10	11	
—	M. Connal, Esq., for use of Hall,				0	10	0	
—	Interest on Bank Account,				1	11	2	
					£336	2	8	

1856.	Cr.							
Nov. 7.—	By New Books, including Subscriptions to the Cavendish, Ray, and Palæontographical Societies,	£112	12	3				
—	Binding,	7	0	0				
					£119	12	3	
—	Stationery,				3	15	3	
—	Printing and Illustrating *Proceedings* of two Sessions,				36	12	0	
—	Printing Circulars, &c.,				13	3	0	
—	Gilt Labels to Portraits,				1	10	0	
—	Salary to Assistant Librarian,	£33	16	0				
—	Commission to do., Collecting Dues,	13	2	6				
—	Fee to Officer of Andersonian University,	4	0	0				
—	Fee to Clerk for extra writing,	1	0	0				
—	Delivering Circulars,	8	6	3				
					60	4	9	
	Carry forward,				£234	17	3	

Brought forward,				£234	17	3
By Rent of Hall,......................	£15	0	0			
— Fire Insurance,....................	3	11	0			
— Gas,....................................	1	13	11			
				20	4	11
— Cleaning Hall, and petty charges,.............				2	3	9
— Rent of M'Lellan Rooms for Professor Rogers' Lecture and Expenses,.........................				15	16	0
— Balance—						
Cash in Union and Savings Banks,.........................	£62	6	0			
Cash in Treasurer's hands,...	0	14	9			
				63	0	9
				£336	2	8

The Philosophical Society's Exhibition Fund.

1855.			
May 15.—To Balance per Deposit Receipt from Corporation of Glasgow,...............	£647	14	8
1856.			
May 15. — Interest to this date,............................	29	3	2
	£676	17	10

We have examined the Treasurer's Account, and compared the same with the Vouchers, and find that there are in the Union Bank of Scotland Fifty-eight Pounds and Fifteen Shillings; in the Savings Bank, Three Pounds and Eleven Shillings; and in the Treasurer's hands, Fourteen Shillings and Ninepence,—together, Sixty-three Pounds and Ninepence, at the Society's credit at this date.

The Treasurer has also exhibited to us a Voucher which he holds for money lent the Corporation of Glasgow, from the proceeds of the Philosophical Society's Exhibition in 1846, with interest thereon to 15th May, 1856, being £676 17s. 10d.

THOMAS DAWSON.
MATTHEW P. BELL.

Report by the Treasurer, November 1, 1856.

The moveable property of the Society remains the same as last year, with the addition of new books purchased since that time.

The number of members at the commencement of Session 1855-6 was..........	263	
New members admitted during the Session,..	42	
		305

From this there fall to be deducted from present Roll—

Resigned,	9	
In arrear two years,	12	
Left Glasgow,	4	
Dead,	5	
		30
On the List for 1856-57,		275

Of the above 275, there are 8 members in arrear of one year's dues.

Mr. Cockey also made a Report on the progress of the Library, which now contains 2,559 volumes.

The Society then proceeded to the fifty-fifth annual election of office-bearers.

Mr. John A. Mathieson and Mr. Robert Hill were requested to act as scrutineers of votes.

Dr. Allen Thomson proposed that Professor William Thomson be elected President; that Professor W. J. Macquorn Rankine be re-elected Vice-President; that Mr. James Bryce, jun., be elected second Vice-President; that Dr. Thomas Anderson be elected Librarian; that Mr. William Cockey be re-elected Treasurer; and that Mr. Alexander Hastie and Mr. William Keddie be re-elected Secretaries.

Which motion having been seconded by Mr. William Murray, was carried by acclamation.

The votes of the Society were then given in, in writing, for twelve members of Council, and the scrutineers retired to number the votes.

Dr. Thomas Anderson, Professor of Chemistry in the University of Glasgow, exhibited a specimen of trap rock from Lochwinnoch, containing particles of pure iron, such as has hitherto been only observed in meteoric stones, along with portions of nickel. Professor Andrews of Belfast had observed that iron occurred in extremely minute particles in trap rocks in the north of Ireland; but in the specimen produced, the particles were comparatively large. From a portion of the powdered mineral, Professor Anderson detached the particles of iron by applying the magnet. He stated that six per cent. of iron had been extracted from the rock by means of dilute acid.

Professor William Thomson made some remarks on the curious fact of iron occurring in a rock which had not been exposed to aqueous action, as had been the case with all metalliferous rocks.

Mr. W. Murray and Mr. Bryce also offered a few observations, the latter suggesting that the influence of trap and basaltic rocks in deflecting the needle, might be caused by the existence of iron in these rocks.

Through the kindness of Mr. Clark, Curator of the Botanic Garden, a specimen of *Encephalartus horridus,* or *Zamia horrida,* bearing a magnificent amentum or cone, was exhibited to the Society, and described by Mr. Keddie. The plant is a native of South Africa, whence it was sent to the garden, twenty years ago, by Baron Ludwig, according to whose computation of its age at that time, it must now be 250 years old. It belongs to the natural order *Cycadaceæ,* holding an intermediate place betwixt the tree-ferns and the palms, and having a marked affinity to the *Coniferæ* or pine tribe. Different species of the genus *Encephalartos* yield a starchy substance which the Caffres bake into bread. The plant is diœcious, and the amentum of the specimen exhibited was supposed, at this immature stage, to be the male, consisting of anther-bearing scales. (It ultimately proved to be the female, producing seemingly perfect seeds. See *Proceedings,* Nov. 18, 1857.) This is the first time the plant has flowered in Glasgow. The flowering of this interesting plant is not the only indication of the skilful and successful management of the garden by Mr. Clark. The *Victoria Regia,* the great water lily, which has this year failed almost everywhere else, has been in flower in the Glasgow garden since the 19th of July. The improvements which have been introduced by the Curator into the greenhouses have already added much to the value and interest of the collection. With improved heating apparatus, a new orchid-house to be erected by private liberality, and a marine aquarium in prospect, nothing will be awanting to complete the equipment of the garden, except a new palm-house, which the wealthy merchants of Glasgow will perhaps be disposed to add as a gift to the institution, when they see the directors, with their meagre and inadequate income, striving to render the garden worthy of the second commercial city of the empire.

Dr. Allen Thomson, as one of the directors, complimented Mr. Clark on his able and successful management of the garden.

Dr. Allen Thomson exhibited and described a variety of interesting objects in natural history.

The scrutineers having given in their Report, the following was declared the list of Office-bearers for the present Session, the names of the Councillors, conformably to the rule of election, being arranged in accordance with the number of votes recorded for each, the four members of Council at the top of the list being those who retire next year :—

President.

PROFESSOR WILLIAM THOMSON.

Vice-Presidents.

PROFESSOR W. J. MACQUORN RANKINE. | MR. JAMES BRYCE, jun.

Librarian.

DR. THOMAS ANDERSON.

Treasurer.

MR. WILLIAM COCKEY.

Joint-Secretaries.

MR. ALEXANDER HASTIE, M.P. | MR. WILLIAM KEDDIE.

Council.

MR. WILLIAM RAMSAY.	MR. WILLIAM MURRAY.
MR. ROBERT BLACKIE.	MR. C. RANDOLPH.
MR. WALTER CRUM.	MR. C. GRIFFIN.
MR. ROBERT HART.	MR. JAMES NAPIER.
DR. JOHN STRANG.	MR. ALEXANDER HARVEY.
MR. J. R. NAPIER.	DR. ALLEN THOMSON.

December 3, 1856.—Professor WILLIAM THOMSON, President, *in the Chair.*

The following gentlemen were elected members :—Mr. Walter Neilson, Ironmaster, 28 Woodside Place ; Dr. John Grieve, 67 St. George's Road ; Mr. Thomas D. Clavering, Russia Broker, 22 Royal Exchange Square ; Mr. Thomas Muir, 18 Carlton Place ; Mr. George Baird, 8 Greenhead Street ; Mr. William Renison, Writer, 20 Buchanan Street ; Mr. John Ure, Merchant, 49 Howard Street ; Dr. Robert Kirkwood, Town's Hospital ; Mr. Joseph Townsend, Chemist, Crawford Street.

The President described the Atlantic Electric Telegraph, and produced specimens of the Microscopic Shells obtained in taking soundings between the coasts of Ireland and Newfoundland.

Mr. William Whitehouse being present, favoured the Society with some additional information with respect to the Telegraph, and received a vote of thanks.

Dr. Allen Thomson exhibited the Shells under the microscope, and described their nature and their relations.

December 17, 1856.—*The* PRESIDENT *in the Chair.*

The following gentlemen were elected members of the Society:—Mr. Thomas Russell, Engineer, 204 Sandyford Buildings, Dumbarton Road; Mr. John Kidston, 71 West Nile Street; Mr. John Mann, Accountant, 153 Queen Street.

Mr. Bryce read the following papers:—I. On the Discovery of Native Copper in the Trap Rocks near Barrhead. II. On the Discovery of Coal-bearing Strata and Coal Fossils in the Island of Bute. III. Notice of the Geological Relations of the workable Copper Veins recently discovered in Bute.

On the Discovery of Native Copper in the Trap Rocks near Barrhead. By JAMES BRYCE, M.A., F.G.S.

THE existence of native copper in this locality was lately made known to me by John Graham, Esq., of Barrhead, who kindly furnished the many beautiful specimens now exhibited. It has long been known to him, and a matter of notoriety in the neighbourhood; but no account of the discovery, or of the conditions under which the metal is found, has hitherto been published, so far as I am aware, in any scientific journal; yet the great interest of the discovery as a scientific fact entitles it to a permanent record. The metal occurs in a native state very sparingly, even in the great repositories of its ores, as in Cornwall, Norway, and other places; and its existence in basaltic rocks is of such extreme rarity, that only two other similar cases are known. Cape D'Or, at the western extremity of Nova Scotia, between Chignecto Bay and Minas Channel, in the Bay of Fundy, receives its name from the considerable quantity of yellow, gold-like, native copper found there in overlying basaltic rocks, under circumstances very similar to those now to be described, as will be seen by consulting the admirable work of Mr. Dawson, entitled *Acadian Geology,* p. 93. The other instance is at Nalsöe, in the Faröe Isles, where native copper is found in trap with mesotype, but only in minute disseminated particles of a crystalline form, and in strings branching through amygdaloid.

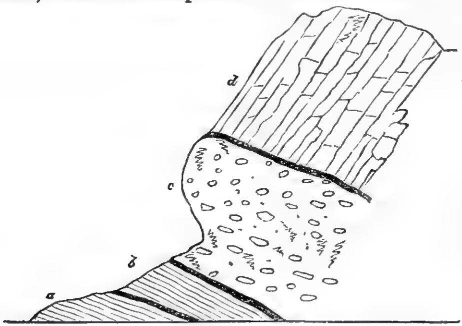
I lately visited the locality at Barrhead, in company with Mr. Alexander Cowan of that place, by whom it had been previously examined, and who also has favoured me with several fine specimens. The locality in question is the Boylestone trap quarry, about a quarter of a mile north-west of the railway station at Barrhead. The rock is a coarse crystalline greenstone, a member of the trap series which forms the Fereneze hill ranges, erupted through, overlying and much altering the lower coal strata, where these are cut off by it. Through this rock the metal is distributed irregularly in large, thin plates, usually attached firmly to the rock, and also coating its surface in broad, very thin films, as if laid on by the electrotype process. It occurs also sometimes, but more rarely, in large lumps, and in flattened dendritic masses; but no continuous lode or vein has been anywhere noticed, such as to justify the establishment of mining operations, or encourage the hope of a profitable working on the smallest scale. We can hardly say that there is any decided indication on the surface that the metal exists below. In fracturing slabs of the rock along a scarcely perceptible seam, plates of the metal are often found lining both sides of the fracture; but the seam is often found without these plates. Often also these are found associated with a greenish-black, earthy vein, which abounds in the quarry; but this vein exists in many places where there is no copper. Supposing that this vein, from its peculiar aspect, and the copper associated with it, might consist of an impure ore of copper, I submitted a specimen of it to Dr. Thomas Anderson, Professor of Chemistry, who most kindly examined it for me, and reports that it does not contain a trace of copper, but consists merely of various earthy matters. The plates, films, and lumps, are all alike perfectly pure metallic copper.

The origin of native copper has been ascribed by some to a decomposition of its ores, and a subsequent infiltration; and to such an origin Mr. Dawson seems inclined to refer that of Cape D'Or. This would assume the existence in that locality of other ores, of which there is no evidence. It is a more philosophical view to regard it as an original underived product. These trap rocks had their source far down in the plutonic depths, in the great subterranean laboratory where all the earths and metals may exist together in a state of fusion, and whence the copper may have been brought up along with the earthy components of the trap. The circulation of electric currents, and the development of chemical affinities throughout the mass of rock while slowly passing into the solid form, would account for the deposition of the pure copper in the plates and films as we now find it. Many masses of native copper are found loose on the surface along the northern shores of Lake Superior, the largest of which would weigh from 3,000 to 4,000 pounds. They appear to be derived from great repositories of metallic copper there, associated with rocks of igneous origin; and M. Agassiz is of opinion that the metal has been poured out in a melted state among the rocks from a great *focus* of copper, as he terms it, existing deep below the surface. Such is by far the most probable origin. Trap dikes and igneous outbursts are but the surface vents of the hypogene laboratories, where a chemistry is at work which may only permit the metals to exist in a pure, uncombined state. Pure metallic iron exists also in our trap rocks. Dr. Thomas Anderson, at a late meeting of the Society, described its occurrence in the trap of Renfrewshire; and Dr. Andrews of Belfast finds it disseminated, in minute plates, in the traps of Antrim. (*Brit. Assoc. Report*, 1852, *Trans. Sec.*, p. 34.) Trap and other intrusive rocks are well known to be intimately related to the vast development of gold in Australia, California, and the Ural.

On Coal Bearing Strata in the Island of Bute. By JAMES BRYCE, M.A., F.G.S.

IN a paper on the geology of Bute, which I had the honour of submitting to the Society, on the 1st December, 1847, certain strata on the shore at Ascog were referred with hesitation to the old red series. They consisted of limestone and limestone breccia, sandstone, shale, and coal, the whole capped by trap, and in some parts considerably altered by overlying and intrusive beds of that rock. Very few fossils had then been found in them; none certainly of a character to determine the age. Recently, however, fossils from the locality, which came into my own hands and into those of my friend Mr. James P. Fraser, enabled us about the same time, and independently of one another, to decide this question, and without hesitation to refer the strata to the carboniferous series. They seem to be upon the same horizon as the lower marine beds of the Clyde basin, such, for example, as occur to the north-west of Glasgow, and in the neighbourhood of Paisley. The strata hang on to the flanks of the old red sandstone at Ascog, and are connected with an isolated overlying mass of trap which appears on the shore, and occupies the cliffs near Ascog mill. A portion of them are shown in the annexed woodcut, taken from the paper already referred to. The features are now slightly altered by the action of the sea, which is rapidly wearing some of the cliffs here. The section represents the south side of the promontory, south of Ascog mill.

On the north side of the promontory, several thin courses of nodular limestone traverse beds of brown coloured crumbling shale, which is of considerable thickness, and rises into banks west of the road. The changes produced upon these strata by the proximity of the trap are described in my former paper, and need not now be repeated. The limestone shale and coal seams extend under high water mark; and when the tide is unusually low considerable pieces of coal are often dug out from beneath the sand and mud covering the tideway. Workable seams have been searched for, but as yet without success. It is probable, indeed, that from the position of these beds and their limited



(a) *Limestone;* (b) *shale with thin coal seams;* (c) *limestone breccia;* (d) *trap.*

extent inland, they will, like the similar strata in Arran, never turn out to be of much economic value. Their occurrence here, however, is a matter of great geological interest, as presenting a striking analogy with Arran, marking, with it, the extreme outer limit of our great coal field, and attesting the uniformity of the conditions of the surface which prevailed at this remote era.

The fossils by which the strata were identified are given in the following list. The species have been determined by Mr. Fraser, from specimens in his collection and my own. To his well known skill in this department I willingly submit my own judgment.

Plantæ.

Sphenopteris bifida, not uncommon in the shales.
——— affinis, ditto.
——— furcata, ditto.
——— dilatata, rare.
Pecopteris nervosa, rare.
Calamites nodosus, abundant in the shale and sandstones.
——— undulatus, ditto.
Trigonocarpum olivæforme, rare.

Brachiopoda.

Producta punctata, not abundant.
——— sulcata, ditto.
Spirifer semicircularis, somewhat common.
——— trigonalis, rare.
——— duplicostata, rare.
Lingula squamiformis, abundant in the shales.
Orthis radialis, rare.

On the Geological Relations of certain Copper Veins recently discovered in Bute. By JAMES BRYCE, M.A., F.G.S.

THERE has very recently been discovered in Bute a vein of copper ore which promises to be of considerable economic value. It occurs in Kaimes Hill to the north-west of Port Bannatyne, on the face of an old quarry of clay slate, which has been worked down to the level of the chlorite slate below. The vein is three feet wide, and the veinstone is a porous quartz, with much black matter in the cavities, which analysis shows to contain a considerable quantity of manganese. Much chlorite occurs with the quartz, and also layers of clay slate, in a soft soapy condition. The ores are yellow and black copper ore; and both the clay slate and quartz are thoroughly impregnated with the oxide of copper. Transverse sections of the slaty laminæ exhibit a rich copper ore. The copper lode is properly a bed and not a vein, as the veinstone and ore are interstratified with the slate, and follow the strike of the beds. The direction is 33° east of north, and the dip 57° east of south, at an angle of about 40°. In order to reach the vein upon the strike, it was necessary to open a shaft through the accumulation of rubbish heaped up in the process of working the slate quarry. The shaft already opened is eighteen feet deep and six feet wide. The bed is about three feet wide, and is intersected by a whin dike about fifteen feet north-east of the shaft; but the perpendicular distance across to the dike from the shaft is only five feet. The dike is ten feet wide, and ranges 18° east of north, and west of south; so that it intersects the vein at an angle of 15° (33°—18°). In the slate between the bed of ore and the dike there are several quartz veins without metal. The copper lode underlies with the dip of the slate, in conformity with the slope of the hill, so that an adit of about sixty fathoms, driven through a hill-side to the hollow in which the quarry is situated, would completely drain any workings which might be established. Messrs. John Taylor & Sons, mining engineers, have expressed their opinion that the promise of the metal is such as to warrant the expenditure of £1,000 in effecting this object. About half a mile towards the E.N.E., the veinstone and metal again appear in another slate quarry on the strike of the beds; and hence it is probable that there really exists here a considerable deposit of copper ore. But this, of course, can only be determined by the establishment of works, in regard to which the proprietors are now in treaty with several parties who are desirous of obtaining, in the first instance, a lease of the grounds. As a mere matter of scientific interest, if for no other reason, it is greatly to be desired that the economic value of this lode should be thoroughly tested. Scotland is extremely poor in copper ores, though abounding in those older rocks in which this metal is usually found; and therefore any new instance of its occurrence is marked with a peculiar interest. Its development in this locality seems intimately connected with the intrusion of igneous rocks; and yet Arran, which abounds with rocks of this class of almost every age, is entirely destitute, so far as we yet know, of any repository of metallic ores.

Dr. Scouler exhibited and described the Remains of the Dinornis and Palapteryx, from New Zealand.

January 14, 1857.—*The* President *in the Chair.*

Mr. Robert Ness and Mr. Alexander M'Casland were elected members.

Dr. Scouler exhibited, from Mr. Colin Brown, the Jaw of the Palæotherium from the Isle of Sheppy.

Mr. Bryce read a paper "On the Geology and Physical Geography, Natural Resources, and late material Progress of India; with notices of its Means of Defence against foreign invasion."

January 28, 1857.—*The* President *in the Chair.*

The following gentlemen were elected members:—Dr. John Scouler, 75 Bath Street; Mr. Robert Hutcheson, 60 Abbotsford Place; Mr. Thomas Fleming, 73 James Watt Street; Mr. Robert P. Wright, 9 Bath Street.

The Rev. Dr. Macvicar of Moffat, read a paper on "An Adaptation of the Philosophy of Newton, Leibnitz, and Boscovich to the Atomic Theory of Dalton."

An Adaptation of the Philosophy of Newton, Leibnitz, and Boscovich to the Atomic Theory. By John G. Macvicar, D.D.

Philosophy, which, in the following pages, is invoked to explain the atomic weights and the physical and chemical functions generally of the simplest forms of matter, has been viewed in all ages as consisting in an inquiry into causes. Nor this without good reason. For philosophy is nothing else but the science of reflection, nothing but the spontaneous effort of the intellect to satisfy Curiosity; and about nothing is Curiosity more alive than about the causes of things. Every child, as well as every full-grown man, in the very degree that he is quick, is also eager to know the cause of every phenomenon which strikes him. And this is right. For if there be anything of an objective nature that is certain, it is the existence of God; and let it be but granted, that to Him, as First Cause, the material universe stands in the relation of a creation or effect, and then the doctrine of causation in Nature is secured in its integrity. Whether we make use of the terms parent and offspring, producer and production, cause and effect, or any others of the same kind, there enters essentially into the relation between the two terms the affirmation of a certain continuity or resemblance between them; and that to which an Almighty Being, acting as a great First Cause, has awarded existence, can scarce be other than a system of causation itself. At all events, we are logically bound to hold it to be so until the contrary appears. Such, therefore, is the point of view in which nature is regarded in the following pages—as a system of causation, a dynamic system.

As to the METHOD by which the author obtained the first principles, which have led to the results, of which a few are here communicated, it was that which has just been hinted, namely, *the doctrine of causal continuity and resemblance*, implying in a Cause not only a productive, but also an assimilative power, the Effect being not only produced, but produced so as to bear also the signature of the cause which evolved it; so that the creation not only exists, but bears upon its bosom the signature of the Creator's attributes; by a reference to which, therefore, Nature may be investigated in regions where the senses fail, and hypotheses framed, which being pursued logically onwards and outwards till we reach the region of the palpable, may be verified or rejected by comparing their consequences with the data of observation. Is it said that such a speculation, even though based in reason and religion, and though explaining phenomena innumerable which no other hypotheses can explain, while contradicted by none, is still but a hypothesis after all—let that be granted; but let it also be remembered, that there is nothing better for us, call it by what name we please.

There may indeed be much that is against a hypothesis, though its power of explaining phenomena be very great; as for instance its lengthiness or its obscurity, or the fact that it requires additional complications or limitations the more it is applied to explain phenomena. But a hypothesis is free from every logical objection when its terms are reduced to two, viz., *one fact*, postulated as substance to work upon, and *one law*, which shall determine the phenomena and functions of that substance. Any hypothesis that is more complicated than this does not fully satisfy the demand of intelligence for unity in first principles. And no hypothesis that is simpler than this can belong to the philosophy of common sense; for this philosophy demands, in reference to everything that represents reality, that it shall have respect both to substance and attribute—being and action. It is to this that I have at last succeeded in reducing the hypothesis, of which the first lines are now to be unfolded.

The one fact which I build on as Substance, or Material, is that which is given by the history of philosophy as the catholic belief of the observing and reflecting men of all refined ages and nations, namely, the universal æther or medium of light. And respecting its intimate nature and constitution I postulate nothing but that when existing in a state of rest it consists of individualized particles existing apart, though somehow touching each other. In this respect all that follows is nothing more than the working out of an answer in the affirmative to Newton's query, when he asks in his latest scientific publication, "Are not gross bodies and light convertible into each other? . . . . The changing of light into bodies, and of bodies into light, is very conformable to the course of nature, which seems delighted with transformations."—(*Opt.*, 2d edit., 1718, qu. 30.) It will be observed, however, that I borrow no less from Leibnitz and from Boscovich than from Newton, while it is only since the atomic theory of Dalton under some form or other has been pursued to the extent that it has, and given those definite conceptions of molecular quantities and functions which now prevail, that such a hypothesis as that now entered upon has become possible, at least as a speculation in positive science, capable of being verified or of being rejected.

The one law which I build upon is that which has been already hinted as the law of causal continuity or resemblance. Borrowing a name for it from that case of its operation, by which our food is digested and our life is maintained from hour to hour, we may designate it *the Law of Assimilation*, and it may be thus laid down:—

All things tend to assimilate —

- I. themselves to themselves in successive moments of their existence, *i. e.*, to maintain their types or species, under influences tending to cause a departure from them; as also—
- II. all other things to themselves (and consequently to be assimilated to these others in their turn), *i. e.*, to group species and types into genera and families, and to give general harmony to nature.

Of this law it may be shown that all the characteristic phenomena of the intellectual and moral sphere are manifestations, to the full extent that they are manifestations of law at all, and not of a self-possessed liberty under no law but that of its own activity. Here, however, looking only to it in its grand cosmical function, as the expression of the Divine will to us articulate with regard to His works, as the impression of the Divine immutability upon Nature, and as such, the Cosmotectonic law, we may deduce from it the following consequences, by which we reach Body or Matter as commonly conceived, with which alone we have to do here:—

Of Inertia.

I. Any substance considered merely as such (*i. e.*, merely as a thing of which nought is predicated but *existence* in a certain position in space, and *mobility* under force applied from without), if now at rest, must, under the law of assimilation, assimilate itself to itself in successive moments of its existence. It must, therefore, continue at rest. And if it be put in motion, and thus once constituted a moving thing, it must, under the same law, assimilate itself in like manner in its every successive element of motion to the first, and therefore it must continue in motion. Moreover, its first element of motion, as it is simply a change in space from one point to the next adjacent, cannot but be an element of a straight line. And it is accomplished in a certain time. But under the law of assimilation, it must in every similar and equal element of time following, accomplish a similar and equal element of motion. It is obvious, therefore, that the whole motion must be both rectilinear and uniform. And thus a particle of substance conceived as devoid to the utmost of all specific properties, and only subjected to the law of assimilation, gives us a particle possessing *inertia*, and thus brings us at once by a long step near the conception of body or matter.

Of Elasticity.

II. But any substance or thing of limited extent, existing in space, must necessarily possess a form (meaning by form the confines between that thing and the surrounding space), and let any such thing which is intrinsically amorphous, that is, wholly passive as to form, or purely plastic, be placed under the law of assimilation, and it follows, that whatever the form which it happens to possess, when put under that law, to that (its original form) it must assimilate itself in successive moments of its existence; and that form, therefore, it must tend to maintain and to restore when any forces applied from without tend to disturb or to alter it—yet not without a homage demanded by the same law to any new form which may be transiently impressed. It must assimilate itself to the latter in alternate moments. And with this reciprocating action, the phenomenon of inertia conspiring, there must result in a form thus conceived, as originally wholly plastic and perfectly homogeneous and exempt from internal change, a perfect *elasticity*. Here, therefore, we again make another great step towards the conception of matter or body; for all observation, all calculation, lead to the inference that if we could but reach the last elements of matter, they would be found to be perfectly elastic. It is true that in this deduction of elasticity, only the law under which it exists is given, and not the mechanism by which it is accomplished. The latter is of more difficult deduction, and only appears in general terms in the following paragraphs.

But Form implies relations of parts, and of these relations the most eminent is that of all the parts to one, which is the centre. And here it becomes necessary for us (without postulating any particular form as that of the ætherial atoms), to view them as having each a centre; which, while it may be designated according to the object in view, Centre of inertia, or Centre of elasticity, may be designated generally as *Centre of force.* But the ætherial centres of force as given by nature are obviously in a state of separation from each other. Each ætherial element, therefore, has volume; and around its centre of force there is a self-isolating, and, of course, elastic ambient, which we may call its *atomosphere* or *atmosphere.*

Now, in this centre and its atmosphere, it appears, that on the application of a force from without, in connection with elasticity, and explaining it, two other modes of action must present themselves.

Of Repulsion.

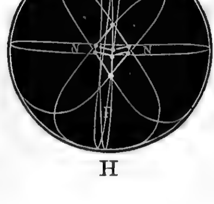
III. In every case but that in which the ætherial element, molecule or mass, is conceived to move away as fast as the force is impressed, which is impossible, the elastic action of the whole must imply the oscillation or vibration of the centre, or of the centres of force found in the molecular mass—a vibration which will be greater or less according as the force impressed or the resistance opposed is greater or less. Moreover, this oscillation or vibration of the centre must, in its turn, set agoing and maintain in the atomosphere around it, a system or systems of undulations of the same periods as itself, and determined in form and direction by the law of assimilation as usual. Now, such systems of undulæ, when of the same periods and dimensions, as, for instance, when emanating from the centres or nuclei of similarly constructed molecules, must constitute an apparatus of mutual repulsion between these atoms or molecules; for the undulæ advancing from the different centres or nuclei must meet each other face to face;—each wavelet must resist the farther progress of the other, whence, that they may still hold on their radiant course, the centres or nuclei from which they emanate must tend to retreat from each other; for the law of assimilation implies a continuity of force between the advancing front of an undula and the centre whence it issued, and therefore a state of tension in the atomosphere in that direction in which the undula is proceeding analogous to rigidity.

Of Heat.

IV. But such a mode of action in the atoms or molecules constituting a sensible mass, must be productive of a sensible phenomenon. The mass must expand or increase in volume, and that to an extent and under modifications determined by the atomic or molecular structure of the mass expanding. Here, then, we have a phenomenon, which, so far as appears, answers to *heat*. Its further consideration must, however, be deferred till we become acquainted with specific molecular structures. It may be merely added here, that according to this view there is good ground and reason on both sides to affirm now that heat is only motion, and now that it is due to a special agent, caloric; for when any attempts have been made to define caloric, it has generally been described in much the same terms as the atmosphere or atomosphere around the nuclei here. It may, indeed, be said, that this insulative atomosphere, which, according to the views here advanced, constitutes all the volume of every atom and molecule, ought rather to be named electricity than caloric, as will presently appear. But this were a dispute about names merely. The atomosphere is, according to what is here advanced, the common ground both by calorific and electric action, and both of these are purely modes of motion not only convertible into each other, but into such motion as is palpable to the senses, and commonly goes by the name.

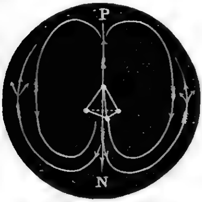
Of Polarity.

V. From the Law of Assimilation, however (operating as inertia, and demanding symmetry, as will appear hereafter), it follows that these systems of undulæ emanating from the centres and nuclei of atoms and molecules, must ever tend to form themselves into sustained currents in the atomospheres of these atoms and molecules—currents in which the successive undulæ shall chase each other continuously in the line which is at once the most rectilinear and that of least resistance. And thus, as another function of the heat, which must



H

actuate every molecule which is a member in the universe, we shall have the phenomenon of *currents of force* possessing peculiar characters, not possible to be investigated at present, but which we may (by anticipation) designate by the general term *polarity;* for the law of assimilation demands that every such current of finite section shall be accompanied by another, dynamically and symmetrically related to it, equivalent in force, and flowing in a contrary direction. With respect to these currents, it may, however, be mentioned here, that there will be two grand classes of them according to the morphological character of the molecules in which they circulate. Thus all molecules must be either homopolar (that is, with similar poles), as fig. H, or heteropolar (that is, with dissimilar poles), as fig. M; the latter representing a nucleus composed of four ætherial atoms or elementary forces, the former a nucleus of double that number constituted of two of the others united face to face. Now, in the former case, the currents must circulate between the polar and the equatorial parts in each molecule, and this is believed to be generally the case in the repose of nature: in the latter case they must circulate between the poles, as in those molecules and masses commonly regarded as magnetic, idio-electric, &c.



M

It is not alone a mechanism of repulsion, however, whether acting directly as heat, or indirectly as polarity, which our grand law presents to us. It gives phenomena of a grander order—phenomena which transcend the idea of mechanism altogether.

OF ATTRACTION.

VI. The elementary particles or physical points constituting the atomosphere of a molecule, or any masses or molecules whatever existing at the same time in different places, although they be homogeneous or similar to each other in kind, and in this respect tend each to maintain its present position, or to withdraw from others if encroached upon by them, yet, inasmuch as they occupy different positions in space, must, under the law of assimilation, tend in successive moments to be assimilated as to the space they occupy, that is, they must tend towards each other; in popular language they must attract each other. And as this is a mode of action dictated simply in relation to space, culminating towards the confluence of those elements actuated by it into the same space, and thus pointing to a centre as its limit, *our physical element now presents itself to us as a centre of attraction invested by an atmosphere* *or atomosphere which is inert and elastic, which is retained by its intrinsic attractiveness or contractility around the centre, and is subject to be actuated by heat and polarity.*

Of Gravitation.

VII. Moreover, if elements or masses thus tending towards each other be considered merely as elements or masses existing in different regions of space, and tending towards each other in consequence of this difference of position, the law of assimilation in giving the phenomenon gives also its law. Thus, in reference to each centre of force, the tendency or attractive power in the various concentric shells that exist around that centre must, under that law, be assimilated in all. These must all be equal in this respect. Each considered in its totality, must be isodynamic, whether the surface of that particular spherical shell be small, because it lies near the centre, or large, because it is more remote from the centre. Now, these spherical shells or surfaces which thus, under the law of assimilation, must be isodynamic, vary directly as the square of their distance from the centre. The value of each, therefore, considered as a force, when estimated in terms of the distance, must vary inversely as the square of the distance. And thus we obtain the law of gravitation, not only to the extent generally admitted, but as that by which all things are brought and kept together, and in relation with each other, from the inconceivably minute atomosphere of the least elements of the material system to the orbit of Neptune, and we know not how far beyond. And thus our single law applied to that which, when postulated, is next to nothing without it and merely something, and as fast as thought can proceed, gives as its successive manifestations inertia, elasticity, repulsion, heat, polarity, attraction, gravitation ; and thus imparts a scientific homogeneity to properties, some of which have been hitherto regarded as quite heterogeneous and unrelated to the others except in so far as they are co-existent in the same subjects. Nor this only. It exhausts inquiry respecting them. It withdraws them from the position of mere data of nature, merely unaccountable or ultimate facts. It gives their genesis out of a single principle. It remains only for those who are competent to conceive the subject better, and to construct a calculus whose simplest functions shall express these facts and relations on which all the movements of Nature depend.

Elements of Morphology.

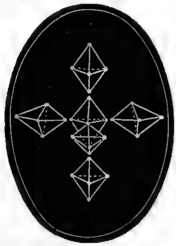
Our synthesis, however, does not terminate here. We have, in fact, only reached as yet the conception of matter, as it manifests itself to us in the most remote regions, whether those in which the least elements of bodies lie concealed, or those in which the heavenly bodies revolve. We have supposed only homogeneous or similar atoms, or else masses composed of them. We have supposed the second part of our grand law, the function of mutual assimilation, to have previously accomplished its end, to have succeeded in reducing all individualized objects to similarity to one another, or to have found them thus in harmony with itself from the first creation.

It belongs to us now to consider that many conditions of existence may obviously arise in which the ætherial atoms or elements shall enter into union with one another, and constitute molecules of various kinds. It remains that we investigate under our law the forms and structures of these molecules, the chemical functions which they must fulfil, and the sensible properties which they must display.

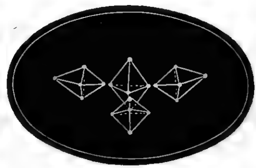
And here we have at once to predicate of all of them without exception, that for all of them the law of assimilation lays down this formula, that the etherial elements of which the molecule is built up shall always tend to assume positions which are similar in reference to others which correspond to them, or to some place and ultimately to some point in the molecule. In a word, the law of assimilation in reference to molecular construction is a law of *symmetry*, and might perhaps be advantageously so named.

Nor this only in these general terms. The idea of maximum assimilation implies among symmetrical forms a maximum of symmetry towards which all must culminate, and which each will attain so far as the conditions of existence will permit. Nor is this culmination-form difficult to be discovered. In a word, that form in which more than any other all the parts or particles are assimilated to each other in their positions, all being similarly placed in reference to each other, and to one point (which is the centre) is the spherical superficies. Thus are we led to *the spherical shell* or *cell*, as the culmination-form of the merely molecular world. And this deduction is verified by observation in reference to the ultimate structure of plants and animals, in which the cells being insoluble wait to be seen; and we have every reason to believe it to hold very generally in reference to the inorganic kingdom also, most bodies indicating their cellularity by being so very light compared with what they might be, as is illustrated by platinum, gold, &c. As to crystalline forms, they, being necessitated by the imperfection of their constituent molecules to be highly angular, can only display many bevelments and truncations, as they do,—that is, many nisus towards the spherical. And as to the great number of prisms in inorganic nature, and of filaments and cylinders in organic forms, their genesis is necessitated by the linear currents from which it is next to impossible to escape, or to screen anything, whether in nature or the laboratory. Call them electric or by any other name, these currents modify everything, and make every object to be different from what it would be if developed as an individual far out in space, under no influences but those attaching to itself.

1. Hence all individualized molecules and combinations viewed as insulated, or as defined by their self-insulating atmospheres, may be distributed into two grand classes, viz., those which depart from the spherical by having too much matter on the axial region, rendering them *prolate* (see fig. H^6), and those which have too much matter on the equatorial region, rendering them *oblate* (see fig. H^4).



H^6



H^4

2. Hence also a primary condition in the construction of a molecule is, that it shall have one part which may be called its equatorial region, and two others in geometrical relation with it, which may be called its polar regions. And in reference to the latter, we may here remark, that the most urgent condition to individuality, insulability, and repose in the molecule is, that they be similar to one another, and the molecule may be, as we may say, *homopolar*.

Laws of Chemical Union.

Such being the first lines of morphology under the law of assimilation, let us now suppose that two dissimilar molecules are brought into the presence of each other, and let us see what phenomena must arise under our grand law, viewed now in the second phase of its agency, that is, as a nisus or tendency towards mutual assimilation, —a nisus or tendency in each atom, molecule, or mass, to induce its own features upon the other. And here many cases present themselves, thus,

1. We may suppose more powerful molecules to be mixed with such as are weaker, and so related that they do not tend to the genesis of a new species by rushing into union with the former. The law of assimilation leads us in such a case to infer, that those which are more powerful will succeed more or less in impressing their own features upon those that are weaker. Thus let a molecule of a powerful and stable kind be brought into the presence of such as are tending to spontaneous

decomposition, it will tend to impress its own stability and to retard or arrest their decomposition. And on the other hand, let a powerful molecule in a state of change be mixed with such as are tending that way, it will assist them to change. Moreover, in virture of its own form and metamorphosis, it may also decide the change which they shall undergo· In a word, we shall have the phenomena of *catalysis.*

2. But in general, when dissimilar molecules are presented to each other with no impediments in the way of their coalition, the immediate effect of the law of mutual assimilation must be the merging of their differences by their *union, and the genesis of a new species,* in which, however, the types of both are preserved. In this way alone can the law of assimilation accomplish all its ends, and save itself as having two functions which sometimes seem to touch on the contradictory.

And here we may remark, that a mechanical apparatus presents itself by which chemical union shall be effected, and new species generated. Thus, since the molecules which are presented to each other for union are dissimilar, the system of undulations awoke and sustained by the radiant heat of each in the atmosphere of each, must also, on a general view, be dissimilar. The forms and intervals of the undulæ, when they emanate from analogous regions in the dissimilar molecules, as for instance both from equators or both from poles, must be dissimilar. They will therefore not meet face to face, beat for beat; they will not act repulsively as they would do if they were of the same dimensions. Hence the law of assimilation operating as the law of mutual attraction will not be resisted, as it must be in the case of homogeneous molecules. It will not be prevented from bringing dissimilar molecules very near each other. But when two molecules are thus in contiguity, the systems of undulations issuing from certain regions in the one, will be caught by those re-entering certain regions in the other. What in another region constituted an apparatus of repulsion, here constitutes an apparatus of attraction. The two molecules will rush into union; and that not chaotically or accidentally, but by certain parts, viz., those in which the emanating and re-entrant currents in the one and in the other are of most harmonic dimensions. Thus looking to fig. H^4, page 61, suppose one atom of H to be as yet by itself, and so shorn of its self-insulative atomosphere that others could get at its nucleus, and suppose these others to accost it, then the first that comes up must be drawn into the equator of the atom which was there before; for since both atoms of H are similar, similar currents must emanate both from the poles of each and from the equators of each. But the currents which emanate from the poles of each, will be attractive to the equators of each, and enter there, for the equatorial angles being formed by four lines of force, are dissimilar to the polar angles, which are formed by only three lines of force. Let the second H, therefore, come by its pole upon a pole of the first, it will be repelled and swept round till its own pole is drawn to the equator of the other. And so of a second and of a third atom of H, after which the structure will be completed so far as its equator is concerned. But the H^4 thus generated is dissimilar to H. The system of undulations proper to it, therefore, both at the equator and the poles, will be dissimilar to that proper to H when existing alone. Let another H then come on, it will not be repelled from the pole of H^4 as before; it will be attached there; and thus after one atom of H we shall have under the law of assimilation two, one on each pole, giving fig. H^6.

3. Under the law of assimilation, it also follows that the measure of the chemical activity of a molecule is the amount of its defect, when compared with the spherical shell as the type of form, or the form of repose; and, therefore, *those molecules possess the greatest chemical activity which are most highly prolate or most flatly oblate; and those will tend most readily to unite which are prolate and oblate in relation to each other.*

4. It is, moreover, to be considered, that a group of two or more molecules is, when considered as a group, or mass, dissimilar to a single molecule, or group of molecules, if different from the first in the number it consists of. A single molecule, therefore, will tend to unite with a group of the same kind previously existing, or one group with another, if they be dissimilar. And this they will do in both cases, not chaotically or accidentally, but symmetrically, as the law of assimilation operating in the particular molecules aggregating shall determine. Thus along with the phenomena of chemical union, we must have those of *crystallization*, the nisus at the spherical showing itself by bevelments, truncations, &c., and those of the *organization* of plastic fluids when in contact with solid parts, &c.

5. And conversely, if a group of molecules, constituting a solid mass, be surrounded by a fluid, it must, under the law of assimilation, tend to become diffused as a fluid itself, or as it is commonly said, dissolved in the ambient fluid—the æther, the air, water, alcohol, oil, sanies, &c. Hence all solids must tend to be *volatile* and *soluble* when in contact with fluids (especially when the cohesion of their particles is diminished, as for instance by heat), as the greater number are found to be even to such an extent as is appreciable by the balance. Hence also the molecules, or chemical atoms, or equivalents of bodies, if exposed to violent processes of solution and of ignition, as is now usually practised, will tend to give off more or less of the ætherial matter they consist of, and *after severe processes in the laboratory, atomic weights will come out too*

light, give fractional numbers, and be representative of mutilated molecules, not of those with which nature operates.

GALVANIC ELECTRICITY.

6. Where union has been already accomplished, the law of assimilation may also be applied, so as to produce very interesting phenomena in causing the molecules to retrace the steps which they have taken in the course of nature; and thus to set free a current of force at the disposal of the chemist or engineer.

Thus let A Q be a mass of water insulated in space, or say in a simple cell of a galvanic combination. Each particle of *a q* is well known to be resolvable into an atom of H and one of O. And let the water in one end be bounded by some substance capable of resolving it more or less into H O, as for instance a plate of zinc attacked by sulphuric acid, then the stratum of water adjacent to Z, or at least certain particles in that stratum, will be transformed into HO. But this HO thus developed will, under the law of assimilation, tend to transform into similarity with itself the next particles adjacent to it towards the other side of the cell, and, in fact, the whole water lying in that line. And thus while at Z there is a stratum of atoms of O tending to adhere to Z; at the other side of the water, as for instance at the copper disc or C, there will tend to be a stratum of atoms of H tending to adhere to C. But this assimilative operation awoke by the action of zinc and sulphuric acid upon the atoms of A Q adjacent to it, and tending to stretch through the whole mass of A Q lying between Z and C, must be resisted by the heat, and the chaotic undulating action or tension which must be speedily generated in both Z and C, if they as well as A Q remain insulated. Let Z and C then be brought into contact above by a fit medium, or by sloping them towards each other, so that each may rest upon the other, then the state of chaotic undulatory action in each will be symmetrized in both, and the action will proceed and be sustained. For the undulatory action caused in Z by the successive incidence of particles of O upon its surface, must be assimilated to that of O, and representative of O. That which is caused in C, on the other hand, by the successive incidence of atoms of H, must be assimilated to that of H, and representative of it. Now O and H are dissimilar to each other. The undulatory systems representative of both respectively, will therefore be also dissimilar. When, therefore, these currents meet in opposite directions, they will not meet face to face with the same forms and intervals, so as to resist each other and maintain a state of tension, but after merely developing currents circulating at right angles to their direction and representative at once of their mutual resistance, and of the equatorial currents of molecules generally, they will pass each other, each reacting on the other only so as to establish a dynamic equivalence in force, and a harmonic relationship in form between them. And thus a state of things must result very favourable to the continuance of the action at z, and to the transformation of the particles of a AQ successively into HO, all the way between z and C. Thus previously to the establishment of the contact between Z and C, that is, during the state of tension, atoms of O must often have been repelled from z by being met by pulsations of z of the same dimensions as their own, and so must atoms of H have been repelled from C for the same reason. But now that the undulatory system proper to O flows continuously through z round into C, and from C through AQ to z again, it tends, instead of repelling atoms of O from z, to impel them on it, coming as it does upon their back with a force applied to them, and tending towards z; and for the same reason the H current, by its own undulatory action, carried round till it came up behind the atoms of H, pointing towards C, will tend to cause them to face and strike with more effect upon C. And thus whole lines of AQ may be transformed into atoms of HO, HO, HO, &c., all the way between Z and C. A closed or circular current of force will be kept up through the combination as long as there remains material for sustaining the chemical action at the z end of AQ.

(*a.*) It follows from these views, however, that the atoms of H must not only tend to develop themselves upon C, but to adhere to it, and in the very proportion that they do so, must impair the current. A grand desideratum, therefore, for constituting a current that shall be constant, is to withdraw the atoms of H as fast as they develop themselves on C, as for instance by presenting to them atoms of O with which they may unite and relapse into *a q*.—(*Grove.*)

(*b.*) Moreover, it follows from these views also, and under the same law of assimilation, that while z is being assimilated to the liquid medium in the region of z, that is, dissolved, a moment of liquid saturation shall arrive when the assimilative influence of the solid particles in the solution shall be more powerful than those of the liquid parts, and the dissolved particles of z will now assimilate themselves to C by forming a deposit on its surface. To z they cannot attach so easily, both because it is undergoing solution and change, and because of the repulsive action which is stronger between homogeneous than heterogeneous particles; C therefore will tend to be coated with z. But when C is coated with z, it is assimilated to z, the law of assimilation has accomplished its end; the action due to it, the current, will therefore cease. In order to an effective apparatus, which shall be constant, therefore, not only must C be kept clean or clear of H, but also of Z.—(*Daniell.*)

(*c.*) It is also to be considered, that while the assimilative influence of the action at Z represented by H O tends to assimilate all the corresponding lines of *aq* between Z and C, by transforming them into H O, the assimilative influence of the unchanged *aq* tends to reassimilate that which has been transformed into H O, and to effect its relapse into *aq*. The mass of water between must therefore act as a resistance to the formation and progress of the current. Another condition, therefore, to the successful establishment and maintenance of such a current, must be to diminish, as far as possible, the breadth of AQ between Z and C, the resistance being proportional to this breadth.

FRICTIONAL ELECTRICITY.

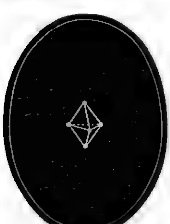
7. It follows from our views, however, that currents may be developed otherwise than by molecular transformation or chemical change. There is, in fact, in every body, a great amount of undulating action awoke and sustained by the specific heat of its constituent molecules. On the simple application, therefore, of two dissimilar masses to each other, under the law of assimilation, traces of a current may be established; and when that application is rendered forcible, as by heat, pressure, or friction, it may be expected that that current shall often become palpable to the senses. Thus, let F (see a fig. of Electrophorus), represent a stratum of fur, and R a stratum of resin, and let them be rubbed together, the systems of undulations representing each, actuating each, and existing in each in a chaotic state, will, under the law of assimilation, tend to pass upon the other, thus so far assimilating the other to itself. The previously existing systems of undulation in both, will therefore be no longer merely chaotic in either. From the first moment of presentation, pressure or friction, each will begin to act in a manner normal to the surfaces of contact; and supposing this action to have penetrated both, the remote surface of the fur will be actuated by the system proper to the resin, and the remote surface of the resin by that proper to the fur, while at the region of union common to both, both will symmetrically interpenetrate perpendicularly to the common surface of the fur, and resin. Let then the fur and the resin be separated, the surface of the fur just taken from contact, will now manifest strongly the system previously tending to pass upon the resin, that is, the system proper to itself, while the corresponding surface of the resin in like manner will manifest that proper to itself; and by applying conductors in various ways, at various moments, so as to relieve the tension, and constitute currents which, without conductors, immediately stop, a variety of interest-

ng phenomena may obviously be obtained. It is, however, to be remembered, that every system of undulations is, in its own right, accompanied by an equivalent system in harmonic relationship with it, and vibrating or tending to flow simultaneously in an opposite direction, so that the view here advanced is not to be taken as at variance with the ordinary explanation of the phenomena of induction and decomposition of electricities. But these phenomena, as well as the whole subject, cannot be satisfactorily explained, until we become acquainted with the molecular structure of the bodies which display them. Towards this object, therefore, let us now direct our endeavours.

Hydrogen.

It is easy to conceive many conditions of the medium of light in which two of its constituent particles shall unite together, and form a coupled particle thereafter. Thus, let a red ray be met by a green ray, or a yellow by a blue—the particles constituting these dissimilarly affected rays are for the time dissimilar to each other. Their elements will therefore tend to unite. And although the first effect of that union usually will be their mutual assimilation, productive of the vanishment of the colour of both, and the restoration of mutual elasticity to both, and therefore the restoration and conservation of the integrity of the æther, or medium of light, yet in certain circumstances the ætherial atoms may remain united, and form a couple. Thus, should the act of union have discharged so much of the insulative atmosphere, or "atmosphere of electricity or caloric," of each ætherial atom, that the resulting united atmosphere is more similar in volume to that of a single ætherial atom than to that of two, the law of assimilation will forbid their separation until the lost volume can be restored. It will, on the contrary, tend further to unite them, so as to reduce the volume of the couple to the same dimensions as that of a single particle. And of this operation, if allowed to take full effect, the result will be the confluence of both into one, with the recovery of sphericity of the atomosphere of the couple (now merged into one centre of double force). But such an issue is resisted by the law of assimilation in its primary function (which is assimilation to self in successive moments)—that is, self-conservation, the permanence of the individual, the species, the type. There will remain, therefore, a coupled atom, consisting of two centres of force, more or less distant from each other, invested by a common atomosphere, of which they are the foci, and which, therefore, cannot but possess a prolate form. This atomosphere is therefore very ill conditioned with respect to the law of assimilation, which, as has been shown, always calls for sphericity. It is, in fact, wholly destitute of an equator. But where there is one such couple generated, there will usually be more than one; and let two such meet in dissimilar states, they will not fail immediately to unite, so as to become each an equator to the other, that is, crosswise; and thus there will be generated a group of four particles of light or of æther, which, when duly related to space under the law of assimilation, and viewed in reference to the lines of force which join the four centres of force of which it consists, is obviously an elementary tetrahedron, the centres of force its angles, and the lines of force extending between them its edges.

Here, then, we have already a form which, viewed in reference to its nucleus, is cellular, and in reference to its investing atmosphere, is spherical; and which, therefore, under the law of assimilation, is in these respects perfect and ultimate. But such is its peculiarity, that viewed in reference to the same law, it is also merely rudimentary and hemimorphic. If we say that it has an equator, then it has only one pole; if we say that it has two poles (composed each of two centres of force), then it has no equator. Each of its constituent forces, in fact, has three, and not one opposite to it. The law of assimilation, therefore, is not fulfilled even as to its most urgent condition. The form has not similar poles. But this condition may be fulfilled by the attachment of a single particle of light, or an elementary force opposite the centre of any of its four faces. And this, therefore, under many conditions of existence, we may expect it to take to itself from the æther. And thus we obtain a molecular species, whose atmosphere may be spherical, though naturally somewhat prolate (see the black portion of fig. H), and whose nucleus may be described as a triangular double pyramid or bipyramid. And this we may look for both in nature and the laboratory.



H

But what must its properties be, and how shall we be able to compare them with those of known substances? To this it is to be answered, that as yet we have nothing to compare it with but the medium of light. But in reference to its relation to light this appears, that it must repel in a very high degree rays incident upon it (III.); for each of its parts consists of single particles of light; in other words, between it and the medium of light there is the greatest amount of assimilation, the greatest amount of identity, and there will therefore be the greatest amount of repulsion. But to repel light powerfully, is to be highly refractive or reflective; and such, therefore, will this our first species be. It will also obviously be the lightest of insulable bodies. Moreover, its particles must have but a very slender tendency to unite with each other; for its polar angles are identical, and its equatorial angles differ less from the polar angles than they can in any other molecule in which there is any difference at all. If once invested with their atmospheres, therefore, the particles of this body will be very persistent in the fully insulated or aeriform state. It will also keep true to the law of the compression of aeriforms in an eminent degree; for no pressure, however great, can impair or transform the structure of its particles. Now, in all these respects it agrees with hydrogen. Should the reader hastily infer from this, its most early genesis, that we should expect an atmosphere of hydrogen, and not that which we have, let it be remembered that we must have oxygen, else we immediately die; and we cannot have both hydrogen and oxygen, for the first flash of lightning would explode the mixture, and reduce the whole to mere vapour. In reference to higher regions, however, comets, nebulæ, &c., the inquiry as to the existence of hydrogen, and that still more elementary species, composed of four ætherial particles, to which we have not here given a name, is open. But on that we do not enter here.

It is more relevant to our present purpose to remark, that under the law of assimilation, operating in the presence of the æther upon this molecular species, which we have found to agree, so far as we can reach its properties, with hydrogen, and which we may designate by H, we are led to expect three combinations of it with ætherial matter, undistinguishable in the laboratory, perhaps, from pure hydrogen, though all were really to be found there, but differing in important respects both from each other and from their parent.

Thus, suppose an atom of H, $w=5$ to exist under the assimilative influence of some powerfully *prolate* spindle-shaped or linear form, such as a comet when nearing the sun, or the tissue forming the trunk branches or petioles of a plant, it will of course tend, by catalysis, to be assimilated in form, that is, to become prolate also; and this it may accomplish symmetrically, by taking from the æther an additional particle for each pole. It is then in harmony with its position. Its form is still generally similar to fig. H, and its weight is now 7.

Supposing a particle of H, on the other hand, to exist under the influence of an *oblate* or tabular form, as, for instance, a comet in its distance from the sun, or the leaf of a plant, it will now tend to become oblate also; and this it may accomplish by uniting with three particles of æther or of the medium of light, one on each of the three angles of its equator. Its atomic weight now = 8.

But this combination, H, thus loaded on the equator, will no sooner escape from the region whose assimilation or inductive influence generated it, than it will tend to improve its symmetry, and restore its sphericity, by uniting with two particles more—one for each pole—so that it may combine in itself the features of all the three varieties, and thus we reach an atom of double H. This is, however, a much less perfect species than the simple form. And, therefore, under the law of the permanency of species, here acting for the recovery of the original type, we are to expect that the simple and original atom of H will, at the first moment that the temperature is high, or a chemical is presented which invites 2 H to unite with it, escape from the five accessory particles of light superadded to it; while they, in their turn, moving under its assimilative influence, as well as acting to preserve their own type, which is also that of H, will immediately resolve themselves into another H. And thus the atom of double hydrogen will effloresce into 2 H. The first combinations of H—those, namely, with the æther in which it is dissolved—give these numbers of combination so usual, viz., 2, 3, and 5.

But before we have the third, we shall have the two former; and these two are dissimilar, and their differences are the very counterparts of each other. When, therefore, they meet in the same region, they will unite; and this they may do in either of two ways, viz., equators to equators, or poles to poles. Suppose at present the first mode of union. We thus obtain them united in couples (or rather in pairs). But such couples being dissimilar on their alternate aspects, and very defective in reference to sphericity, they will in their turn unite when they meet; but that only until three have done so; for, on the occurrence of three in one, the circle is closed most beautifully by a combination of the most exquisite symmetry, as in the figures below, its equator a regular hexagon, and its axis, as it were, distributed into six meridional parts. It is also such, that its investing atomosphere will naturally assume the spherical as that which is proper to its form; while the nucleus will ultimately symmetrize itself, as in fig. 1. Towards the genesis of this molecular species, therefore, hydrogen, existing in the æther, tends; and this species, above all, we may expect in

1 2 3

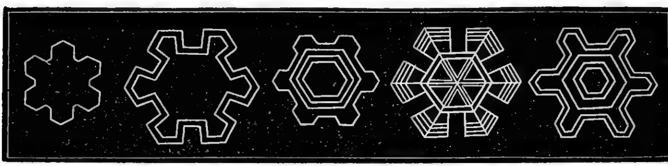
nature (if our hypothesis be at all answerable to nature) most abundantly. But what is it? Comparing it with H, as to refractive power it must obviously be much lower; for many of its angles are formed of groups of two and three particles of light; and thus, being dissimilar, will not repel single particles of light, or a ray, so powerfully as H does. Moreover, its atomic weight is 3 (7 + 8) = 45 (= 9, when H is estimated at unity). And as the law of assimilation will demand that, when in the fully insulated or aeriform state, it shall have, if possible, the same volume as H, the specific gravity of the two aeriforms must be in the same ratio. Thus, common air being taken as unity, and the specific gravity of H = ·069, that of this species must be ·622; in all which respects it agrees with common vapour.

In this respect, however, the aeriform now under consideration differs from H—that whereas in H, the equator as also the poles in each and all are so similar, that union between atoms of H can only take place under very peculiar circumstances—as, for instance, in a most intense cold, or under most intense pressure; in this species, on the other hand, there are in each particle three segments of the equator and three poles, dissimilar to the other three. Such particles therefore will readily unite, especially by their equators; for this they may do, so as at the same time to do homage to the law of assimilation, in giving birth to a higher order of symmetry. Whilst H, therefore, will be very permanent as an aeriform, this species will tend to condense. While H will be a permanent aeriform or gas, this will be a condensing aeriform or vapour.

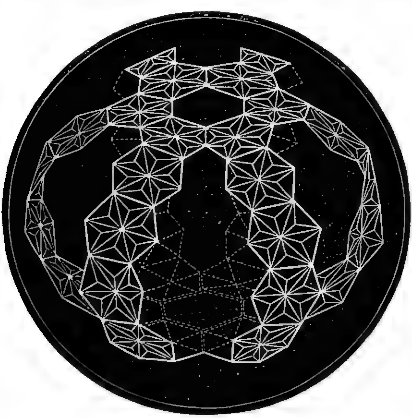
And here the symmetry of the structure shows that where the temperature is low enough to admit of a rigid combination among the particles equatorially united, a star-like form of six rays (see the figure below) is to be expected.

Moreover, the star-like bodies will tend to unite, and that in groups of 20, 36, and higher numbers, into beautiful, isometrical, basket vesicles, which being very light, may well suit to form the beautiful fine-weather-clouds.

It is also to be considered, however, that the single particles may unite poles or equators, in which case rhombohedral vesicles of defective symmetry must result, and these may give the ragged clouds, (nimbri, &c.) On the breaking up of the former, if sufficient cold be carried down to the lower strata of the atmosphere, to preserve the rigidity, it is only necessary to inspect the figure above to obtain an explanation of the usual forms of snow flakes, as represented in any work which gives them.



And let the temperature be such as not to insist upon the rigidity of the star-like combination, and then these star-like cloud elements will unite in couples only, giving an exquisite molecule, of which fig. AQ may give some idea, composed of 36 particles of vapour, its atomic weight $45 \times 36 = 1620$. As to its properties, some that are very remarkable present themselves. Thus, since, according to this view, a particle of water is a hollow cell or basket of dew, we are at once able to understand the phenomenon, that into a certain volume of water we may introduce a great quantity of different salts without adding to that volume. The particles of salt may nestle in the interior of the particles of



$AQ = aq^{36}$

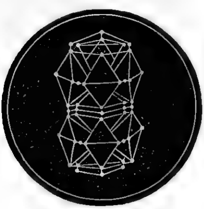
water. Again, it might be shown that it is at a certain temperature only that this molecule will be spherical. On one side of that temperature it must be prolate, while on the other it will be oblate. Now, a given number of spherical molecules, under similar conditions of existence, must occupy less space than the same number of equivalent spheroids, whether prolate or oblate. A volume composed of such molecules, therefore, will at a certain temperature manifest a minimum or a maximum density, both below and above which it will expand. And thus, supposing our molecule to represent a particle of water, it explains what has hitherto been regarded as an anomaly in that liquid.

It further appears that when such a molecule is heated, so as to vaporize, or explode into vapour, a great quantity of heat must be engaged; for aeriform atmospheres are wanted for no fewer than thirty-six particles of vapour. But to balance this, the volume of vapour resulting must be very great. In these respects, also, our molecule represents water. Moreover, it is obvious that when a group or mass of such molecules become solid, whether by themselves, as in ice, or in the tissue of plants abounding in water, the elements of the rhombohedral or hexagonal system of symmetry must manifest themselves. And this, too, has been remarked of ice, and of aqueous or monocotyledonous plants. By thus viewing water as vapour in a molecular state, each molecule composed as stated above, we also obtain the reason of the uniform great per centages of water in the great products of nature, which seem otherwise altogether arbitrary and accountable. Thus the form of the aqueous particle is such, that to constitute a complete symmetrical shell of water for a single atom of another kind, such as an atom of sea salt or of urea, one of water will be required for each pole of that atom, and twelve to invest its body, and to unite into a shell along with these polar particles of water. Now, this gives (as any one may find who makes the calculation) 2·56 per cent. of salt for the sea, and 1·3 of urea for urine. And these may truly be regarded as the normal quantities, as a reference to nature will show. And this also leads us to regard the liquids holding these salts in solution, not as merely mechanical or accidental, but as of a symmetrical, or chemical nature. And so of organized fluids and tissues generally. Allowing a particle of water to each element that goes to constitute the peptonic or proteine molecule (the number of which elements we may estimate by the number of atoms of nitrogen in the formula), or reducing them all to their simplest terms, as has been done by C. Schmidt, in his formula for the muscles of insects (viz., $C^8\,H^6\,N\,O^3$), we obtain about 80 per cent. of water.

PRIMÆVAL ABYSS.

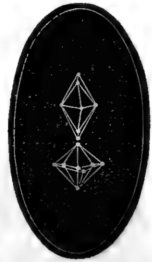
Enveloped in an atmosphere of vapour, therefore, its extent depending on the existing temperature, we thus arrive, in our hypothesis, at an aqueous mass, in the bosom of the universal æther, gathered till it became a primæval abyss.

And therein, towards the central parts, as soon as it has attained to a certain depth, there can be no doubt that a molecule so delicately constructed as a particle of water will have to yield under the crushing effects of the tremendous pressure to which it is exposed. In fact, the space required to accommodate a single particle of water (which consists of only 36 atoms of vapour), is competent to contain no fewer than 100 of the latter, when compacted together as steam, at a maximum of density. Such compacted vapour or steam, therefore, we may look for in the central parts of our abyss. But though it is impossible for the particles of that steam to reunite equatorially, so as to recover the form of water while the pressure continues, there is nothing to prevent them from coupling by their poles. And this they will tend to do, because the six parts of which these poles consist are alternately dissimilar to each other. We thus obtain as our second molecular species a sort of double vapour (fig. *A m*), more permanent than a particle of water, yet considered as a form, more defective, inasmuch as its poles are still six-partite; and its equatorial region, instead of being the most expanded of all, is more contracted than two other regions, one on each side (forming the equators of the particles of vapour of which it consists). Its axis, under the law of sphericity, is also much too long. Moreover, there is to be observed on the alternate summits of the polar parts an ætherial element which is both supernumerary to the symmetry of the molecule, and so placed that by the discharge of these supernumerary particles the axis will be shortened, and the molecule improved. We are therefore to expect that when two atoms of vapour unite thus pole to pole into a particle of double vapour (as soon as the nascent state or epoch is over), they will give off six ætherial elements, thus reducing the weight of the new species from 2 × 45 = 90 to 90 — 6 = 84, which, when H = 1, gives 16·8. So long, however, as this molecule is naked, and its equatorial region so contracted, compared with what may be called its thoracic and pelvic regions, it must be open to such transformation as will improve it in these respects. And for this an opportunity will occur, when one of the six elements, from



A m

the circle of six of which it consists, is any how thrown out. In which case, this destruction of the molecule will be indicated by the appearance of 3 H, for every particle of double vapour destroyed: for the rejected element (see the accompanying figure) consists of two loaded hydrogens, which on being set free will give three light hydrogens.



The five double elements which remain are then capable of closing at the poles, while by the same movement they expand at the equator, so as to produce a most exquisite molecule (fig. N), of which the following must be the characteristic properties. It is so perfect in a morphological point of view, that it must be possessed of great repose, or, in the language of the laboratory, it must be a very inactive or inert substance. Its atomic weight must be 84 — 15 or 14, = 69 or 70; and therefore when H = 1, equal from 13·8 to 14. Its specific gravity, in the fully insulated or aeriform state, must be fourteen times as great as that of hydrogen, viz., ·97; for the law of assimilation provides that all fully insulated and individualized molecules, that is, the molecules of all aeriforms, shall have equal volumes, or at least volumes in the simplest ratios to each other. Its action upon light, that is, its refractive power, must be lower than that of the double vapour which we have already constructed and designated by the symbol *Am*; still lower than that of an equal quantity of the single vapour, or *aq*; and vastly inferior to that of the first constructed species, which we have found to represent hydrogen. Now, in all these respects this molecule agrees in its properties with nitrogen, and may therefore be taken to represent it, while the parent molecule agrees with ammonia, and may be taken to represent it.

N

Oxygen.

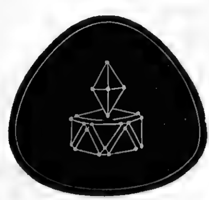
On comparing the form of the particle representing nitrogen with the form of that representing steam, it will be seen that they are of quite different orders, and wholly unconformable. That of steam is, in all its features, hexagonal, that of nitrogen is pentagonal. However closely, therefore, they be pressed together, they cannot unite conformably, organically, or chemically. They both exist, however, under the law of assimilation. Each must, therefore, tend to assimilate the other to itself, and ultimately that which is the weaker of the two, must yield and adopt the order of form of the other, so long as it exists in its presence, if it be capable of it. Now, of the two, vapour and nitrogen, vapour is the more tender. It is also exquisitely capable of being transformed, so as, in its transformed state, to apply itself most symmetrically and completely to nitrogen. Thus, let a particle of vapour, supposed to be on the pole of an atom of nitrogen, be assimilated to the latter, that is, let one of the six parts of which it consists, be excluded from the circle of six, and then the five remaining elements may immediately fall upon each other in such a way that their union may be more complete than it was when, along with the sixth, they constituted a particle of vapour. But it is now of the pentagonal system of forms. It is now like nitrogen. It may, indeed, be said to form the negative icosahedron (see fig. O), of which nitrogen is the positive; for on constructing these two diagrams, it will be seen that each of them is bounded by twenty triangular faces, five for each polar region, and ten for the equatorial region, all equal to each other, which is the conception of the icosahedron. But in N the five polar faces are salient, as in the icosahedron of geometry, while in this species they are re-entrant, so that the poles here touch each other in the centre of the form. This species is, therefore, altogether in want of an axis, but this the nitrogen, with which, on its development, it enters into union, will supply on one side, while the atom of hydrogen discharged from the circle of six, when it was a particle of vapour, will supply it on the other.

O

By the assimilative influence of the nitrogen, assisted by pressure, we thus obtain, in the abyss, a new species, to which the following properties must attach:—(*a*) Its atomic weight must be $45-5=40$; for although the atom of hydrogen now in the pole was loaded when forming one of the six members in the equator of the particle of vapour, not only would the law of the maintenance of the original type (see page 68) lead us to expect that it would recover itself simply as H when the molecule of *aq* was transformed, but the forces which are supernumerary in reference to H when loaded are necessary to complete the symmetry of the new species O. Thus its equatorial region consists of ten times three forces, which, to complete their relations, require ten in the centre. Hydrogen being taken as unity, the atomic weight of this new species, is therefore 8. (*b*) Its angles are all composed of groups of three forces, and its centre or axis, as has been said, consists of a group of ten. Its repulsive action, therefore, upon a ray of incident light, must be very small compared with that of hydrogen, and small when compared with that of vapour or nitrogen. In other words, its refractive and reflective power must be very low. (*c*) From being merely an equatorial form wholly wanting in polar parts, it must tend to unite with almost every substance; for it can scarce be so bad in reference to the law of sphericity as when existing alone. It will, therefore, be parasitic in a high degree, and (in consequence of its low reflective power), it will be destructive of the lustre of other bodies. It will, therefore, be a corrosive substance. (*d*) When no other bodies are presented to it for union, its own particles will unite among themselves and go in couples (as in this figure); for of such a couple the atmosphere may be spherical, though of a single particle it cannot, at least with the same facility. In this coupled state, therefore, it will also be less active than when existing in single atoms. This species may, therefore, be expected to be known in two states of existence, one much more active than the other. (*e*) When existing permanently in the aeriform state, there can be no doubt that it will exist in coupled atoms. The volume of such coupled atom, therefore, under the law of assimilation, being assimilated to the volume of a single atom of hydrogen, of vapour, or of nitrogen, it will weigh double what the atomic weight would indicate, and half a volume of this kind of gas will be equivalent to a whole volume of the other sorts. Thus the genetic equivalents of a volume of vapour must be one volume of hydrogen, and half a volume of this species; and the spec. grav. of hydrogen being ·0693, of vapour ·623, of nitrogen ·970, that of this species must be 1·109. Now, in all these respects, this new species represents oxygen.

O

And thus we find vapour to be dimorphous in a very beautiful manner. In union with a molecule of the pental or pentagonal series of forms, such as nitrogen, it can only exist as H O. But let it be disengaged from such union, and go free, or let it unite with H, or any other molecules of what may be called the trinal or trigonal series, and it relapses into *a q*, the properties of which cannot but be very different from those of H O. And, indeed, in H O, this primordial species, have we not the index and type of the three great classes of chemical properties, the *acid* represented by H outstanding on the pole of a molecule, the *basic*



HO

by O in a similar manner outstanding, and the *neutral* by *aq*? Hence H meeting O, and entering into union and producing *aq*, is an epitome of all synthetic chemistry.

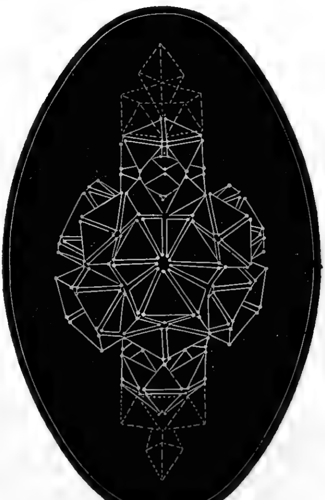
THE MIXED ATMOSPHERE.

Oxygen, being developed (through the assimilative power of an atom of nitrogen) by the transformation of a particle of vapour into H O, cannot but tend to relapse, along with the hydrogen, into vapour, as soon as the mitigation of the pressure will allow. And, accordingly, there is no such combination as H O N known at the earth's surface. No oxygen, therefore, can be obtained from the abyss by the aid of one atom of nitrogen only. But let there be a second atom of nitrogen there, and let it be substituted for the atom of hydrogen in the pole of the atom of oxygen, giving the combination N O N, and now the oxygen is protected on both poles from the access of hydrogen, however much there may be nascent around it; and thus protected it may escape from the region of danger. But of such a combination the axis is too long. As soon, therefore, as N O N escapes from the region of constraint, it will break up. Each particle of N being spherical, will break off, and form an aeriform volume by itself; while the atoms of oxygen, as has been shown, will couple, and two of them within one atomosphere will form one volume. And thus, as the organic composition of such an atmosphere, due to the permanent decomposition of vapour in the abyss, we shall have four volumes of nitrogen, and one of oxygen gas. And such is generally supposed to be the normal composition of the atmosphere. But on constructing an integrant element of such an atmosphere, that is, a cubical portion with four atoms of nitrogen to the side, and therefore consisting in all of 64 N and 16 O, it will be seen that there is a blank in the symmetry which another atom of O is wanted in the centre to supply. This additional atom of oxygen gas, therefore, we may expect in the repose of nature, giving, as the normal composition of the dry air,—

	Vol. per cent.		
64 N	= 79·01	79·19	found by Dumas and Boussingault.
17 O	20·99	20·81	

NITRIC ACID.

In what has preceded, we have seen particles of vapour going in couples when necessitated, but tending to form into spherical groups, and succeeding in doing so. We have also seen particles of oxygen going in couples; but not less than vapour they tend also to form into spherical groups, though to this their identity in all their corresponding parts is opposed. The same remark applies also to nitrogen, though from the perfection of the individual atom in this case a spherical and dense molecule of nitrogen is still less to be looked for. As to the number of individuals requisite in either oxygen or nitrogen, to constitute such a molecule, it is not as in vapour 36, but only the third part of that number; for in both species, in both O and N, the regions of union are regular pentagons; and to this figure the isometrical polyhedrom belonging is the dodecahedron. And therefore the most perfect molecule of oxygen and nitrogen, will be a dodecatom. Now, though we are not to expect in the atmosphere a dodecatom of oxygen, and much less a dodecatom of nitrogen, yet the demand of oxygen for union, and the differences of the two, O and N, are so great, that we may expect, under peculiar circumstances, the development of a dodecahedral molecule, composed of both; two particles of nitrogen, which has positive poles of its own, being caught to form poles, and ten of oxygen, which is itself an equatorial form, being caught to form the equator. But such a molecule will possess great assimilative power, and wherever it meets with vapour or water, as it must do everywhere in nature, doubtless it will transform a particle in each pole into HO. We thus obtain a magnificent molecule, its formula $HO,NO^{10}N,OH=2(NO^{5}+HO)$, which is the well known formula of nitric acid.



And here we may apply our method to deduce a property which has been hitherto obtainable only by experiment. Thus, as this molecule is so delicately constructed and so large, we cannot expect it in the aeriform, we can only expect it in the dense state; for such heat as is implied in the aeriform state would certainly dissipate it in a short time. But as it is composed wholly of aeriforms, the dense molecule which we are to expect must be the lightest which is compatible with sphericity. Now, the poles of this molecule are triangular, which leads us to the tetrahedron, or a tetratom, as the lightest isometrical liquid molecule possible. And this, under the law of assimilation, we are led to regard as occupying the same volume as a particle of water, which in our theory is the grand cosmical regulator of the volumes of dense bodies generally. The specific gravity, therefore, must be

$$\frac{4\,(H\,O + N + O^{10} + N + O\,H)}{A\,Q} = \frac{4\,(45 + 70 + 400 + 70 + 45)}{1690} = 1{\cdot}55,$$

as has been determined by experiment.* This is not the only molecular combination of oxygen and nitrogen which may exist. Thus, in culminating towards it, or falling away from it, we may obviously have two atoms of N with one of O, as a medium of union between them, (the same combination as we have supposed to be previously developed in the abyss), in which the want of equatorial matter may be supplied by an atom of O on each of the corresponding faces of this pentagonal form, thus giving $N\,O^6\,N = 2\,(N\,O^3)$ which must be an acid under the same circumstances as $N\,O^{10}\,N = 2\,(N\,O^5)$ is acid. Here, however, as is shown by the latter, the charge of O is not complete. We may therefore have an addition of an atom of O to each pole, rendering them rather basic than acid, and giving $O\,N\,O^6\,N\,O = 2\,(N\,O^4)$ peroxide of nitrogen.

The Solid Globe.

In this way, by following out our hypothesis, we also reach eminent species which never escape from the abyss, some of them such as Silica constantly appearing and proving to be what may be called residuary species. And whether the entire hypothesis be only a dream, or something more than a dream, it is certainly curiously representative of Nature. It is felt, however, that not only would models of molecular forms, such as those that were used when this paper was read, but far more time and illustration than were even then possible, be required to render it generally interesting.

February 11th, 1857.—The President *in the Chair.*

The following gentlemen were elected members:—Mr. John Taylor,

* In this way it is often possible to deduce the spec. grav. of liquids and solids in our hypothesis, on the supposition that all the volumes of all liquid molecules are similar to one another, or in simple ratios. It often happens, however, that the same aeriform molecule may condense with nearly equal facility into a variety of liquid molecules, such that they are complementary to each other, and each supplies, to a certain extent, the defects of the others. In this case the calculation becomes more difficult, as for instance, in reference to that nitric acid obtained from all others by boiling them down to it.

Merchant, 6 Hope Street; Mr. Archd. Thomson, 3 Royal Terrace; Mr. Thomas Jackson, jun., Coats House, Coatbridge; Mr. James Robertson, L.R.C.S., Ed., Surgeon, Renfrew; Mr. William Johnston, 6 Holland Place, St. Vincent Street.

Mr. Cockey read a paper "On Bessemer's Process for Manufacturing Malleable Iron."

Bessemer's Process for Manufacturing Iron. By MR. WILLIAM COCKEY.

THIS invention was first published to the world at the meeting of the British Association, at Cheltenham, in 1856; and having excited a great deal of attention, the makers of bar iron were generally anxious to ascertain the value of the process. The experiment described in this paper was performed at the Coates Iron Works, by Mr. Jackson.

Seven and a-quarter hundredweight of No. 1 pig iron was put into a founder's cupola, and when melted, was run off into a cylindrical furnace of fire-brick, two feet deep, by about eighteen inches diameter, previously heated, round the bottom of which there were six twyres for delivering the blast from a blowing machine. The air was forced in at a pressure of about eight pounds to the inch, afterwards increased to ten pounds, and rising through the melted iron, a violent ebullition commenced, and a red flame, from combustion of the carbon, issued from the top of the furnace. In fifteen minutes from the commencement of the experiment, slag began to be vomited, and the combustion was very vivid. In twenty minutes, most violent combustion was going on, and slag was vomited forth in large quantities, accompanied by showers of scintillating sparks, which were thrown to a distance of twenty or thirty yards, surpassing in splendour the finest display of pyrotechnic art. This violent commotion had nearly ceased in about thirty minutes from the commencement, and ten minutes later the furnace was tapped, and the purified iron run off. The exact weight was not ascertained, but it was believed not to exceed three and a-half hundredweight, or half the quantity of pig iron put into the cupola.

When sufficiently cool, the Bessemer iron was taken to the rolling mill, and rolled into a bar, which was cut and piled, again rolled, and the piling and rolling once more repeated. The result was a bar of crystalline iron, destitute of fibre, and, as was afterwards ascertained, possessing very few of the properties of good malleable iron.

The theory advanced by Mr. Bessemer was, that to convert cast iron into malleable iron it was only necessary to deprive the former of its carbon and other impurities, which he was able to effect by driving atmospheric air through melted pig iron, in the manner here described; but it seems to be generally allowed, that although he was successful in producing nearly pure iron, it was not in the mechanical state which is requisite for toughness and malleability; and that in order to bring it into that condition, the process of puddling, or some one analogous to it, was necessary.

An experiment such as here described cannot be regarded as conclusive of the failure of Mr. Bessemer's patent; but it is probable that before it can become practically useful some modification of the process must be adopted. The subject is well worthy of further investigation.

March 11, 1857.—*The* President *in the Chair.*

Mr. George Anderson read a paper "On the Best Means of Promoting Education among the Working Classes."

The Education of the Working Classes, and the Best Means of Promoting it. By Mr. George Anderson.

Hitherto every scheme that has been proposed for the better education of the masses seems to take for granted that the masses not only require, but demand such a measure; but it appears worthy of consideration, whether the failure of every such scheme does not go far to answer that question.

That there is a loud cry through the country for extended education, no one can deny, but so far, that cry proceeds only from the educated classes—from those who have themselves learned the value of education; and, unfortunately, that is not a large proportion of our people, and, more unfortunately still, that limited proportion is weakened by dissension, and thus perpetually neutralizes its own efforts.

It appears to me, that at this juncture it may be well for the real friends of education to pause before renewing the contest—to look about them and consider whether, after repeated failures in one direction, it might not be better to inaugurate a new course; and I will endeavour to point out what course I think holds out some hope of success.

Educational State of Great Britain as compared with other Countries.

By the census of 1851, we find that the population of England and Wales (with the Channel Islands) was 18,070,735, of which total there were at school 2,124,324 being 1 in $8\frac{1}{2}$ of the population. The population of Scotland was 2,888,742, of whom were at school 368,517, which is 1 in $7\frac{3}{4}$ of the population, or 1 per cent. better than England. Taking the two together, we have—

Population,	20,959,477
At School,	2,492,841

Or about 1 in $8\frac{1}{3}$ of the population.

Now, other countries have, by the best authorities, been stated as follows :—

Berne,	1 in 4	Canada,	1 in 7
Sweden,	1 ,, 4	Prussia,	1 ,, 6
Saxony,	1 ,, 5	France,	1 ,, 6
Massachusetts,	1 ,, 5	Denmark,	1 ,, 7
Whole U.S.,	1 ,, 6	Holland,	1 ,, 8

It is thus seen that England stands very low in the scale, and I fear the reality is lower than even these figures fully show; for I find from the Minutes of the "Committee of Council on Education," the most reliable educational statistics we possess, that our scholars range from three to fifteen years of age, and that fully 25 per cent. are under seven years. Now, in Prussia, for instance, the returns appear to be taken from seven to fourteen, during which term of age nearly all the children are at school, whereas in England, of the children of these ages, only one-half are at school.

Of children in Great Britain, of *our* school age, three to fifteen, we have nearly 6 millions,* of which only 2½ millions are at school, 600,000 are known to be at work, and there remain between two and three millions educationally unaccounted for.

But as three to fifteen may be considered too long a range, a large part too young for being generally at school, and a large part at the other end of the range gone to work, we will take the period from five to ten, during which ages it can hardly be doubted that all ought to be at school. We find there are of children at that age 2½ millions in the population. Now, the Minutes of the Committee of Council show that 59 per cent. of the scholars in the schools inspected by them are of that age; and as these schools may be taken as a fair basis for estimating the educational state of the country, we are probably not far wrong in assuming that there are of our children, from five to ten years old, one and a-half millions at school, and one million entirely unaccounted for!†

We find in Massachusetts and in New York State, that there is actually a larger number of children of all ages, at school, than the population shows of the standard school age :—

In Massachusetts, in 1851, of children five to fifteen,	196,536
Of all ages at school,	199,429
In New York State, in 1850, children five to sixteen,	735,000
At school, all ages,	795,000

* Census 1851—Children of three to fifteen, 5,789,366; At school of all ages, 2,492,841.

† Census 1851—Children five to ten, ... 2,448,699
Scholars of all ages, 2,492,841, of which 59 per cent., . 1,470,776

Unaccounted for 977,923

In New York City, in 1850, children five to fifteen,	90,145
At school, all ages, ...	102,974
In Great Britain, 1851, children five to fifteen,	. 4,694,583
At school, all ages, ...	. 2,492,841

Bad as the state of matters is thus shown to be, there is great room for doubt whether or not any amelioration is taking place—whether the education of this country is advancing in even as high a ratio as the population.

Connection between Ignorance and Crime.

The intimate connection between ignorance and crime is a fact almost too patent to require proof. Any amount of evidence might be brought forward, but one or two statements on that point may be sufficient.

Mr. Clay, the chaplain of the Preston House of Correction, says, that one in fourteen of the whole male working-class population comes annually within the grasp of the law, and that of all who are imprisoned in Lancashire, only 2 per cent. can read and write properly.

Out of the prisoners sent to the Preston establishment, he further says, that "72 per cent. (nearly three-fourths) are in a state of such utter debasement that it is in vain to attempt to give them instruction, as they could not understand even the words used in doing it." In 1853-54, he had 16,500 male prisoners, and of these 9,641, nearly 60 per cent., could neither read nor write at all.

Captain Willis, of Manchester Jail, says, that out of 8,294 prisoners 32 per cent. could neither read nor write.

Captain Greig, of Liverpool, states, that out of 25,111, only 2 per cent. could read and write well, while 50 per cent. could do neither at all.

The criminal statistics for 1854 give an increase of 9 per cent. on the committals of the previous year; and on the subject of instruction the following is the result:—

Criminals of superior education, . . .	2	per cent.
Could read and write well, ...	4	—
Total educated, ...	6	—
Could read and write imperfectly, . . .	37	—
" read only, ...	20	—
" neither read nor write, ...	37	—
	Giving 94	per cent.

who have little or no instruction.

From the United States we have similar reports. Out of 28,000 criminals, only 128 had got a common school education; and out of

27,000 committed in 1850, 14,000 were foreigners. In that educated country, the uneducated foreign element, which comprises only one-tenth of the population, appears to produce half the crime.

After giving an account of several of the foreign systems of education, taking Prussia as the type of the compulsory system, and Massachusetts as the type of the voluntary, the paper proceeds—

Proposed Remedial Experiments.

With such figures as the educational statistics of England give us, the friends of education can have very little doubt as to the urgent necessity for some change. This necessity has been long felt, and many schemes have been propounded to meet the evil, but hitherto these efforts have been made under the belief that there was a great deficiency in school supply, rather than a want of school demand. Statistics do not, however, bear out this view very fully, but rather point to another cause—to the total apathy and indifference to education, on the part of those for whom schools and teachers have been already provided.

Turning to the Minutes of Council for 1856, I find that the schools examined by Her Majesty's inspectors over the whole country numbered 4,800, with 3,069 teachers, and 8,465 pupil-teachers. At the very ample allowance of eight square feet of area for each scholar, these schools were sufficient for 811,794 children, while there were in attendance only 537,583, only two-thirds of what they might have accommodated.

Now, as the schools inspected by Her Majesty's inspectors represent only about one-fifth of the whole scholars in the country, and as we find in that fifth a surplus school accommodation for 274,211 children, it may be supposed that there is, over the whole country, a surplus of accommodation for a million and a-quarter of children. There are no certain data to go by, and this may be an over-estimate, as much of the surplus accommodation may be so situated as not to be available; but, making every fair allowance, there remains the undoubted fact, that there is in the country greatly more school accommodation than is taken advantage of.

The Reports of Her Majesty's inspectors are nearly unanimous on this point; but I will only give one quotation. It is from the Report by Mr. Marshall:—

"There is one evil more in need of remedy than all others put together, which the measures adopted by the Committee of Council have done nothing to relieve—one obstacle more fatal to the further progress of public education than any other which experience has detected, towards the removal of which not even the first step has yet been taken. Immense progress has everywhere been made in the extension and improvement of school fabrics, the supply of suitable and skilfully devised apparatus, and the gradual creation of an adequate staff of competent and devoted teachers. Towards all these objects your Lordships' measures have furnished the most important aid. But when the schools have been built, often at great cost, and with excellent judgment, and the teachers have been installed in their office, full both of zeal and capacity, what has been done to secure inmates for the one and pupils for the other? Evidently nothing."

In looking over these Reports, which contain much valuable and interesting information, we cannot help being struck with the fact, that most of these inspectors have felt so deeply the extreme difficulty of *inducing* parents to send their children to school, or, if they did send them, to keep them there for any useful period, that nearly all of these Reports recommend a compulsory enactment.

In the face of all the evidence on this point, it becomes very difficult to avoid the conviction, that all our magnificent educational schemes, if they go no farther than the building of schools and the providing of teachers, will never educate the people. Towards that grand object there appear to be two courses. We must either treat ignorance as a police delinquency, and pass a compulsory educational law, or we must wait the slow process of years, the tardy leavening of the mass below with the ideas of those above, till the masses of our population get to appreciate the education we seek to give them, and become willing to avail themselves of our teachers and our schools. If there be a third course, it must be by founding on one or other of these, and either by establishing a modified compulsion, or by endeavouring by some means, legislative or otherwise, to stimulate that tardy leavening to a more rapid fermentation, and to imbue the masses, by some speedy means, with a strong desire for education.

The causes at present in operation to produce the slow result are, the weight of moral obligation, the sense of parental duty, slowly growing with the growing intelligence of the people. To produce more rapid results, we must appeal to some more lively feeling, even if it be a less elevated one. We must appeal in the plainest and most direct way to self-interest, and I need hardly add that the plainest and most direct is through the medium of the magic letters, £ s. d.

In short, I wish to bribe the people into educating their children, by proposing to them some unmistakeable and quickly realizable pecuniary benefit from their doing so. I propose that uneducated children should be placed for some years under certain disabilities in the matter of earning wages, and that a premium be put upon education, by allowing all who shall come up to a prescribed educational standard to earn wages at an earlier age.

I would not press for an immediate general measure, because it is as yet untried; *but I will now proceed to show that we have particular facilities for making a large experiment in that direction, with the very smallest legislative change, and of arranging it in such a way that it would inflict no disability not already existing, while it would hold out a large premium to a numerous and important class of our working population.*

The class to which I allude is that of factory workers; and I wish to draw particular attention to the present educational condition and prospects of that class. There are special reasons why I should make it thus prominent. One of them is, that it lies within my own sphere of knowledge, and I am therefore more competent to speak of it; but my principal reason for selecting this class is, that it exclusively has been made the subject of a very peculiar legislative experiment, greatly with a view to its education; and through that circumstance we have ample statistics to aid our investigations. Moreover, though the number of those employed in factories at any one time is only about 700,000 over the whole country, yet the number who have, at some period of their lives, been so employed is of course very much greater, and in fact their domestic life ramifies through our whole working population, and they may be fairly supposed to represent it.

The Acts for restricting the labour of children, young persons, and females in factories, and for providing for the education of children so employed, have been in existence for upwards of twenty years, and it is therefore not premature, after such a period of probation, to inquire how they have accomplished the ends for which they were passed, and what has been their effect on the condition of the classes they were intended to benefit. Our inquiry is purely an educational one; and in any strictures I may pass on the Factory Acts, I wish to be distinctly understood to refer to the educational provisions of these Acts, and to no other branch of them.

The principal regulations of these Acts are—

That children under eight years of age cannot be employed at all in factories.

Those from eight to thirteen may be employed for the limited service of $6\frac{1}{2}$ hours per day, subject to the condition of attending school for three hours daily, with constant certificates of that attendance.

At thirteen years of age children reach the status of full time workers, allowed sixty hours' labour per week (ten hours per day), and with no educational provisions or restrictions whatever.

The shortened labour, from eight to thirteen, was humanely intended by the Legislature not solely in tenderness for the physical powers of a child of that age, but also for the purpose of securing its education, and thus, by combining moderate industrial training with useful intellectual teaching, gradually to raise the factory population to the status of an educated class. A very noble object indeed, and a seemingly feasible plan for its attainment; but alas! when we examine the actual results, our illusive hopes vanish like a dream. We find that though for upwards of twenty years the factory population have been under the bondage of this teaching, and though generations of children have grown up under it, the race of to-day is as ignorant and untaught as those that went before.

It was reasonably enough expected that when the labour of 1,000 children was reduced from 12 hours to 6½, nearly 2,000 would be required to do the work, and thus, that not only the children then in employment, but a largely increased number would at once be brought under the benefits of an educational training. The very reverse of this occurred; for whereas in 1835 there were employed in factories nearly 60,000 children (56,455), we find that in 1838 there were only half that number (29,283); and even now, with all the immense extension of the factory system that has taken place, we are still 10,000 short of the numbers of 1835, the numbers now being 46,071.

Thus, instead of doubling the number under education and lucrative employment, the immediate effect of the measure was to banish from factories one-half of the children employed in them, and substituting nothing—providing nothing—simply to drive them out, helpless and uncared for, to the tender teachings of the streets.

In Scotland the banishment was almost total. I have no return for 1835; but I find that in 1850, in the whole of Scotland, there were only 929 children receiving education under the Factory Act; and in Glasgow, with her population of 400,000, there were only 140.

Very complete returns, moved for last session, by Mr. Brotherton, have just been laid before Parliament, and through these I am enabled to produce the most recent evidence on factory education :—

The total factory hands in Great Britain and Ireland are	682,497
Of these are school children, ...	46,071

Or about 6 per cent. of the whole.

The census of various districts is as follows:—

England and Wales, total workers, ...	572,077
School children, ...	44,769

Or about 7¾ per cent.

Ireland, total workers, ...	32,988
School children, ...	114

Or 3½ per 1,000.

Scotland, total workers, ...	77,432
School children, ...	1,188
Or $1\frac{1}{2}$ per cent.	
Lanark, total workers, ...	23,821
School children, ...	236
Or 1 per cent.	

We thus arrive at the full value of the Factory Act as an educational measure. We find that over the three kingdoms 6 per cent. of those employed are receiving education under the Act, and that their ages range over the five years between eight and thirteen. If they are divided equally over these years, as is probably near the fact, it follows that one-fifth attain the status of full time workers annually. One-fifth of 6 per cent. is twelve per thousand, which is thus the proportion of educated workers raised into the general mass every year. It will thus take just eighty-four years for the Factory Act to complete the education of the whole workers, provided we could contrive that all the educated additions remain so long!

If a more complete *reductio ad absurdum* is wanted, Scotland will afford it, her factory school children being $1\frac{1}{2}$ per cent., a-fifth of which is just three per thousand raised annually into the uneducated mass; so that, if we could insure patriarchal longevity, the scheme would be complete in 333 years!

The foregoing results also take for granted that the factory school children really are taught; and to show how far this is the case, I must refer to the inspectors:—

Mr. Redgrave says (Report 1852):—

"The millowner cannot legally employ a child without having obtained certificates of its having attended school, and the parent is responsible if it be permitted to neglect school; but the law has imposed no condition, and provided no security that anything shall have been learned at school."

And farther on:—"In several schools which I have visited I have found factory children well advanced; but in general the factory children are the least informed in the school—a result not of their inaptitude or inferiority, but of the irregular and uncertain intervals of their attendance."

Mr. Horner testifies (Report 1855):—

"The so-called education clauses in the Factory Act enact no more than that the children shall attend a school. Nothing is said as to the kind or quality of the education they are to receive, and unless it be such a case of gross ignorance as is scarcely conceivable would be met with in any one professing to teach, or for immoral conduct on the part of the teacher, the inspector has no power to require that the children shall be sent to a school where they may have a reasonable chance of getting some instruction.

"Before the passing of the Act of 1844, certificates of school attendance were not very rare which had been signed by the schoolmasters with a ×, as they were unable to write.

"The inspectors, when the bill of 1844 was in preparation, did not fail to represent the disgraceful state of the places called schools, certificates from which they were obliged to admit as a compliance with the law; but they were successful in obtaining only thus much, that the figures in the school certificate must be filled up in the handwriting of the schoolmaster, who must also sign his Christian and surname in full."

I think it is thus sufficiently demonstrated that, whether as regards the number taught or the learning they acquire, the half-time system established by the Factory Act, considered as an educational measure, is a complete failure; and I have been thus particular in pointing out its deficiencies, because there appears to be an opinion gaining ground in this country that it might be advisable to extend this half-time system to other employments; and also because I wish to bring under notice a better scheme, that to which I have already alluded, and which I will introduce, in the words of its author, Sir John Kincaid, inspector of prisons and factories for Scotland:—

(Report, April, 1850.)—"In consequence of a letter from Mr. Cornewall Lewis, enclosing a communication representing that the employment of young children in the houses of their parents and others, at winding and handloom weaving, prevailed in some districts to a considerable extent, and was fraught with serious evils, bringing on disease of the spine, and the various affections arising out of it, I have devoted much time to that interesting inquiry, and have every reason to believe that it does prevail to a very considerable extent in Scotland, and that the injurious effects have not been over-rated.

"My inquiries were, in consequence, especially made to ascertain in what manner the different parties interested would be affected, were the Ten Hours' Act extended to children eleven years of age.

"My information leads me to believe that the factory labour required from a thirteen years' child, can equally well and with equal safety be performed by one of eleven years. There are, of course, exceptions at both ages, but that is a consideration which, in my mind, may be very safely left to the managers of factories; for it is not their interest to employ a child who is not equal to the work.

"The most important consideration in treating on this extension, relates to the poor children themselves; for while many of the latter are employed at labour unsuited to their years and destructive to their health in unwholesome places, others of them are roaming idle about the street at the very age when poverty and idleness are most prone to engender evil habits and associations which can never after be shaken off."

Again, he states (Report, Oct., 1852):—

"I believe it will not be disputed that the usual employment of children in factories can as easily be performed by a child of ten years of age as one of fifteen, as the active employment of their eyes and fingers are almost the only physical exertions required of them.

"The Act, which was intended to benefit the children by precluding their being employed as young persons, has in my district proved altogether a failure, and bears very hardly against the class it was intended to benefit, for few of them receive education in the factories, and only a fourth of them outside. I would therefore respectfully submit, whether education should not be substituted for age as the qualification for a young person to be employed in factories, namely, that every child, eleven years of age, who could read, write, and understands what he reads and writes, should be eligible for employment as a young person, and none under fifteen years of age should be eligible who could not.

"I have consulted millowners and many other individuals well qualified to judge of this proposition, without meeting a dissentient voice. All are of opinion that its beneficial effects would be immense; for while, under the present Act, poor as well as profligate parents and relations are tempted to practise all manner of deceit, even to the extent of forging baptismal certificates, to bring their children within the prescribed age for employment in factories as young persons, the alteration suggested would oblige them to put their shoulders to the wheel to get their children educated."

Mr. Redgrave, I find, expresses a somewhat similar opinion in the following words:—

"The present qualification for the labour of youth is simply age and health. It is therefore the interest of the parent, in making out the right of his child to work for longer hours, and to earn increased wages, to prove it to be older than it really is, and to lessen the period of its attendance at school, which thus becomes a burden upon the parent, who relieves himself from the irksome responsibility the instant he can. But if employment were made the reward of education, if a certain amount of acquired knowledge, or a certain number of years' attendance at school, were made the qualifications for labour, an interest would at once be created in the right direction, the value of education would be appreciated by those who are now insensible to it; the punctual attendance at school, and the advancement of his child, would then be the objects of a parent's solicitude; and even though that anxiety were limited by the selfish advantages he would derive from his child's qualification for employment, the great moral duty of the parent would be performed, of securing to his child the important advantages of an uninterrupted and extended course of instruction."*

Such testimony is entitled to the greatest weight, proceeding as it does from those whom Government has selected to protect the interests of children and young persons employed in factories, and who have through that position the very best means of forming a correct opinion.

The circumstance that we have this Factory Law already in existence, and with it a high class administrative staff in active operation, renders the experiment of the easiest description. We have simply to add an educational certificate to the presently required medical one, and an inspecting schoolmaster in addition to the inspecting surgeon, and the experiment can be started into full activity. It is not necessary that Sir John Kincaid's detail should be exactly adopted, if the principle of action is recognized. If parents can be convinced that a few years' teaching, given to their child before the age of eleven, will give them the benefit of several years' earlier wages from the child's labour than they have at present, there is at once originated a new educational lever. In addition to the weight of all higher motives, and without in the least degree weakening the influence of these where they exist, we bring a supplementary influence that will act in quarters where the other is dead, and argue in terms which the most degraded and ignorant parent can understand and feel.

At present the anxious desire of parents to get their children into factories, at as early an age as possible, is exemplified by the constant tricks and frauds they have recourse to in order to deceive the certifying surgeon into giving a certificate of thirteen, long before they have reached that age; and it may fairly be expected that the same anxiety would induce them to give their children education, if that were made the sole passport to earlier wages.

I do not advocate this as a perfect or complete scheme, but merely as one worth trying. If confined to the factory class, it can be introduced under the most favourable circumstances, not only as regards facility of working out, but with the best chance of securing the favour of those whom it aims at benefiting. It would come before them in-

* I have since seen in *The Journal of the London Society of Arts*, 27th February, 1857, an excellent paper by Mr. Redgrave, on the general application of the half-time system of education. He ably advocates an educational test as the qualification for earning wages; and the discussion which followed the reading of his paper was decidedly favourable to the scheme.

flicting no disability which their children are not already subjected to, but holding out to them a premium which they cannot at present obtain.

If successful with that class, it would be advisable very soon to extend it to all other employments; for though that could not be done without imposing disabilities which the children in those employments are at present exempt from, the proved benefit would easily overcome that objection; and besides, viewing the matter in the light of abstract justice, it can hardly be maintained that there is any equitable reason for exempting other employments from even those present regulations as to age, teaching, and labour hours which are deemed necessary and beneficial to factory workers. In many other employments the manual labour is more severe, and the situation less healthy; and if one class of children and females is entitled to legislative protection, why not all?

The principal objection that has been urged against the scheme is the insufficiency of the teaching that can be given to children under eleven years of age; but allowing this objection all the weight it merits, —be the standard ever so low, if it only reaches the rudiments of education, it is immensely better than the total blank which is the measure of their present instruction; and certainly I do not think it is quite practicable to give a child under eleven the mechanical arts of reading and writing well, and much other simple teaching, which would prove to many youthful minds most successful in introducing them to subsequent self-culture.

Neither am I blind to the fact, that this plan, unlike all preceding ones, makes no attempt to provide the educational supply, while the best evidence of its success will be in a greatly increased demand for schools and teachers; but, in my opinion, hitherto it is the small demand that has kept the Legislature lukewarm on the question of a national scheme of school supply, and I do not in the least doubt, that, if in any way we can make the demand urgent, parties will find some means of reconciling their differences, and working out some practical and comprehensive scheme in keeping with the progress of the age, and worthy of a great, a free, and an enlightened people.

Dr. Allen Thomson described "The Phenomena and Mechanism of the Focal Adjustment of the Eye to Vision at different distances."

On the Phenomena and Causes of the Adaptation of the Eye to Distinct Vision at different distances, as illustrated by recent observations and experiments. By Professor Allen Thomson, F.R.S.

The author having given a preliminary sketch of the opinions of physiologists on the focal adjustment of the eye, proceeded to detail various recent observations by himself and others, tending to establish a correct view of the mechanism of this internal change of the organ of vision. In the first part of the paper the structural arrangements within the eye related to the process of adjustment were described. The author referred—1. To the structure and attachments of the circular and radiating fibres of the iris and of the ciliary muscle, pointing out the circumstances which prove incontestibly the muscular nature of these fibres, and the manner in which their combined contraction has the effect of compressing the lateral and posterior parts of the crystalline lens, while they leave the anterior surface comparatively free. 2. The author showed that the crystalline lens is suspended in such a manner in its capsule, by means of elastic fibres, which pass both to its anterior and posterior surfaces from the zonule of Zinn, that during the contraction of the ciliary muscle, these bands being shortened, the lens is permitted to increase in thickness from before backwards; but when the ciliary muscle is relaxed, the elastic bands being drawn outwards, tend to restore the flatter shape of the lens adapted for distant vision. 3. The author showed that the space called posterior division of the aqueous chamber of the eye, hitherto usually regarded as existing between the iris and the lens, has no real existence; for by sections of the eye made in the frozen condition, it may be proved that the posterior surface of the iris in its whole extent, excepting for a narrow space close to the margin of the lens, lies in accurate contact with the anterior surface of the lens. The author exhibited to the Society a number of sections of the human eye, made in the manner referred to.

In the second part of the paper the author proceeded to consider the phenomena which may be observed during changes of adjustment. He referred more particularly to the recent catoptric observations of Cramer, Helmholtz, and Donders, from which it has been ascertained, that of the dioptric media of the eye the crystalline lens is the only one which undergoes a change, and that the change in the lens which accompanies adjustment for near vision, consists mainly in the increased curvature and advancement of its anterior surface; while for distant vision this part returns to its flatter condition.

The author described a series of observations and experiments, from which he had obtained the full confirmation of the results of the continental physiologists. These experiments consist mainly in the careful observation of the reflected images of a candle or other light thrown from the cornea, and from the anterior and posterior surfaces of the lens, during efforts of adjustment. Of these images the corneal one is found to undergo no perceptible change; that from the posterior surface of the lens becomes slightly smaller, but scarcely changes its position;

but the dull, erect image, thrown from the anterior surface of the lens, is observed at every change of adjustment from distant to near vision, suddenly to approach the corneal image, and to become somewhat smaller and more distinct. By the employment of a double light for reflection, and an ingenious instrument, which he has named opthalmometer, Helmholtz has contrived to render the phenomena still more apparent, and to measure with precision the amount of the change in the radius of curvature of the anterior surface of the lens. The general conclusion from all the observations is, that during adjustment for near vision the lens is diminished in its transverse, and increased in its antero-posterior diameter; that the bulging or increased curvature takes place principally in the middle part, while the marginal part of the lens is carried somewhat backwards; that the posterior surface of the lens undergoes a slight increase of curvature, but does not change its place at its central part; and that the cornea undergoes no change whatever, either in form or place. The whole changes by which adjustment is effected belong, therefore, to the lens, and to those structures connected with it, which contribute to the alteration of its form.

In the third part of the paper the author endeavoured to explain the mechanism by which the changes of form of the lens, occurring in adjustment, are produced. This explanation, he showed, is to be sought for in a knowledge of the structure and actions of the internal parts of the eye, described in the first part of the paper.

1. The mode of attachment of the capsule of the lens, by means of the zonule of Zinn and ciliary processes, to the choroid membrane and external coats of the eye-ball, is such as to prevent the lens from receding to any appreciable extent in the vitreous humour, while the condition of the iris in front of the lens, especially at or near the pupil, offers no resistance to its advancement and bulging in that direction.

2. The effect of the simultaneous contraction of both sets of fibres of the iris, and of the ciliary muscle, is to compress the lens laterally; and this pressure is rendered more equal and diffused by the structure termed canal of Petit and the fluid which surrounds the margin of the lens. The result of this lateral compression is the anterior bulging of the lens and the change of its curvature previously referred to.

The author showed that although the contraction of the circular fibres of the iris (and consequent diminution of the size of the pupil) is a very constant accompaniment of the adjustment for near vision, there are yet reasons for believing that the ciliary muscle is the most direct agent in producing the required change of form of the lens, and that the iris is rather only an assistant agent in this action; and in connection with this subject the author described several cases which had come under his own observation, and that of others, in which the motions of the iris and the changes of adjustment appeared to proceed independently of each other.

The author further gave an account of the physiological evidence in favour of the view that the process of adjustment to near vision is an active muscular change; and he described the relation subsisting between this process and the motions of the eye-ball, as well as the influence exercised by the nerves over these motions.

March 25, 1857.—*The* President *in the Chair.*

Mr. Robert H. Leadbetter, and Mr. Matthew Strang were elected members.

The following notices were brought forward by Mr. Bryce:—1. "On the Geological Relations of some Copper Deposits lately discovered near East Tarbet." 2. "On some specimens of Iron, Copper, and other Ores, from Nova Scotia and New Brunswick, with the products of their manufacture;" exhibited by Mr. Thomas Carswell. 3. "On some interesting Marine Fossils, lately found in a quarry within the city;" exhibited by Mr. Colin Brown, Mr. John M'Diarmid, and himself.

I. On Some Copper and Other Metallic Ores from the Neighbourhood of Tarbet on Loch Long.

The ores in question occur on the estate of Erins, about four miles north of Tarbet, and on the western shore of Loch Long. They are found in veins traversing mica slate, which is the prevailing rock in this entire district of country, quartz, always abundant in mica slate tracts, being the chief matrix or veinstone of the ores. Copper pyrites is the most abundant ore, and wide veins of it, obviously rich in metal, were traced, in company with W. Furlong, Esq., proprietor of the estate, over a very considerable extent, not less than two miles; and they probably pass, in their range to the S.W., into the adjoining properties. Other ores are various oxides, yellow, green, and black copper, &c. In the same rock, and adjoining these ores, are also lead, with silver in unusually large proportion, as shown by specimens assayed at the public offices in London. Beautiful specimens of zinc blende are also found, and can be traced interruptedly in veins for some distance. While these and the copper veins occur chiefly in the central and western part of the district, the eastern affords extensive beds of haematitic iron ores. They occur in ironshot mica slate, and in considerable beds on both sides of a mountain stream, whose high banks they form through a distance of more than a mile. The entire district appears to be a rich field, well worthy of a careful examination by an experienced mineral surveyor. Our survey was somewhat hurried, being limited to a single afternoon in the month of September. There seems every probability, however, that the capabilities of these properties will soon be fully tested by the establishment of works, for whose successful prosecution the country offers more than the usual facilities met with in mining tracts.

II. On Some Marine Fossils lately found in a Quarry within the City.

The precise boundary of the upper fresh water and underlying marine coal series not having been as yet exactly fixed, considerable interest attaches, in the eyes of geologists, to any facts tending towards a determination of their respective limits. Such facts, as they come to light, ought therefore to be placed permanently on record; and with this view the present brief notice is submitted. A full descriptive account would be only a repetition of facts well known already. The locality referred to is at the intersection of North Frederick Street with Parliamentary Road, exactly opposite the Town's Hospital. Here a quarry was opened some weeks ago; and a suite of fossils, which determine the nature of the beds, found by Mr. John M'Diarmid of the *Guardian* newspaper office. By him, Mr. Colin Brown, a well known cultivator of geology, was directed to the quarry; by Mr. Brown, my attention was called to it. The strata are calcareous sandstone dipping S. at a small angle; and the fossils are of several marine genera of bivalve and univalve shells, and some plants. The strata are overlaid by common Till with striated boulders, all of the usual western or north-western origin, so characteristic of our superficial deposits.

III. Notice of Some Iron Ores, and the Manufactured Products, from Nova Scotia.

It is well known that the ironstones of the Scottish coal fields do not yield metal of that toughness and strength which are required for many castings, such as ordnance, hydraulic machinery, &c. It is therefore an important object to obtain ironstones from other quarters, to mix with our own in smelting, so as to give a material possessing the requisite qualities. The mode of smelting has undoubtedly very great influence on the quality of the casting, but the purity of the ore is not less influential; and the inferior strength and the brittleness of our iron must in great part be ascribed to the facility given by the hot blast for reducing inferior ores, and so producing large quantities at a low first cost. Having obtained, through the kindness of Mr. James R. Napier, specimens of the ores of Nova Scotia, recently brought over by Mr. Carswell, I have taken this opportunity of calling the attention of members of the Society connected with the iron trade to these ores, which are certainly equal, if not superior to those of Sweden. Their geological position is similar to that of the Swedish ores; they occur in the old rocks and not in the coal formation, as our ores do. The Atlantic coast of Nova Scotia consists of granite and mica slate, with quartz, porphyry, &c. Inland, Silurian and Devonian rocks succeed in interrupted bands. To these follows, along the N.W. of the peninsula, a large and important coal formation, which stretches westwards across the isthmus, and occupies a large space in New Brunswick. The "measures" of this coal formation are remarkably similar to our own, and the great majority of the fossil shells and plants are of the same species also. The chief difference from our fields consists in the absence of clay ironstone, workable beds of which are as yet only known in one locality, the Pictou mines on the north coast, N.N.E. of Halifax. The rich ores, to which attention is now called, occur among rocks of the age of the old red sandstone, highly metamorphosed by intrusive rocks. The most important veins are found in the Cobequid mountains, which terminate westwards in the promontory dividing Chignecto bay and Minas channel, the two head forks of Fundy bay. The veins are in some places 120 feet thick, and range for miles across the hills. The veinstone is a carbonate of iron, lime, and magnesia, known there by the name of ankerite. With this ankerite and with wood, as in Sweden, the ores are smelted. The ore is a peroxide. Similar ores occur at Nictau, N.E. of Annapolis, in the South mountains, in a geological position somewhat higher,—at the bottom, namely, of the carboniferous limestone series, and associated with multitudes of shells of the genus *Spirifer*. The mines can be worked at a moderate cost, and there are no great difficulties as regards transport or shipment, which should enhance the price of the ore, or otherwise interfere with the full development of the mineral resources of this region. That these are most promising will appear from the facts that have been stated, as well as from the specimens of the ores, of the manufactured iron, and of the articles in steel now exhibited.

The copper ores of Nova Scotia, of which specimens are also on the table, seem by no means to possess the same economic value. The region of the older rocks has not yet afforded any veins, though loose masses of pyrites of considerable size are found upon the surface of these rocks in several places, indicating the probable existence of veins below. The new red sandstone, and the associated trap rocks contain veins and disseminated masses in many places. The most remarkable repository of copper is the trap of Cape d'Or, where it occurs native, as in the rocks at Barrhead, described in a paper in the present volume; but here it is not in such quantity, or at least so arranged, as to render the working profitable. Rich veins occur also in the coal formation in several places, associated with fossil plants; but a feeling prevails that they cannot be profitably worked.

The facts now brought forward are drawn chiefly from the excellent work of Mr. Dawson, entitled *Acadian Geology* (Oliver & Boyd, Edinburgh, 1855). Some additional information has been kindly supplied by Mr. Carswell, now of Glasgow, some time resident in Nova Scotia in connection with the mines.

April 8, 1857.—MR. BRYCE, *Vice-President, in the Chair.*

Mr. Walter M'Farlane read a paper "On a new system of Sewerage, and other Sanitary Arrangements for converting the Liquid Refuse, Dry Garbage, Ashes, &c., of towns, into their most valuable uses."

Mr. M'Farlane observed, that in our large towns most of the people are now confined to so small a space, that it is absolutely necessary that arrangements suitable for this new order of things should replace the customs and rude contrivances of a past age. How to purify and dispose of our town sewage is a problem that has been prominently before the public for many years; but it is still as far from a practical solution as ever. He imputed much of the excessive mortality in our large towns to the effluvia evolved from accumulations of excrementary matter in middensteads and privies. The plan of sewerage proposed by him proceeds upon the principle of separating the watery from the excrementary constituents. The watery class, being composed of the underground drainage, rainfall, and waste water of the community, is harmless, and of no value. The excrementary class, consisting of water closet discharges, liquid refuse of public works, slaughter houses, &c., is valuable, but destructive to human life, if allowed to lie for any length of time amongst the population. He proposed to adopt two separate sets of sewers for the removal of these matters. The water sewers would be wholly confined to the conveying away of the underground drainage, rainfall, and waste water of the community, and would require no change in the present system. The excrement sewers would require to be entirely new, and would be wholly confined to the carrying out from the midst of the population water closet and such other liquid refuse, as from its nature is destructive to health, but may be converted to useful purposes. The sewers he would arrange in such a manner as that the solid portion would be retained by intercepting ordure tanks, whilst the liquid parts would flow off, by means of pipe sewerage, to some place or places where their valuable properties would be retained to the community. In order to carry out this scheme, the following new works would be necessary:—1. Excrement supply sewers of glazed earthenware, connecting the water closets with the ordure tanks; 2. Cast iron intercepting ordure tanks; 3. Excrement discharge sewers of glazed earthenware. Having described these contrivances in detail, Mr. M'Farlane next explained the operation of an ordure waggon, such as is employed in the United States and in Paris, for conveying the contents of the ordure tanks to the manure depot. It is an excellent application of the atmospheric principle to this purpose. By the system of excrement sewers, in a population of 400,000, there would only be about 2,000,000 gallons of excrementary sewerage daily, or as much as would fill a sewer from eighteen to twenty-four inches diameter, running at the rate of two miles per hour. No paper, rags, straw, nor other insoluble matter being mixed up with it, there would be no greater difficulty nor expense attending its transport and disposal than the same quantity of water; whilst being so concentrated, its value to the agriculturist would be increased. The solid matters recovered from the ordure tanks might be converted into a concentrated dry portable manure of much value. By thus keeping the excrementary matters by themselves, and separating the liquid from the solid parts, we put them into the best state for converting them to their most profitable use. In a population of 400,000, with the present sewerage system, there are about 22,000,000 gallons of sewerage daily, or in bulk as much as would fill a stream six feet wide by three feet deep, running at the rate of two miles per hour. The great expense attending the transit of such an enormous volume of water, has hitherto prevented the sewage in a liquid state from being disposed of to agriculturists, although an almost universal opinion seems to prevail, that this is the best and most profitable mode of using it. When freed, however, from such an enormous quantity of water, much of the difficulty which has hitherto prevented it from being profitably turned to account will be removed. Mr. M'Farlane then described his plans for the removal of dry garbage, ashes, &c., from dwelling-houses, by means of ash-bins, ash-pits, and ash-shafts.

April 22, 1857.—MR. BRYCE, *Vice-President, in the Chair.*

The President read the following papers, viz.:—"On new Instruments for Indicating and Measuring Electrostatic Forces;" (with Experiments). "On the Comparison of Quantities in Electrostatic and Electrodynamic Effects." "On the Rapidity of Electric Action through the Atlantic Telegraph Cable."

PROCEEDINGS

OF THE

PHILOSOPHICAL SOCIETY OF GLASGOW.

FIFTY-SIXTH SESSION.

Anderson's University Buildings, November 4, 1857.

THE Fifty-Sixth Session of the Philosophical Society of Glasgow was opened this evening,—Professor William Thomson, President, in the Chair.

Mr. William Murray mentioned, as illustrating the progress of scientific education among the working population, that the demand for admission to the popular classes in the Andersonian Institution this winter, greatly exceeds the accommodation of the lecture hall.

Mr. James Bryce and Mr. Charles Griffin were requested to docquet the Treasurer's Accounts.

After some introductory remarks by the President, on the plan about to be adopted of obtaining regular reports from Committees of the Society in the different branches of science, Mr. Keddie, Secretary, read the following Memorials, prepared from the old minute book, with the aid of personal reminiscences by Mr. Robert Hart.

Early History and Proceedings of the Society. By MR. WILLIAM KEDDIE.

THE Philosophical Society was instituted in November, 1802, for the purpose of reading essays and conversing on scientific subjects, for the exhibition of models of machinery, and the formation of a scientific library. The original plan of the Society was subscribed by sixty members, who met on the 8th of December and chose their first office-bearers. The President was Dr. William Meikleham, who in the following year became Professor of Natural Philosophy in the University of Glasgow. The Vice-President was Mr. John Roberton, ironfounder, who was the first to introduce the self-acting screw lathe, and was the patentee of a method of consuming smoke in furnaces, which he explained to the Society at one of its earliest meetings. Amongst the original members were a number of respectable citizens well known for their public spirit and scientific tastes and attainments. Mr. Peter Nicholson, one of three gentlemen who signed a circular letter convening the meeting at which the Society was constituted, was the author of an *Essay on Involution and Evolution; or, a Method of Determining the Value of any Function of a Known Quantity*, a copy of which work, inscribed by the writer, is in the Library; he was also the author of an *Introduction to Increments, Rudiments of Algebra*, and an *Architectural Dictionary.* Mr. David Hamilton, the architect of the Royal Exchange, Hutchesons' Hospital, and several of the city churches, was also one of the original members. The list likewise includes the following:—Dr. James Monteath; Mr. James Cook, the engineer; Mr. William Mitchell, of the firm of Mitchell & Russell, jewellers and watch and clock makers; Mr. William Dunn, the machine maker; Mr. James Hardie, at one time master of police; Mr. Andrew Brocket, mason, the builder of a large extension of the quay wall at the Broomielaw from York Street downwards; Mr. John Buttery, of the Monkland Iron and Steel Works; Mr. James Boaz, accountant, who was for twenty-five years Secretary to the Society, and whose correct and neatly engrossed minutes from 1804 to 1829 are frequently illustrated by careful drawings; Mr. Haldane, engraver; Mr. James Crichton, who had been operator to Professor Anderson, the founder of the Institution bearing his name, and afterwards became celebrated for the accuracy of his thermometers, which still maintain a high reputation; Mr. William Reid, supposed to have been a gentleman of eccentric habits, known familiarly as "Author Reid;" Dr. George Birkbeck, Professor of Natural Philosophy and Chemistry in the Andersonian Institution, who was the first to lecture to a class of working men, and is therefore generally regarded as the founder of mechanics' institutions; Mr. James Spreull, city chamberlain; Mr. James Sword, ironfounder; Dr. Patrick Cummin, Professor of Oriental Languages in the University of Glasgow; Mr. Joseph Outram; Mr. David Muschet, the father of the iron trade of the west of Scotland; Mr. George M'Intosh and Mr. Charles M'Intosh, father and son, the latter the inventor of the patent double waterproof fabric, &c.; Mr. James Laird, a copartner of Lord Dundas in the Dalmuir Chemical Works; Mr. Kenneth Mathieson, the builder;*

* In addition to several churches in Glasgow, Mr. Mathieson built Hutchesons' Hospital and the old Theatre Royal, Queen Street, designed by Mr. David Hamilton, and which was burned down in 1829. His bridges span the Black and White Cart at Inchinnan; the Cree at Newton-Stewart; the Ken near New Galloway; the Doon near Alloway Kirk; the Clyde at Garion; the Forth at Stirling; and the Ban at Agivey in Antrim.

Mr. John Napier, uncle of Mr. Robert Napier of Shandon, and father of Mr. David Napier of Blackwall; Mr. James Dunlop, of Clyde Iron Works; Mr. William Kelly, cotton spinner; Mr. Henry Houldsworth, cotton spinner; Mr. Robertson Buchanan, civil engineer, inventor of the patent steam-boat paddle called the "feathering paddle," and author of works on the *Teeth of Wheels*, the *Heating of Buildings*, &c.; Mr. John Geddes, of the Verreville Glass Works, the famous Colonel Geddes of the Lanarkshire Local Militia; Mr. Charles Tennant, the discoverer of the bleaching powder, and founder of the St. Rollox Chemical Works; Dr. James Towers, Professor of Midwifery in the University of Glasgow. Amongst the early members were Dr. James Watt, a medical practitioner and Baptist preacher, who became an indefatigable contributor to the proceedings; Mr. Matthew Park, mason, father of the late Mr. Patric Park, the sculptor; Dr. Corkindale, the eminent physician; Dr. Andrew Ure, the Chemist, author of the *Dictionary of Arts and Manufactures*, &c.; Dr. Scott, surgeon-dentist, the Odontist of the *Noctes Ambrosianæ*, in which he is represented as singing the celebrated lament for Captain Patoun. Mr. Robert Hastie, father of the present Secretary, was also one of the earlier members of the Society, in the affairs of which he took an active share till his death, in 1827, having for six years occupied the President's chair. In his entertaining work, *Glasgow and its Clubs*, Dr. Strang notices Mr. Robert Hastie's long and useful connection with the Society, observing that "his knowledge of mechanics and mathematics was extensive and practical. His conversation was instructive, his manners mild and affectionate, and his address unaffected and modest. He enjoyed the respect and esteem of the Society in life, and his memory is endeared by the recollection of his intellectual and moral qualities." Mr. James Denholm, author of *The History of Glasgow*, joined the Society at an early period. Mr.

When erecting Stirling Bridge, he consented to a deduction of £2,000 from his estimate, for the privilege of getting his own way with the coffer-dams. Instead of a separate dam for each pier, he constructed in the centre of the river an embankment of two rough stone walls, with puddle between, and from each end there was a similar work continued to the sides. He then pumped out the whole area, excavated, and founded half the piers at once on the north side. When this was completed, he turned the end walls to the south, and completed the operation. Great saving was thus effected; and it was the first time he enjoyed the support of trustees against the engineer. "*So* the bridge is well built, we don't care *how*," said the trustees of Stirling Bridge. Mr. Mathieson also built piers and harbours at Port-Glasgow, Kirkcudbright, Port-Nessock, Stranraer, North Queensferry, Leith (part of the extension, the best paying job, he used to say, which he ever got, although his estimate was £17,000 against £29,000, the estimate of the next competitor). Mr. Mathieson's enterprising labours extended into the railway period, he having built numerous railway bridges connected with contracts on the Greenock, Edinburgh and Glasgow, North British, and Edinburgh, Perth, and Dundee lines.

Alexander Tulloch, a native of Glasgow, but then resident in London, a voluminous writer on various subjects, literary and scientific, and editor of the *Philosophical Magazine,* was elected a member soon after the Society was instituted.

Amongst the subjects first brought before the Society was the supply of the town with water, a service at that period very inadequately performed by water-carts; also, the prevention of smoke in chimneys, which the Society was of opinion might be accomplished by making the vent of considerable length, of tolerable width, smoothly plastered, and narrow towards the top. The subject of the water supply was repeatedly brought forward by Dr. James Watt. When the Water Company were constructing their works, they were advised by this gentleman to carry a pipe across the river, and take advantage of the extensive holm opposite the works for the formation of a great natural filter. The Company adopted the suggestion, and the filter became a source both of power and emolument; in consideration of which they granted to Dr. Watt, when he afterwards fell into indigent circumstances, the privilege of using their water for nothing!* In the year 1803, when the country was roused to the highest pitch of martial excitement by the threatened invasion of Napoleon, the general defence of the nation was a topic of grave discussion in the Society. From this time forwards there are frequent notices of experiments by Mr. Roberton on the rifling of guns and the construction of bullets. In the same year the plan of a telegraph for conveying information throughout the country was described by Mr. Boaz, who patented the invention. In 1805, a conversation on Phlogiston is minuted, but without any indication of the reception given to the Oxygen theory, which had then generally gained acceptance amongst chemists. The prospective advantages of railroads formed the topic of an essay this year.

But the discovery which engrossed the greatest share of the Society's attention for many meetings in succession, was the preparation of coal gas for the purpose of lighting. Mr. George Lumsden, bookseller, and Dr. Nimmo appear to have conducted a series of experiments before the Society on the production of gas, and the latter gentleman undertook to compare the quantities of gas obtainable from different kinds of coal, particularly those of Lesmahagow, Banton, and Newcastle. Mr. Murdoch had applied the gas to economical purposes in a mine at Redruth in Cornwall so early as 1792, and repeated his experiments in Ayrshire in 1796, where he taught the old women to make gas retorts of their disabled teapots. In 1798, he lighted the Soho Foundry at Birming-

* In 1821, after Dr. Watt's death, a letter was produced in the Society which had accompanied a gift to him of £21 "for his suggestions to the Company."

ham with coal gas; and in 1802, at the rejoicings for the general peace, he employed it for the purpose of illumination at the same works. In the year 1805, when the experiments upon coal gas were commenced by the Philosophical Society of Glasgow, the manufactory of Lee & Philips at Manchester was lighted in this manner by Mr. Murdoch. Mr. Richard Gillespie's printworks at Anderston were lighted with gas in 1810. Mr. G. Lumsden had also introduced gas-light into his shop about the same period. The Messrs. Hart had their shop and dwelling-house lighted with gas for ten years before it was adopted by the city. It was not till 1818 that gas-lighting was generally introduced into Glasgow.

The Society, which had met for some time in one of the Assembly Rooms, now removed to Surgeons' Hall, St. Enoch Square; and the proceedings at this period embraced papers, readings, and conversations on galvanism, chemistry, mechanics, manufactures, and vaccination. A proposal was for some time entertained, but ultimately abandoned, for erecting a laboratory in connection with the Society. The improvement of the river now became an attractive object, for which the ingenuity of the members suggested many and various plans. One of these projects contemplated the formation of a lock and dry docks at Govan; the widening of the river at the Broomielaw, and a quay to be built on the south side, a proposal since adopted; also, the erection of a breast between the old and new bridges, to be appropriated for vessels of a small draught of water, which has also been effected. But another suggestion brought before the Society at this period has not met with equal favour from the modern River Trustees, namely, that "the Molendinar Burn be made navigable for small and fishing craft, as far, at least, as St. Andrew's Square!" The Society occasionally indulged a taste for antiquities. The minutes notice as a "precious morceau of antiquity," a Highland wooden lock made with a knife, and procured by Mr. James Crichton from the laird of Ballahulish, who had it from a Popish priest near that place; it was supposed to be as old as the time of Julius Cæsar; and Mr. Hart discovers in the description of its clumsy but ingenious mechanism contrivances resembling those of the unpickable lock of the present day. The first two notices in the department of Natural History are peculiar. Mr. Wyld reported that "on eating a hen's egg that had been boiled in the shell, he discovered in or about the middle of the yolk, a horse's black hair, about eighteen inches long, coiled up spiral-wise," and he confessed his inability to account for the phenomenon. In the year 1809, the Society engrossed in its minutes a correspondence altogether so curious that it deserves to be preserved. The following letter was addressed to the Rev. David M'Kay, Reay, Caithness:—

"Reverend Sir,—At a meeting of the Glasgow Philosophical Society held here last Monday, the members present, on talking on the subject of the Mermaid, said in the newspapers to have been seen by two ladies, your daughter and her cousin, requested me to write you. As many fictitious stories are vamped up with an appearance of truth in these vehicles of public information, I hope you will excuse the freedom I have taken in requesting you to favour me with a few lines, merely stating that Miss M'Kay wrote the narrative which appeared in her name in most of the London papers a few weeks ago. Her account of the matter is wrote with much precision, and bears every mark of being genuine. Several of the members above mentioned could have wished to know if the animal seen took any apparent notice of those who were observing it, whether it betrayed any symptoms of timidity, and the manner in which it ultimately disappeared. There was also published at same time a letter from the schoolmaster at Thurso. Have the goodness to say if, from circumstances within your knowledge, you believe in the accuracy of his statement. Our curiosity is much excited as to the phenomenon, and you may rest assured that that is the only motive, and which we plead for thus troubling you.—I am, &c.,

"J. Boaz, *Sec. Phil. Soc.*

"Glasgow, 23*d Sept.*, 1809."

"Reay, 3*d Oct.*, 1809.

"Sir,—In terms of your and the Philosophical Society's request, I have to inform you that my daughter wrote a letter to Mrs. Innes, dowager of Sandside, concerning the strange phenomenon seen near this place, merely for private information, without the smallest suspicion of any other use to be made of it; but having excited Sir John Sinclair's curiosity, he obtained a copy of this letter, and it seems that by one of his friends it found its way to the English newspapers. Though I never saw the letter either originally or in the papers, I have good reason to suppose that it is a genuine document. With regard to the animal's timidity, I have only to say, that two servant maids and a boy being at the time down among the rocks, it was the cries of the boy that made it first disappear. It soon re-appeared farther out in the sea, and ultimately disappeared, after having taken its course a considerable way along the shore, the spectators following, and walking on till they lost hope of its coming up again. The schoolmaster of Thurso's letter is also genuine, and he is a gentleman whose veracity is not to be called in question.—I am, &c.,

"David M'Kay.

"James Boaz, Esq."

The apparition of the mermaid is recorded in *Brewster's Edinburgh*

Encyclopædia, where the writer of an article on mermaids and mermen says it remained in sight for an hour. "Nothing except the face was at first visible; and as the sea ran high, the creature sank gently under the waves and then re-appeared. The head was very round; the hair thick and long, of a green oil cast, and it appeared troublesome when thrown over the creature's face by the waves. As they receded, it removed its hair with both its hands, which, as well as the arms and fingers, were very long and slender. The last were not webbed. The forehead, nose, and chin were white, and the whole side face of a bright pink colour; the throat was also white, slender, and smooth; and the smoothness of the skin, on which neither hair nor scales were observed, particularly attracted attention. The face seemed plump and round; the eyes of a light gray colour, were small, as also the nose. The mouth was large; and from the jaw-bone, which was straight, the face was apparently short. One of the arms was frequently extended over the head of the animal, as if to frighten a bird, which, hovering about it, seemed to distress it much. When this had no effect, the creature turned round several times successively." Such is evidently the description furnished by the minister's daughter, which had found its way into the newspapers. The schoolmaster referred to in the correspondence was Mr. Munro, Thurso, who likewise publicly affirmed that in 1797, twelve years before the circumstance now narrated, he observed a figure like a female sitting on a rock projecting into the sea, at Sandside Head, in the parish of Reay. "Its head was covered with long thick light brown hair, flowing down on the shoulders. The forehead was round, the face plump, and the cheeks ruddy; the mouth and lips resembled those of a human being, and the eyes were blue. This creature was apparently in the act of combing its hair with its fingers, which seemed to afford it pleasure; and it remained thus occupied during some minutes, when it dropped into the sea." The writer in the *Encyclopædia* cautions his readers against allowing the extreme rarity of the mermaid to militate against the belief in its existence. Naturalists, he remarks, scarcely believed during late years in the giraffe and hippopotamus; they still debate concerning the unicorn and the mammoth, and resolutely denied that such a creature lived as the great sea serpent, "until one was cast up by the waves on our own island!" The animal supposed to have set at rest the question as to the existence of the great sea serpent, was a huge fish, cast ashore on the island of Stronsa, in 1808, measuring fifty-five feet in length, with a mane extending thirty-nine feet from the shoulder to near the caudal extremity. This fish was described by Dr. Barclay in the *Memoirs of the Wernerian Society;* and several of its vertebræ are still to be seen in the Museum of Natural History in the

College of Edinburgh, where they were shown by Dr. Fleming to the writer in June last. In the same year, 1808, an animal of a similar kind was seen by Mr. M'Lean, the parish clergyman of Eigg, on the coast of Coll, near the Isle of Canna, one of the western islands of Scotland. The animal followed the boat into the mouth of a creek, and appears to have frightened the worthy clergyman very much. He was also seen by the crews of thirteen fishing boats, who were much terrified, and hastened to the shore as fast as possible.

It was in 1810 that Dr. Watt proposed to the Water Company the plan of connecting the filters on the south side of the Clyde with the engine on the north side, by means of a flexible pipe carried across the river. The execution of the plan was confided to the celebrated James Watt, then at Soho, and who accomplished the object by constructing and laying down the Flexible Water Main, the principle of which, as he mentioned to Mr., afterwards Sir John Robison, he "deduced from the mechanism of the lobster's tail."

The formation of a tunnel under the Thames had been projected at this early period, and a plan proposed for the purpose by Mr. P. Fleming, one of the members, was discussed by the Society in 1810. The first notice of Geological Science is minuted in this year's proceedings. Mr. Geo. Lumsden exhibited a portion of a petrified tree taken out of a quarry near Sauchiehall, which appears to have excited much interest, as the minute bears that "the members are very much pleased with this attention of Mr. Lumsden." Dr. Watt proposed a method of producing cold, by substituting for Leslie's plan of freezing water by the air-pump, the process of producing a vacuum by filling a vessel with steam and then condensing it.

In 1811 there were frequent readings and conversations in the absence of formal essays, and it was arranged that the subject should be fixed upon at one meeting and discussed the next, so as to afford the members an opportunity of preparing themselves by previous reading and inquiry. The Society appears to have instituted an investigation into the condition of the health of the city before and after the introduction of water by the Water Company; but the result is not stated in the minutes, being probably detailed in a separate memorandum book, to which frequent reference is made as containing digests of the papers and reports read before the Society, but which seems to have been lost.

In 1812, Mr. Freeland produced part of a correspondence with the celebrated Mr. Smeaton, respecting a mode of working under water. This year there was much discussion on the art of memory, which had been reduced to a system by Professor Fenaigle, whose Mnemonical principles were expounded in an essay by Mr. Denholm, and at a subsequent meeting by the Professor himself, who was then teaching his system in Glasgow.

The proceedings of the year 1813 contain a brief notice of another geological specimen, obtained from Stonelaw coal pit, near Rutherglen, and described as a "coaly schistus," with 216 marks arranged in nine lines. It was probably a specimen of sigillaria or lepidodendron, but the minute states that it was a leaf "of a plant to the members present unknown."

In the midst of graver investigations, Dr. Watt is noticed as having shown to the Society a drawing of "an improved tobacco pipe for voiding the smoke with more facility than the common tobacco pipe, and so as to keep the apartment free from the fumes." He also read an essay on Miracles, "particularly accounting for the ocular deception which took place some years ago in Italy, when certain images were thought to have opened and shut their eyes!" The winking Madonna of Rimini is not therefore a new invention.

At this period, Mr. Robert Hastie, then at Halifax, N.S., corresponded with the Society, sending notices of the natural history and geography of that country.

Dr. Watt having resorted to Bute in 1816 for the recovery of his health, returned to the Society with a description of the Vitrified Fort the southern extremity of the island; also, specimens of "pumice stone" from Barone Hill, which he ascribed to a volcano supposed by him to have existed between Bute and Largs. He also brought a specimen of the *Osmunda regalis*, the flowering fern, this being the first purely botanical notice in the minutes.

After meeting for some time in a room in Smith's Court, between Candleriggs and Brunswick Street, the Society removed in 1815 to a room at 35 Virginia Street, rented from Mr. Connal, the first meeting in this place being signalized by a paper on optics by Professor Meikleham. In 1816, Charles Cameron, a chemist, solicited the patronage of the Society, of which he was not a member, to a plan for quenching fires by carbonic acid gas, produced in portable air-tight vessels by the action of sulphuric acid on carbonate of lime. The Society commended the ingenuity of the plan, but expressed doubts as to its practical utility. Mr. Cameron then resolved to put the invention to the test of experiment. A huge barrel was charged with combustible materials, and set on fire. The carbonic acid being generated in a closed vessel, escaped with great force through a tube, like a tuyere pipe, let into the burning materials; and Mr. Hart remembers the amusement occasioned by the mechanical power of the discharge, instead of extinguishing the flames, blowing them into the utmost degree of intensity. The invention appears to have been then abandoned, to be taken up at a subsequent period, as it has lately been in Phillips's patent.

Sadler the aëronaut ascended in his balloon at Glasgow in the year 1816, and his method of inflating the balloon by the help of a fan-blast, suggested to Dr. Watt the application of a similar plan, since generally adopted, for ventilating coal mines. This year Dr. Robert Watt, a medical practitioner, and author of the *Bibliotheca Britannica,* and several professional works, became a member of the Society. He read a paper on "The Natural History of Man," and also brought before the Society his views of the nature of flame, the same, probably, which he embodied in his *Abstract of Philosophical Conjectures; or, an attempt to explain the principal Phenomena of Light, Heat, and Cold, by a few simple and obvious Laws.*"

The versatile Dr. James Watt produced an essay "On Old Age and the Means of in some measure Preventing for a time its Effects." About the same period he reported the result of an operation he had performed on himself for an issue. Having cut open the skin with a scalpel he introduced (not a pea, but) a *pearl button,* which he said, answered the purpose better than any other mode he had seen.

The Union Canal from Lock Sixteen to Edinburgh was now projected, and the Society received on this subject communications and reports from Mr. Hugh Baird, the civil engineer who directed the work.

The Secretary raised the following question, which was discussed by the Society:—"As this age is famous for rising in the air by balloons, and diving in the sea by bells, what would be the result of boring deeper into the earth than ever was attempted?"

A still more whimsical entry soon after occurs:—"June 16, 1817. Discussion on the question, Why oatmeal cakes baked without salt, have not that *wershness* of taste that oatmeal porridge has when unsalted? This question proposed by the vice-president. Decided that the *empyreuma* in toasted oaten bread, and its dryness, requiring more saliva than porridge, may be its cause!"

Mr. Robert Owen's proposed scheme to ameliorate the condition of the poor was considered by the Society this year (1817), and pronounced to be illusory and impracticable.

Mr. R. Hastie read an account of an instrument contrived by Mr. Hunter, called the Nautical Indicator, on the principle of the Armillary Sphere by Ferguson, for finding the latitude at sea by a double solar observation, and thence the longitude, and variation of the compass. Mr. Hart remarks that the description of the invention shows that it must have been very similar to the instrument constructed for the same purpose by our townsman Captain Small.

Lithography and the Kaleidoscope were amongst the subjects of inquiry in the year 1818. Mr. R. Hastie exhibited to the Society specimens of *Urtica whitlowi*, an American nettle growing in Orange County, New York, New Jersey, &c., yielding a fibre which when made into a rope was capable of sustaining a greater strain than Russian hemp. The proposed expedition to the North Pole was at this time an object of interest to the Society.

It is remarkable that no notice appears in the minutes, of the Society's attention having been directed to the introduction of steam navigation. The "Comet" was launched in 1812; but it is not till 1818 that the subject of steam navigation is mentioned in the proceedings; at which period much attention was bestowed on the improvement of steam-boat machinery.

Mr. Fleming, land surveyor, submitted to the Society a plan for depressing the surface of Loch Lomond and improving the navigation of the river Leven.

Messrs. John and Robert Hart, who did not join the Society till the following year (1819), exhibited at this time a working model of the Rev. Mr. Stirling's air engine, with which, says the record, they intend to try a machine for directing the course of a balloon, by means of wings to be wrought by the engine; this at the request of Lord John Campbell (afterwards the Duke of Argyll), who sent them a pair of wings of a large heron for the purpose of being experimented with, the heron having been slain with a view to this appropriation of its wings.

The manufacture of coal gas still occasionally engaged the Society's attention. Dr. Watt suggested an experiment on the production of gas from water in the shape of steam, in combination, however, it is left to be inferred, with some carbonaceous body.

Mr. Andrew Liddell and Mr. James Lumsden became members of the Society this year (1818). The Society now removed to a room in Trongate, opposite the foot of Hutcheson Street.

Mr. Boaz writes this year to Mr. Tulloch, *Star* Office, London, claiming for the late Mr. Roberton, who had been dead for several years, the priority of discovery of a conical cannon ball for which a patent had lately been granted. The claim was published.

A fresh impulse seems to have been given to the interest of the Society in the improvement of steam-boat machinery, by the Messrs. Hart, notices of this subject being frequent in 1820. On the 3d of April this year (the Radical year), the following minute occurs:—"On account of the threatened riot in Glasgow, the Society did not meet this evening." This was Monday evening. The 5th was the "Wet Radical Wednesday of the West," so humorously and graphically celebrated by Dr. Strang in the Glasgow "Clubs." On the 24th of the same month, the Society again had a blank night, when the members behoved to show their loyalty by observing the king's birth-day.

Among the members entered this year are the names of Mr. Robert Napier, smith and bell-hanger; Mr. Neilson of the Gas-Light Company; and Mr. Duncan of Mosesfield, a bookseller. The Society now removed to rooms in Pratt's Court, Argyle Street, opposite the foot of Queen Street, belonging to the Annuity Association.

"Mr. Lumsden's young man, Mr. Hugh Wilson," is noted as exhibiting to the Society the model of an improved printing press, with self-inking rollers, and describing a method of equalizing the pressure upon stereotype plates.

Drs. Watt and Nimmo were engaged in investigating the subject of contagion, this being the period when typhus fever established itself in Glasgow.

Mr. R. Hart exhibited a petrified shell from a quarry in Mull. It is described as resembling "an antique Grecian lamp"—a description in which there is now no difficulty in recognizing that of the *Gryphœa incurva*, a characteristic shell of the Lias.

Mr. William Norval, brushmaker, who this year became a member, was the projector and part proprietor of a steam-boat named the "Argyle," which was purchased as a pattern for the steamers on the Thames, by the name of which river it was for long distinguished.

The first "life preserver" was brought down from London in 1820, by Mr. R. Hastie. It was exhibited to the Society, and described "as a boddice of oiled cloth worn round the waist." Its buoyant property was tested by Mr. Robert Hart at the Dominie's Hole, and found to be capable of keeping five persons afloat.

Mr. Robert Hall, proprietor of the paper works near Cathcart, at a place since known by the name of the Paper-mill Farm, this year became a member. He was a descendant of Nicholas Dechand, a French refugee, one of the earliest paper-makers in Scotland, and who occupied the works near Cathcart.

Mr. John Thomson, a chemist, and originally an engraver, brought under the notice of the Society a correspondence he had had with the Bank of England, with a view to prevent the forgery of their notes. He proposed several ingenious devices, one of which was a method of printing the letters of the notes in two colours. This being submitted by Thomson to Congreve, at the suggestion of the Bank, was afterwards discreditably patented in Congreve's name.

Mr. Murdoch, of the firm of Messrs. Murdoch and Aitken, exhibited a paddle which he had introduced for steam-boats, on the principle of a canoe paddle. A similar contrivance had been suggested some time before by Captain Dumotte; but neither plan came into use.

"The heating of kirks" was more than once discussed. As a matter of economy, Mr. Matthew Spreul thought it would be cheaper to keep a large building constantly heated 365 days in the year, than to heat it fifty-two times a-year, or once a-week.

Mr. James Watt, architect, produced a specimen of charred wheat, taken from a vault at Castlecary, where it had been left by the Romans, that being one of their Scottish stations. Quantities of this wheat were obtained from the same place many years afterwards, when that part of the Roman Wall was crossed by the Edinburgh and Glasgow Railway.

Mr. Macdonald, silversmith, exhibited to the Society a pair of unusually large silver spurs, each weighing about fourteen Troy ounces, which he had bought as so much silver in the way of business. They were made in Spanish America, or some other country where the exportation of silver as bullion was prohibited, and the expedient of manufacturing it into articles for export was consequently resorted to for the purpose of evading the law. Mr. Duncan of Mosesfield, the bookseller, bought the spurs from Mr. Macdonald, after seeing them in the Society, and was in the habit of passing them off upon his friends as the spurs of King Robert the Bruce, lately disinterred, along with his remains, at Dunfermline. The report of Robert the Bruce's spurs having been exhibited at the shop of Mr. Duncan, speedily got wind, and reaching the ears of the Earl of Buchan, that nobleman negotiated the purchase of them from Mr. Duncan, who now felt that he had carried the pleasantry too far; but finding himself unable to get out of the predicament gracefully, it was thought better to allow the Earl to carry off the spurs and deposit them in his collection, with the spell of their antiquity and royalty unbroken.

The Society requested that this paper might be continued at its next meeting.

November 18, 1857.—*The* President *in the Chair.*

Mr. Ebenezer Miller and Mr. David Donaldson were elected members.

Mr. Cockey gave in the following abstract of Treasurer's Account for Session 1856–57 :—

1856.	Dr.						
Nov. 1.—To Cash in Bank,		£62	6	0			
— „ in Treasurer's hands,		0	14	9			
					£63	0	9
— Entry Fees from 41 new Members, at 21s.,		43	1	0			
— Annual Payments from 7 Original Members, at 5s.,		1	15	0			
— Annual Payments from 279 Members, at 15s.,		209	5	0			
— From 3 Members in arrear, at 30s.,		4	10	0			
					258	11	0
— Sale of Society's *Transactions*,					0	6	0
					£321	17	9

1857.	Cr.									
Nov. 7.—By New Books, including Subscriptions to Cavendish, Ray, and Palæontographical Societies,				£70	10	0				
— Binding,				9	4	0				
							£79	14	0	
— Stationery,							0	16	0	
— Engraving Plate and Printing Diplomas,							8	15	0	
— Printing Supplementary Catalogue and Index,							14	2	0	
— Printing Circulars,							11	4	0	
— Salary to Assistant Librarian,				£39	15	0				
— Commission to do., Collecting Dues,				14	0	0				
— Fee to Officer of Andersonian University,				4	0	0				
— Delivering Circulars,				6	13	2				
							64	8	2	
— Rent of Hall,	£45	0	0							
Less received from Church Congregation,	30	0	0							
				15	0	0				
— Fire Insurance,				4	5	0				
— Gas Account,				1	18	6				
							21	3	6	
Carry forward,							£200	2	8	

Brought forward,				£200	2	8
By Postages and petty charges,				2	3	9
— Joiner's Account for Repairs,				0	16	0
— Charter-case for Treasurer's Books, &c.,				1	2	0
— New Gas Fittings,				3	13	0
— Balance—						
Cash in Union Bank,	£98	5	0			
Do. in Treasurer's hands,	15	15	4			
				114	0	4
				£321	17	9

The Philosophical Society's Exhibition Fund.

1856.				
May 15.	—To Balance per Deposit Receipt from Corporation of Glasgow,	£676	17	10
1857.				
May 15.	— Interest to this date,	30	9	2
		£707	7	0

Glasgow, *November* 13, 1857.—We have examined the Treasurer's Account, and compared the same with the Vouchers, and find that there are in the Union Bank £98 5s., and in the Treasurer's hands, £15 15s. 4d.—together, £114 0s. 4d., at the Society's credit at this date.

The Treasurer has also exhibited to us a Voucher which he holds for money lent to the Corporation of Glasgow, from the proceeds of the Society's Exhibition in 1846, with interest thereon to the 15th May last, being £707 7s.

JAMES BRYCE.
CHARLES GRIFFIN.

Note by the Treasurer.

The Society's moveable property continues exactly the same as at last balance, with the addition of books purchased since that date.

The number of members at the commencement of Session 1856-7 was	277	
New members admitted during the Session,	41	
Non-resident members replaced on the list,	2	
		320

From this there fall to be deducted from present Roll—

Resigned,	8	
In arrear two years,	7	
Left Glasgow,	8	
Dead,	3	
Placed on non-resident list,	3	
		29
On the List for 1857-58,		291

Of the above 291, there are 5 members in arrear of one year's dues.

Mr. Cockey, in absence of the Librarian, stated that the number of volumes in the Library is now 2,701.

The Society remitted to the Council to take into consideration the propriety of increasing the insurance on the books and other property.

The Society then proceeded to the Fifty-Sixth Annual Election of Office-bearers.

Mr. Murray moved the re-election of Professor William Thomson as President; and of Mr. James Bryce as Vice-President; the election of Mr. Robert Hart as the second Vice-President; and the re-election of Mr. Cockey, Treasurer; Mr. Hastie and Mr. Keddie, Secretaries; and Dr. Anderson, Librarian.

The motion was seconded by Mr. Crum, and carried by acclamation.

Mr. Robert Blackie moved, in accordance with a suggestion from the Council, that the Society should pass from that part of the rule of election requiring that the whole twelve members of Council be elected every year, and only elect four members in room of the four retiring from the top of the list, and a fifth in place of Mr. Hart, appointed one of the Vice-Presidents. Mr. Blackie stated that this was the practical result of the rule from year to year, four new members being elected, and the other eight re-elected. He further proposed that the Society should conform the rule to the practice, and gave notice of his intention to move at next meeting to delete, in the Rule of Election, the words, "Of the twelve retiring members of Council, four shall not be re-eligible till they have been out of office for one year;" and substitute the following for the last clause of the rule:—"The four Councillors at the top of the list to retire and be ineligible till they have been out of office for one year."

The proposal to limit the present election to five members was agreed to.

Mr. Robert Mackay and Mr. Michael Connal were appointed Scrutineers of the election, and retired to examine the voting papers.

Mr. Keddie read a report on the state and progress of the Botanic

Gardens, from materials furnished by Mr. Clark, the Curator. Through the exertions of Mungo Campbell, Esq., the Orchidaceous House has been completed, and is now occupied with the valuable collections of orchids and ferns. The whole of the conservatories have been heated by hot water pipes. The specimen of the *Encephalartus horridus*, or *Zamia horrida*, exhibited to the Society on the corresponding night of last Session, bearing a magnificent amentum or cone, the first which had been produced by this species in the country, was at that time supposed to be the male or anther-bearing plant. On the maturation of the amentum, it was found to be the pistiliferous or female plant, having produced ripe seeds, specimens of which were laid on the Society's table. Some of the seeds have been sown by Mr. Clark, who is in hopes of being able to present before the Society a young plant of the Encephalartus. There being no evidence that the specimen could have been fertilized by the transmission of pollen from an antheriferous plant of the same species, or by hybridization with the pollen of another species, it becomes an interesting question in vegetable physiology how its fecundation was effected, whether by the transmission of pollen, or by Parthenogenesis, as in the instance of the *Cœlebogyne ilicifolia*, a diœcious Euphorbiaceous plant at Kew, which has never received the fertilizing pollen of the same species, yet has ripened seeds from which a fourth generation has been raised there.

Mr. Keddie then read a continuation of "Notices of the Early History and Proceedings of the Society."

Early History and Proceedings of the Society. By Mr. William Keddie.

In the year 1821 the improvement of the city lamps occupied a share of the Society's attention, the subject being repeatedly brought forward by Mr. James Lumsden, the Treasurer, who appears to have superintended the lighting department of the Police Board. Two meetings of the Society were devoted to a discussion on the cause of the moisture formed within the globes of the street lamps. Several members maintained that the moisture was deposited from the air rarified by the heat of the gas, the more especially as it was observed to condense chiefly on the windward or coolest side; and it was not till the subject was discussed a second time that, by dint both of argument and experiment, the members were brought to the belief that the water was formed in the process of combustion by the combination of hydrogen and oxygen. Mr. Lumsden consulted the Society as to the best method of illuminating the dial of the Tron steeple clock. Various plans were proposed—amongst the rest, one by the Messrs. Hart, to have one or more reflectors placed above the dial, so as that the incidental rays, falling therefrom on the gilt letters and hands, might be reflected down to the street, according to the law of optics, that the angle of incidence is always equal to the angle of reflection. Mr. Lumsden rehearsed to the Society a report he intended to submit to the Police Board on small lamps, requesting the Society in the meantime to institute an experimental investigation into the most efficient method of lighting. The name of Dr. Thomson, the Professor of Chemistry, and long afterwards the President of the Society, is for the first time mentioned in the minutes in connection with the lighting of the city. A letter from Dr. Thomson, addressed to the Police Board, was produced in the Society, recommending rather half the number of lamps, and a greater flame in each. Mr. Lumsden's small lamps were intended to evaporate the moisture formed within the globes; and when mounted on the lamp-posts they were found to answer the purpose perfectly, so far as the moist atmosphere within was concerned; but the conditions of the cold and humid external air not having been consulted with equal foresight, the effect of the first shower of rain on the hot surface of the glass could scarcely have been exceeded by one of the street riots of those turbulent times, and the Police Board soon found it necessary to exchange their new lamps for old ones.

In the course of the year, Mr. Andrew Liddell exhibited to the Society a model of Messrs. Harts' apparatus for illuminating the dial of the Tron steeple, which had been approved of and adopted, the two ingenious brothers receiving a formal vote of thanks for their contrivance from the Police Commissioners.

Dr. James Watt, who had taken an active interest in the Society for many years, died on the 3d of March, 1821.

Mr. Robert Hastie having taken charge of the improvements going on this year in the old bridge at the foot of Stockwell Street, after the death of Mr. Crichton, the civil engineer, described to the Society the plan which was adopted of widening the bridge by projecting the pathway on either side upon iron arches.

Mr. Andrew Smith of Mauchline, well known as a maker of snuff-boxes, exhibited an instrument for tracing drawings. The Society commended this invention, to which they gave the name of Apograph; it was employed by Mr. Smith in producing figures in relief upon the lids of his celebrated snuff-boxes. Repeated discussions subsequently arose on the claims of successive inventors of instruments similar to Mr. Smith's.

The Society consisted at this time of 120 members, each of whom paid three guineas of entry-money and ten and sixpence annually. The business seems to have been carried on in an unconstrained, conversational manner, as it was not till 1821 that a proposal was made that members, on addressing the President, should rise from their seats. The motion was brought on at a thin meeting, and defeated by ten to four. The Society was more punctilious in other respects, having at an early period blackballed a candidate for admission on the ground of his holding a subordinate social position. The members occasionally dined together. A Society dinner is recorded in November, 1817, when the minute mentions that Mr. Burn of the Black Bull "agreed to provide a decent dinner at three shillings a-head." Sundry legends, descending to us from this period, hint that, in accordance with the social habits of the time, the members not unfrequently adjourned to one or other of the snuggeries described by Dr. Strang in the *Clubs of Glasgow,* and continued their discussions, under the presidency of Mr. Robert (familiarly and lovingly known as Bob) M'Call, who had fought a duel in the West Indies, was a leader of the Glasgow fashions, and whose acknowledged superiority as a compounder of rum-punch entitled him to the honours of the chair at a symposium of the Philosophers.

Mr. Andrew Henderson, artist, the editor of a curious collection of *Scottish Proverbs,* and one of the humorists of the *Laird of Logan,* joined the Society in 1821. A portrait of himself, from his own palette, is preserved in the Library of the Andersonian Institution. Mr. Henderson signalized his entry into the Society by reading an essay on the Fine Arts, tracing the history of "the great Masters," from Noah and Tubal-Cain down to Reynolds and Opie. In a similarly comprehensive spirit, Mr. James Watt, architect, afterwards produced an essay on the rise and progress of architecture, from the time of Adam to the building of the Pyramids of Egypt; followed up by essays on the architecture of Greece and Syria. The Society was so much pleased with Mr. Watt's essays, that it had the peroration of one of them published in the newspapers, expressing a hope that the time was not far distant when the labour of the man of science and the artist would be appreciated, not, as at present, "by the square foot," but according to their respective merits; and the recent purchase of the Elgin Marbles was referred to as a proof that government was at length disposed to encourage art in this country.

On the same evening that Mr. John Ure was proposed as a member, in 1821, there was exhibited to the Society Mr. Cameron's machine for making soda water, and which was afterwards sold to Dr. M'Gavin, who employed the apparatus for several years in his shop in Nelson Street. The machine was constructed on the same principle as the portable apparatus now sold under patent. The first machine was imitated by a druggist in Edinburgh; but it was blown to pieces by an explosion of the gas. Mr. Cameron was the inventor of the fire-extinguishing apparatus noticed in last paper. He was the first chemist and druggist employed in the Glasgow Apothecaries' Hall.

Mr. Robert Hart this year suggested the substitution of the air-gun for the ordinary method of firing harpoons into whales, to prevent the animal from being frightened away by the noise of the discharge. Mr. Boag brought forward a plan for suspending the galleries of a church from the roof, so as do away with pillars—an expedient which the Society deemed unwarrantable in practice, but Mr. Nicholson, the mathematician, thought not impossible, if the lofts were hung from truss beams. A plan for trapping common sewers, to prevent the escape of noxious effluvia—an object of sanitary reform of the highest importance, but still neglected by the public authorities—occupied the attention of the Society at this period. The *pigmentum nigrum* of negroes was a subject of investigation; and Dr. Nimmo read a paper on the Properties of Croton Oil.

Mr. Lumsden speedily revived the subject of the street lamps, proposing that they should be capped with earthenware, tinned inside, the metal tops having been found corroded by the gas.

Not unmindful of the Ducal project of a flying machine, Mr. Hart exhibited a feather, made of silk, with steel stiffeners, two of which measured seventy feet from tip to tip, belonging to a flying apparatus, made by Mr. M'Millan above thirty years previously, and attached to one of Lunardi's balloons.

Mr. Andrew Henderson allegorized the river Clyde by a female figure, which unfortunately has not been preserved in the margin of the minute-book, where so many pictorial illustrations appear; although immediately afterwards Mr. Freeland exhibited what is described as "a molten image of the god Buddha," to which a niche is assigned, and a reference is minuted as "per margin."

Mr. R. Wallace, afterwards editor of the *Glasgow Mechanics' Magazine*, and subsequently of the *Scottish Mechanics' Magazine*, brought forward an essay on the subject of Weights and Measures, called forth by Mr. Clelland's statement then published. Mr. Wallace proposed to find a fixed unit of measure, that would remain the same in all ages, and which, even although destroyed, and no vestige of it, or of any former standard or measure were in existence, could be found anew, at any time and in any country. This he proposed to deduce from the unchangeable and uniform convexity of the earth, the result of the general law of gravitation. In another paper he recommended the dividing of the standard, whatever it might be, duodecimally, decimally, or binally, giving preference to the latter mode. This essay was published on the recommendation of the Society.

Mr. P. Fleming presented a copy of a work of his on the Base Line for Trigonometrical Surveys. The base line was a fertile topic of discussion at subsequent meetings.

Mr. Hugh Wilson submitted a new oar, so constructed as to enable the rower to sit with his face to the bow of the boat.

Mr. Hart exhibited a pigeon with only one leg, and no vestige of another.

In 1822, a paper was produced by Mr. James Beaumont Neilson, on the "Method of Purifying Coal Gas, by passing it through a weak solution of Sulphate of Iron." Mr. James Thomson, chemist, introduced the subject of "Calico-printing and Turkey-red Dyeing." The Circulating Medium and the Principles of Political Economy came under review. Among the new members this year was Mr. Archibald M'Lellan, coachmaker, the founder of the City Gallery of Art.

Mr. Allan Clark exhibited an "Arithmetical Machine," making it, says the minute, "perform addition, subtraction, multiplication, and division." When set, it added up the sum of £999,999 19s. 11d., or one penny less than a million of pounds sterling. The idea of this contrivance had occurred to Mr. Clark fifteen years before.

Mr. Thomson propounded to the Society a plan for the application of mechanical power for the benefit of the public. The power of five men is equal to that of one horse, was his first proposition; the second was, that the value of one horse's power is £50 per year. Therefore the power of one man is equivalent to £10 a-year. Thus, a number of men walking or treading on the periphery of a large wheel, would have all the effect and steadiness of a horse-gin. And in cities such as this, where power is required in almost all manufacturing processes, the poor, destitute, and strangers without resources, might occasionally be employed on such tread-wheels, and receive wholesome food for their labour till they got other work. These wheel-houses, it was suggested, might serve as places of call, where labourers might be got at all times. In all places where there is a redundant population, the labour of a number of the people might thus be turned to account. This method of applying force for the public benefit was particularly recommended by the author as suitable for workhouses, bridewells, and other places. This paper gave rise to much grave debate, extending over more than one sederunt, and running into devious channels, as may be inferred from the fact of the Society's having seriously entertained the intention of recommending the plan as suitable for raising water in such towns as

Carlisle and Paisley. The Secretary was actually instructed to prepare an outline of the project, to be communicated to the Philosophical Society of Paisley. On the third night, the draft of a letter was accordingly produced. But at the same meeting there was read from the *Eclectic Review* an article in which Mr. Thomson's ideas of the application of human force to the peripheries of wheels were found embodied in a treatise on the tread-mill, which had been already adopted in various English prisons. This unexpected discovery caused the Society rather suddenly to resile from its intention of acquainting the kindred institution in Paisley with a cheap and ready way of raising water at the Sneddon, which would have anticipated by nearly twenty years the more elaborate and costly process of bringing it down from the braes of Gleniffer.

The allusion to prison discipline in this discussion, seems to have induced Mr. R. Hart to describe, as he did at another meeting, a machine for cutting corks, employed in the prison of Edinburgh. Another night was occupied with the consideration of a method of killing whales by rockets, and caterpillars by tobacco smoke.

The Society this year (1822) passed a law rendering it incumbent upon every member to contribute to the proceedings, and shilling fines are frequently recorded afterwards for non-compliance. Instead of a paper, Mr. Peter Aitken showed a number of natural curiosities,—among the rest, a piece of rock crystal, with a great number of what appeared to be red hairs running through it; but a cross section seen through a magnifier, disclosed, instead of hairs, a lozenge-shaped cavity, filled with titanium, or with oxide of copper. Another specimen, with the hairs running in various directions, belonged to a class associated vulgarly with the name of some "Saint." Experiments were made before the Society with the air-gun, disproving the supposition that a gleam of light is produced at the moment the compressed air rushes from the magazine.

Mr. Boaz endeavoured to account for the disruptions and irregularities of the earth's strata, by supposing that the planet had slowly altered the position of her poles, the polar and equatorial regions having changed places, causing the remains of tropical animals and vegetables to be found near the pole, and those of polar animals and plants near the equator. The Society gives little evidence as yet of its having paid much attention to the progress of geological science, which by this time had laid its foundations broad and deep in the principles enunciated by Hutton, illustrated by Playfair, confirmed by William Smith, and recognized as the basis of its investigations by the London Geological Society. In the minutes, the figure of a fragment of the spine of the *Gyracanthus* is introduced as part of the body of a fish or serpent. The superficial markings of a lepidodendron, are assigned to "the root of an aquatic yellow-flowered plant, the lotus." Mr. Edington is reported to have discovered "in one of the stones for the new gaol, a petrified rattan cane, which," says the minutes, "being the production of an inter-tropical climate, is the more rare." The supposed cane was no doubt the calamite, and the climate that of the carboniferous era.

In the month of August, 1822, King George the IV. visited Edinburgh, and the Philosophical Society of Glasgow united, with the other public bodies, in welcoming His Majesty by loyal addresses. The Society's address was presented by Sir John Sinclair, who was elected an honorary member, and presented some of his papers to the Library. In reply to the Society's loyal wish, that His Majesty might long be spared to administer the laws with impartiality, and that under his reign the arts and sciences might flourish with unprecedented splendour, Mr. Secretary Peel expressed the satisfaction he felt in acquainting the Society that His Majesty had been pleased to receive the address very graciously. Two guineas and a-half was voted to a member for writing out the address.

A new fork for toasting bread was exhibited by Mr. R. Jamieson, described as consisting of a long wooden handle, one end of which was fixed in an iron gimbol-joint dependent therefrom; and a small oblong skeleton frame, furnished with two sharp points for transfixing the shave of bread to be toasted. When one side was sufficiently browned, "the other was turned to the fire, by merely twisting round the handle 180 degrees, thus saving the trouble of turning the bread on the toaster, as commonly done by the old method."

Mr. Buttery, of the Monkland Iron and Steel Works, interested the Society by two essays on the manufacture of iron and steel. He mentioned that Dannamore iron was worth £38 per ton, while British iron could be got at £7 10s. Dannamore iron, he observed, gave off a peculiar odour when hot. He also stated that a greater quantity of pig-iron could be made in winter than in summer, the proportion being as 40 to 25.

Mr. Lumsden, we are next informed, "intimated that he would read some of his ideas on lamps." He now proposed that a glass chimney should be placed within the globe for the escape upwards of the impure air, and allowing fresh air to enter by other openings. The paper was illustrated by thirteen diagrams and numerous models of the detached parts of lamps.

Mr. Robert Hastie presented a journal of the weather, kept by his son, Mr. Alexander Hastie, in Halifax, Nova Scotia. There were long debates at this time on the solution of the theorem of the base line. Mr. Watt, architect, produced a specimen of granite from St. Petersburg, used in erecting an edifice there, in which there are sixty-four pillars, each fifty-two feet high, six feet eight inches in diameter, the bases and capitals being of brass, and each shaft one entire stone, weighing 210 tons. The engineering of this structure was executed by Mr. Baird, a native of the west of Scotland.

Dr. Strange, who had just returned from India, read a paper on waterspouts, opposing the theoretical views of Franklin as to their formation. Mr. John Hart maintained the opinion that waterspouts were owing to electrical action; and the Society resolved to put his hypothesis to the test of experiment. For this purpose a powerful electrical machine was borrowed from Dr. M'Gavin. A Leyden jar having been charged minus, to represent a cloud in that state, the brass knob was held over a cup of water, representing the sea—when there appeared on its surface a little nipple, like the rising of the water, accompanied by a hissing noise.

Mr., afterwards Dr. Clelland, received the diploma of an honorary member of the Society, and presented a copy of the *Annals of Glasgow* to the library.

Mr. Lumsden is represented as "exhibiting" several specimens of poetry by Dugald Moore, a young man in his employ. For the first time, the Society engrossed in its records a poetical minute, in the form of verses from a heroic poem or dirge, and a love song. Encouraged by the reception given to the compositions of Mr. Moore (afterwards the author of several volumes of poetry, of more than average merit), Mr. Robert M'Call, formerly mentioned, ventured to produce what he described as a kind of *jeu d'esprit* on the subject of a method of navigating vessels; and his verses being practical as well as poetical, were also entered in the minutes. His invention was intended to save ships from being wrecked, as well as to navigate them by a new power. A vessel was to be furnished with pumps, wrought by the agitation of the waves of the sea, which pumps were not to deliver water by raising it to the deck, but to discharge it at the sea-level. How vessels were either to be propelled or prevented from sinking by this method, is not so clear in the old minute-book as it was to the sanguine mind of the inventor, when he said or sang—

> "My men on board, each man a ship can save,
> And her despairing crew from watery grave;
> But if, for want of pumps, a few go down,
> I'll strive to bring them up, to add to my renown."

After its fine poetical phrenzy, the Society relapsed into plain prose;

and it being moved by Mr. Thomson, seconded by Mr. Fleming, and carried, "that the poetry in pages 169, 171, and 172, be expunged, as being foreign to the business of the Society," the poetry was expunged accordingly.

Amongst the subjects of discussion at this time were the following:—The density of water in boilers, it being believed to increase with the increment of saline matter; the freezing-point of sea water; the manufacture of snow soap, then a favourite piece of household economy with the ladies; the singeing of muslin by gas; the natural history of the cocoa-nut palm; to which miscellany the sprightly Mr. Robert M'Call contributed a paraphrase he had written some years ago on a passage in the Proverbs of Solomon.

A communication was received from a gentleman in America, maintaining that the globe of the earth is hollow and populated, there being a large opening at each end for the admission of light from the sun; while the water rushing through perforations in the sides would satisfactorily account for the currents of the ocean.

Mr. John Thomson, the chemist, being desirous of imitating the reverberations of thunder, proposed to inflate a small balloon with carburetted hydrogen gas, and explode it, along with some bladders of the same gas, at a great height in the atmosphere, in order to ascertain thereby, and compare, the respective reports with that of thunder, and for other purposes, which may hereafter occur. In endeavouring to interest the Society in this experiment, he mentioned that the Messrs. Hart were prepared both to aid in its performance and to bear part of the expense. The bladders were afterwards launched into the air, attached to a bellows, and exploded by a match, at a considerable height, with very little sound, and no reverberation.

In 1823, the Cranstonhill Water Company having removed their works up the river, to Dalmarnock Bridge, Mr. John Hart instituted experiments, which he reported to the Society, on the filtration of water.

The old Glasgow Observatory was broken up at this time, for want of public support. The instruments were sold for £590. The Society made unavailing efforts to recover them; but after commencing a subscription, which reached £7 10s., abandoned it in despair.

An essay was read by Mr. R. Hart on the economy of fuel, which afterwards appeared in *Wallace's Scottish Mechanics' Magazine.*

Mr. Houldsworth's patent method of heating apartments by steam-pipes was considered by the Society, when Mr. R. Hart suggested an improvement, by which hot water would rise, by a vacuum in the pipes, in place of steam.

Mr. Buttery reported, that he had united silver and steel in the proportion pointed out by Mr. Faraday of the Royal Institution, London, and found that the steel was not improved by the silver.

There is a notice of a method of raising ships by wind bags, which had been sent in by David Masterman, an operative mechanic. Mr. Hugh Wilson exhibited lithographic prints, executed with ink made from coal tar, by a process conducted by Mr. Thomas Clark, the chemist, in the manufactory of Messrs. Macintosh & Co.

Steam-boats for canals were proposed by Mr. Thomson, the chemist, who stated that the Forth and Clyde Canal banks could be lined with whinstones for fourpence a square yard. Mr. M'Call thought that a better way would be to have a rack fixed on logs floating the whole length of the canal, and each vessel to have a wheel to work on the said rack. Mr. Boaz suggested the plan of a chain being laid at the bottom the whole length of the canal, and a barrel or windlass in the boat, to operate upon the chain. Mr. John Hart proposed to run a locomotive engine on the bank, and pull the boat—a plan which was actually tried at Lock 16.

The reading of essays having become irregular, the Society entertained the idea of reviving the flagging industry of the members by one of two ways—either by imposing a fine of five shillings upon defaulters, or by holding out a premium of five shillings for doing their duty, in the form of a deduction to that extent from the annual payment. The choice of the Society was deferred.

The rattle of the rattlesnake was shown by Mr. Robert Rankine, a gentleman who was afterwards drowned while bathing, in a foreign country. Artesian wells also engaged attention. Mr. R. Wallace exhibited and described a drilling machine for piercing plates of metal, and which has since come into general use. Mr. Freeland raised the question, whether water freezes sooner than otherwise under pressure, in consequence of Captain Ross having brought water and mud from a depth of 800 fathoms, at 25° or 26° Fahrenheit. This gentleman also gave the Society an account of a voyage he had performed to America, describing particularly the dolphins, porpoises, and flying fish he had witnessed in the Atlantic.

Plants were exhibited, the collection of a medical officer in Captain Parry's expedition.

In the absence of a formal essay, the members engaged in what is described as a desultory conversation, on apparitions, witches, and traditions of this and other kinds, and as to their being real or imaginary.

A recommendation was brought before the Society in favour of planting oysters in the Frith of Clyde, similar to the mussel-beds there. A question as to the possibility of working a steam-boat by the water-press, is minuted as "quite preposterous."

A scheme was broached for improving the Highlands by the introduction into the glens of the cultivation of mint and carroway, the latter for the sake of the seeds, from which the oil might be expressed for sale; also the preparation in the quarries of stones for building.

A paper was read by Mr. John Hart on Dioptrics and Acoustics, which was afterwards published in *Brewster's Journal* and *The Mechanics' Magazine*.

Iodine became an object of interest to the Society at this period.

In 1824, Mr. Batchelor described a waterspout he had seen in the previous year, about three miles south of Linlithgow. After the connection ceased between the earth and the cloud, the portion that had communicated with the earth, "crap up," he said, and assumed the form of a golf club.

A banker's check was produced by Mr. H. Wilson, crossed with five lines printed on both sides, on the one with an alkali, and the other with an acid, so that any attempt of a fraudulent kind to discharge the figures would infallibly be detected, whatever reagent might be employed.

In November, Mr. Robert Hastie, the Chairman, claimed the priority of invention of a Nautical Indicator, assumed by another person, for the late Mr. Hunter, and as an act of justice to his memory. At the following meeting, a letter was received from Mr. Hunter, stating that he was still alive, and thanking Mr. Hastie and the Society for their interest in his invention. Mr. William Northhouse, editor of the *Glasgow Free Press*, became a member this year (1824). Much interest was excited in the Society by the principle of Döbereiner's Lamp, and numerous experiments were made on the action of hydrogen upon platina.

The improvement of the navigation of the Clyde, to admit of large vessels being brought to the Broomielaw, was a frequent topic of deliberation. The anticipations of the members, and probably the public also, were not at this time very sanguine. Early in 1825, Dr. M'Clure produced the tin model of a buoy or camel for floating vessels, by the aid of which he thought it not unreasonable to expect that ships of 250 or 300 tons might be brought to the Broomielaw. The minute mentions specially, that the invention and model are the property of Bailie Robertson, one of the magistrates of the burgh of Calton.

Mr. Wallace produced the sketch of a city improvement, which was afterwards carried out in the opening of London Street. This gentleman having now entered upon the editorship of the *Mechanics' Magazine*, solicited papers from the Society for the pages of that useful miscellany.

The Water Company having at this time shut off the water supply during the night, Mr. R. Hart contrived a self-acting water-cock, to prevent houses, by the inadvertence of the inmates, from being flooded in the morning when the water was turned on.

Mr. Scoullar, father of Dr. Scoullar, exhibited a variety of specimens or swatches of cotton, linen, woollen, and tartan, rendered waterproof, together with flexible pipes for conducting water, prepared by Mr. Macintosh's patent process.

Mr. Thomson, at a subsequent meeting, showed a specimen of caoutchouc cloth, the same kind as Sir Humphrey Davy had got a pair of boots made of.

A piston was exhibited, consisting of angular pieces, with a coiled spring in the centre, tending to force out these pieces to the periphery of the circle, so that they might always be in contact with the inside of the cylinder.

In the month of July, 1825, the members were specially invited to witness the ascent of a balloon from the Gas Works.

Sir H. Davy's experiments on preventing the decomposition of copper sheathing on ships, were explained to the Society by Mr. Thomson. The refining of sugar was also repeatedly brought under notice.

An account of the preparation of indigo in India, by Mr. Robert Hastie, son of the Chairman, and then resident in Bengal, was read to the Society.

Mr. R. Hart described a marble-cutting machine, contrived by himself, and employed by Mr. Thom in a work at the corner of Anne Street and Jamaica Street.

Mr. J. Beaumont Neilson brought forward a paper on Iron-making, accounting for the superiority of winter-made to summer-made iron, from the greater quantity of oxygen in the blast during cold weather—a position combated by several of the members.

A question was raised, but not answered—What is the best method of drawing one's own portrait?

Mr. William King Clark read one or two essays on the habits of bees, which he had studied with the help of a glass-hive.

Some attention was given to the improvements of carpet-weaving in Kilmarnock, and shawl-weaving in Paisley.

The last notable part of the proceedings of the year 1825, was a paper on "The Upper Navigation," by Mr. Boaz, who was at great pains to illustrate the benefits which would ensue from making a cut from Cambuslang to the Point-House at the mouth of the Kelvin.

The Society agreed that the two papers on this subject should be embodied in the next part of its printed *Proceedings*.

The Scrutineers gave in their report, from which it appeared that the following four gentlemen were elected in the order of the number of votes attached to their names,—viz.:—Mr. James Couper, Mr. John Condie, Mr. George Anderson, Mr. J. P. Fraser.

President.

Professor William Thomson.

Vice-Presidents.

Mr. James Bryce, jun. | Mr. Robert Hart.

Librarian.

Dr. Thomas Anderson.

Treasurer.

Mr. William Cockey.

Secretaries.

Mr. Alexander Hastie. | Mr. William Keddie.

Council.

Dr. John Strang.	Mr. Alexander Harvey.
Mr. J. R. Napier.	Dr. Allen Thomson.
Mr. William Murray.	Mr. J. P. Fraser.
Mr. C. Randolph.	Mr. George Anderson.
Mr. C. Griffin.	Mr. John Condie.
Mr. James Napier.	Mr. James Couper.

December 2, 1857.—*The* President *in the Chair.*

The Hon. Andrew Galbraith, Lord Provost of the City of Glasgow, was, on the motion of the President, elected a member of the Society by acclamation.

The President exhibited a specimen of Magnesium, procured by Professor Heintz of Keil, by electrolysis, from the chloride of magnesium, fused with common salt.

Mr. Walter Neilson proposed that the Library should, on certain days of the week, remain open till nine or half-past nine o'clock, for the accommodation of members whose time is occupied during the day. The proposal was remitted to the Library Committee.

Mr. Edmund Hunt read a paper "On certain Phenomena connected with Rotatory Motion."

On certain Phenomena connected with Rotatory Motion, the Gyroscope, Precession of the Equinoxes, and Saturn's Rings. By EDMUND HUNT, *Secretary to the Institution of Engineers in Scotland (with a Plate).*

THE subject of Rotatory Motions is one of the most interesting to be found in mechanics, and very much has already been written about it.

In 1854, Mr. Elliot, then of Edinburgh, received a prize medal, value £10, from the Royal Scottish Society of Arts, for a paper bearing on this subject; and the same paper was, I understand, afterwards read before yourselves. From *The Transactions of the Royal Scottish Society of Arts*, I find that the subject has been brought before them several times since, by Mr. Elliot, Professor Sang, and Professor Smyth. In 1854, Professor Baden Powell read a paper on the subject at the Royal Institution of Great Britain, London; and more recently a very elaborate paper on the subject has been written by Major J. G. Barnard, A.M., Corps of Engineers, U.S.A., and is given in *Silliman's Journal* for July, 1857. Mr. Elliot's explanation is peculiar to himself; Major Barnard follows the French mathematician, Poisson, who wrote on the subject in 1818 or thereabouts; and in the Report of Professor Powell's paper a detailed explanation is not given, but allusion is made to a variety of earlier authorities, in such a way as to convey the impression that they are all unanimous, whereas to me they seem otherwise. The number of *Silliman's Journal* for November, 1857, contains a short paper on the gyroscope, by Professor Newton; and a lecture on the subject has very recently been delivered before the Liverpool Literary and Philosophical Society, by Professor Hamilton. I have here briefly alluded to the most modern writers on the subject, but it has been touched upon to a greater or less extent by almost all the most celebrated mathematicians and astronomers since Newton's time.

In the present paper I do not propose to deduce results by means of profound analytical investigations, but shall attempt to follow and explain the actions under consideration in a simple and popular manner, and, in doing so, I shall pass over much old ground, so as to make perfectly intelligible anything new I may have to say.

A true explanation of the phenomena of the gyroscope is founded on what is known as the principle of the composition of Rotatory Motion. Professor Powell says this principle was originally discovered and demonstrated by Frisius in 1750; I find, however, that it was clearly stated, though not demonstrated, nearly a century earlier, by Newton, in one of the Corollaries to the remarkable 66th Prop. of the 1st book of the *Principia*. Playfair states the theorem in his *Outlines of Natural Philosophy*, and refers to Frisius' demonstration. He says: "When a body revolves on an axis, and a force is impressed, tending to make it revolve on another in the same plane with the first, it will revolve on neither, but on a line dividing the angle which they contain, so that the sines of the parts are in the inverse ratio of the angular velocities with which the body would have revolved about the said axes separately."* Airy, in his *Mathematical Tracts*, demonstrates this theorem, and a variety of others connected with it, as a foundation for his elaborate investigation and quantitative calculation of the precession of the equinoxes.

As Playfair says, "A body free to rotate about any axis, will not rotate permanently about any particular axis, unless the centrifugal forces are balanced with respect to that axis." Airy, however, says, "Since the axis about which the earth is at any instant revolving, does not coincide with the axis of the figure, the centrifugal force will diminish the effect produced by the distant body. With an ellipticity, however, so small as that of the earth, this diminution is not sensible." This seems to indicate that he thinks the earth does not rotate about its axis of figure, but is continually rotating about a new line. Whether this is so or not, I do not see how the centrifugal forces could in any case diminish the action to which he refers—namely, that of the sun and moon—by which the precession of the equinoxes is occasioned; for the directions of the centrifugal forces are at right angles to, and cannot affect the continually changing position in space which the axis should assume, whilst they must continue to act on the earth as long as the axis of figure does not coincide with this position. Again, if with an increased ellipticity of the earth, the centrifugal forces were, according to Airy's theory, to diminish the precessional effect of the distant body, the inclination of the equator to the ecliptic would be gradually reduced by the action of the sun and moon.† I may here remark, that this

* This enunciation of the theorem should be strictly adhered to. In the statement of it to be found in some modern works there is a vagueness which ignores a distinction that exists between the "composition of rectilinear motion," and the "composition of rotatory motion." When two rectilinear motions are compounded, the effect, as regards the position of the body acted upon, is the same as if each took place separately, one after the other; but it is not so in the case of rotatory motions. It is scarcely accurate to say, without some qualification, that two rotations can be replaced by a single rotation, having a relation to the two rotations, analogous to that which the diagonal of a parallelogram has to the sides. We can only conceive of two rotations as acting at separate times, and a particle submitted to them in succession will not be finally in the position in which the single rotation compounded of the two would place it.

† It will be seen from what is said farther on that in some cases the precessional motion is undulatory. If, in the case of the earth, the centrifugal resultant has been insufficient to prevent the undulations at once, it would still do so in time if it had any existence at all, by the accumulation of small effects; or, as Poisson shows, a determinate impulse in the direction of the precessional motion would prevent the undulations. It is not the nutation that I here refer to.

action, due to the disturbed equilibrium of the centrifugal forces, plays an important part in the complete explanation of the gyroscope phenomena; indeed, without it, the gyroscope, or the weight acting on it, would not, under ordinary conditions, move horizontally.

The gyroscope, almost in its present common form, was invented by Herr Fessel about six years ago, and is represented and described in *Poggendorff's Annals for* 1853. He was making a small fly-wheel for a model steam engine, and was spinning it in his hands to see if it was true, when he felt an extraordinary apparent resistance to any angular movement of the spindle, and also found that it did not fall when supported only on one side. A slightly different apparatus, showing similar phenomena, was invented as long ago as 1810 or earlier, by Bohnenberger, and is represented and described in *Gilbert's Annals for* 1818.* I now exhibit a common gyroscope, and some apparatus which can be adjusted to act either as a Bohnenberger gyroscope, or as a Fessel gyroscope, and which can be made to show a great variety of curious and interesting phenomena.

In the Bohnenberger apparatus, a spheroid or fly-wheel is set on pivots in a ring, with its spindle in a diametrical position. At points a quarter round from the fly-wheel pivots, this first ring is supported on pivots within a second ring, which is capable of turning about a vertical axis on pivots fixed on the stationary part of the apparatus. The axis about which the fly-wheel and rings severally turn, all pass through the central point of the apparatus, which ought also to be the common centre of gravity, so that the fly-wheel may be said to be supported at this point, whilst any inclination whatever may be given to its spindle. If the fly-wheel be set spinning, with its spindle in any but a vertical position, and a weight be applied to one end of the spindle, the weight will not bring that end of the spindle down as might at first be expected, but will be carried round in a horizontal plane. The Fessel gyroscope, as now constructed, consists of a fly-wheel set on pivots in a ring, a small conical indentation being formed in a prolongation of the spindle, so that when the ring is set with this indentation upon the pointed top of a pillar, it can turn round this point horizontally, and to a certain extent, vertically. The point of support is all to one side, and when the fly-wheel is not spinning the gyroscope falls down against the pillar. When, however, the fly-wheel is set spinning, the gyroscope does not

* Since this paper was written, I have seen in *Silliman's American Journal* for 1832, the description of a "Rotascope," designed by Prof. W. R. Johnston of the Franklin Institute, for exhibiting various experiments with rotating bodies. One of the experiments described is the same as the Fessel experiment, so that both Foucault and Fessel were anticipated as regards it.

FIG 1

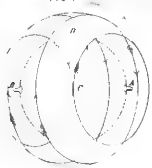


FIG 4

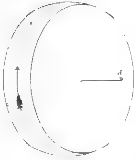


FIG 8.

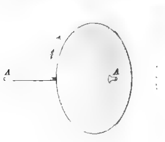


FIG. 10

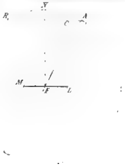


FIG 2

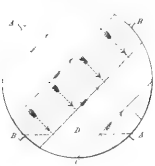


FIG 5

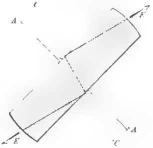


FIG 9

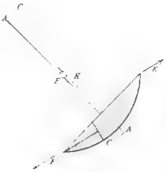


FIG 11

FIG 3

FIG 6

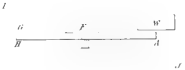


FIG 12

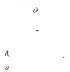


FIG 13

FIG 7

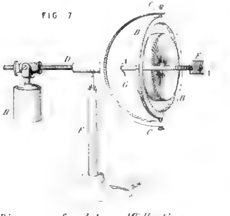
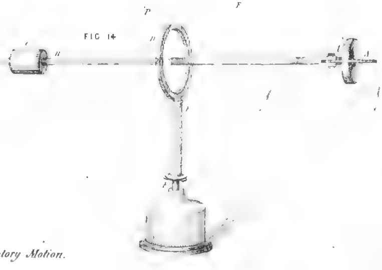


FIG 14



Diagrams referred to in Mr. Hunt's paper on Rotatory Motion.

fall, but moves horizontally round the pillar, its own weight acting just like the added weight in the Bohnenberger apparatus.

In proceeding to explain these phenomena, it will simplify matters if we, in the first instance, confine our ideas to the case in which the spindle of either instrument is in a horizontal position at the commencement of the experiment, and the force of gravity is acting in such a way as would bring the spindle down into a vertical position, were the fly-wheel not spinning. And first—the fact that the instrument is supported at a point, and that any movement in it must be one of rotation or oscillation about an axis passing through that point, must be carefully kept in view. Thus the fly-wheel spins about one horizontal axis, and gravity tends to make it turn about another horizontal axis, these two axes passing through this point of support, and being at right angles to each other.

It will very much facilitate our conception of the various circumstances and conditions under investigation, if we consider the rotatin body as forming part of a sphere of which the centre is the point of support of the body. And, first, let us consider the action on an entire sphere, of two equal impulses, tending to turn it about separate horizontal axes at right angles to each other, the sphere being supposed to be supported at its centre, but free to turn about any diametrical axis whatever. Such a sphere is represented in figs. 1 and 2, fig. 1 being an elevation, and fig. 2 a corresponding plan. Let one impulse tend to turn the sphere about the axis A, the full lines being the paths various points on the surface of the sphere would pursue round this axis, and the arrow-heads indicating the direction of the motion. Let the other impulse tend to turn the sphere about the axis B, the dotted lines being the paths of various points round this axis, and the corresponding arrow-heads showing the direction of the motion. Whatever impulses may have acted on a sphere, it cannot, when left to itself, rotate about more than one axis at a time; for each particle continues to move in one plane as long as no deflecting force is applied to it; and on account of the rigidity of the body, the planes of motion of all the particles must be parallel to each other, and at right angles to the axis. Hence in the case under consideration, the two impulses must combine to produce a rotation about some single diametrical axis, and it makes no difference whether the impulses are imparted simultaneously or in succession. We have therefore to determine the resultant axis, and it must obviously lie between the two axes A, B, and also in the same plane with them,—for no reason can be suggested why it should be to one side of that plane, rather than to the other. And accordingly we find that a point, C, midway between the poles A, B, of the two axes, and at the part where the motion about the axis A tends to lift it, whilst that about the axis B tends to depress it, will be equally acted on in opposite directions, the impulses being equal, and will consequently remain stationary. The same will be the case, under the same circumstances, with all the points lying in the line passing through the point C and the centre of the sphere; and this line being stationary, will constitute the axis about which the sphere will turn, in consequence of the combined action of the two impulses, provided the action on other points does not tend to make any other line the axis. Airy's demonstration, however, as applied to the present case, shows that the combined action on any other point whatever of the sphere is such as to give it a motion round the diametrical axis passing through the point C. I need not give this demonstration here, but may state that it holds good, whether the several points of the sphere are considered to be rigidly connected, or independent of each other, provided, in the latter case, each point be supposed to be acted on by two impulses, tending separately to produce for all points the like angular velocities about the axes A and B. The ratio of the angles which the axis through the point C makes with the axes A and B, depends on the ratio between the angular velocities corresponding to the two impulses. As before mentioned, Airy demonstrates that the sines of the angles are inversely as the two separate velocities.

If any point not in the axis through C is considered, it will be found that the rotation round C is in the direction of the arrow outside the sphere in fig. 1. Thus, if the sphere has been rotating by the first impulse round the axis A, and if the second impulse is applied downwards, at the point A, tending to make the sphere rotate about the axis B, the point A will obviously descend, and begin to rotate in the circle A B D, about the axis through C. In the case of the gyroscope, however, the end of the fly-wheel spindle, which corresponds to the point A, and to which the weight corresponding to a certain extent to the second impulse is applied, does *not* descend. In other words, if a rotating sphere is acted upon by an impulse which causes it to rotate on a new axis, the force of the impulse will be absorbed or spent—that is, whilst it is accounted for by the modified condition of the sphere, it will be incapable of producing a second impulsive effect. In the gyroscope, however, although the weight appears to be constantly producing (or more correctly occasioning) an angular motion of the spindle, its force is not spent in any way, and it continues to possess as much potential energy as though it were supported by a fixed point. It is this that constitutes what is paradoxical in the gyroscope phenomena.

The original rotation of the gyroscope is such as would be produced by a single impulse; the pressure of the weight, however, tending to produce rotation about a different axis is continuous. As the weight is fixed on the spindle of the gyroscope, the axes about which it is in succession tending to produce rotation are horizontal, and at right angles to the spindle. The obvious result of the continued action of the second force will be to cause the position of the actual axis of rotation to be continually varying. Airy demonstrates that if a uniform force act continuously upon the body, tending to give it a motion of rotation about an axis which is always at right angles to the axis about which it is at each instant revolving, and always in the same plane, the angular velocity of the body will be unaltered; and the position of the axis of rotation will have a uniform angular motion in space. In the case of the earth, the action tending to turn it about the intersection of the equator with the ecliptic, is constantly being, as it were, transferred from those parts of the equator which are approaching the ecliptic to those which are receding from it. This is the same as though in the sphere represented in figs. 1 and 2, the second force which commenced acting downwards on the point A, were being continually transferred to the points C, &c., forming the poles of the successive new axes. We have not, however, yet made out that the original axis A would move to C; did it do so, we should at once have the case to which Airy's demonstration last referred to applies, by attaching the weight to the point A; but in the case of the perfect sphere the point A descends. In considering what will be the action of a perfect rotating sphere, supported at its centre, but free to rotate about any diametrical axis, with a weight attached to one of the poles of its original axis of rotation, let the original axis be horizontal, and let it be projected, or pierce the surface of the sphere in the point *a*, fig. 3, the weight being attached to this point. Were the sphere not rotating, the weight would turn it about the axis through *b*, and would descend in the direction of the arrow *d*, and rise up on the other side of the sphere, until it attained its original height, provided, of course, no resistance were encountered. The weight would then return, and it would continue to oscillate backwards and forwards, like a pendulum. If, however, the sphere rotates very slowly about the axis *a*, say in the direction of the arrow *e*, then the effect of the application of the weight will be to make the sphere turn about a horizontal axis between *a* and *b*, and very near the latter. For the instant, this new axis is precisely as though its poles turned in fixed bearings, and the weight turns with the sphere about it, and for the instant moves in a plane at right angles to it, and consequently in an arc of a less radius than that of the sphere. An oscillation of the weight about this new axis would not bring it up on the other side of the sphere to a point directly opposite to its original point, but to one nearer to the point *b*.

The greater the original velocity of rotation of the sphere is, compared with that which the weight tends to impart, the smaller will be the semicircle or other curve through which the weight will move, and the less will be the horizontal arc on the sphere which such motion will measure from the starting point a. Let the original velocity of the sphere be such that in a very short interval of time the effect of the weight is equivalent to that of an impulse, which would cause the new resultant axis to be in the point f; then the weight will begin to move like a pendulum in the circle $a\,i$, whose radius is $f\,a$. A pendulum, however, notwithstanding its motion, is always exerting a pressure on its point of support; and in our case the weight, notwithstanding its motion round the centre f, is constantly tending to turn the sphere about a new horizontal axis. The consequence of this is, that the actual axis of rotation is constantly moving towards h; and as the weight is always moving in an arc, of which the pole f or h of the axis is the centre, it will not describe the semicircle $a\,i$, but the curve $a\,k$. A complete investigation shows that by the time the weight reaches k, the pole of the actual axis of rotation will also reach that point. The upward motion of the weight due to the acting energy caused by its descent will then be neutralized by the retarding action of gravity, and the sphere will be in the precise condition in which it was at starting, except that its axis is now in k, instead of a. The action described will be repeated, the axis moving to b, and the weight moving through the curve projected in $k\,l\,b$, precisely similar to the arc $a\,k$, the weight making a series of vertical oscillations, whilst the position of the actual axis of rotation travels round in the horizontal plane.

In applying what has been said of the sphere to the case of the gyroscope, we may suppose the latter to be formed out of the former, by cutting portions away. Thus A, in figs. 1 and 2, being the original axis of rotation, and the centre of the sphere being the point of support, if we cut away all the portions but that shaded by horizontal lines in figs. 1 and 2, and shown separately in figs. 4 and 5, we shall obtain a sufficiently close approximation to the Bohnenberger gyroscope—supported at its centre. If a weight be applied at one end of the spindle A, it will tend to turn the wheel about a horizontal axis at right angles to the spindle; but this tendency combining with the motion already possessed by the wheel, will make it tend to turn about an intermediate axis passing through C, fig. 4, the precise position of this axis depending on the ratio of the two velocities, whilst it will be the same as though the sphere were complete; for, as before mentioned, the action on each particle is the same as if it were independent of the others. The same weight, however, will produce a greater velocity in the gyroscope fly-wheel than in the sphere, the mass of the former being so much less; but the position of the resultant axis depends *directly* on the angular velocities, not on the forces producing them. Let the action of the weight, during a very short interval of time, be supposed the same as that of an impulse which would have the effect of making the line C C, in the plan, fig. 5, the position of the resultant axis of rotation. At the instant the change of axis takes place, the wheel lies obliquely to the line C C, but each point in the wheel immediately endeavours (if I may use the expression) to rotate in a plane at right angles to this line C C, and the horizontal components of the centrifugal forces due to the rotation consequently act in directions parallel to the arrows E, fig. 5. An inspection of the figure will show that the two halves of these centrifugal forces are directed one *from* each side of the axis C C, and that they are so circumstanced as to tend to produce rotation, in consequence of the planes of their directions not coinciding. The centrifugal forces (their vertical components being balanced, as a little consideration will show) thus give rise to a resultant couple of forces, which tend to turn the wheel round about a vertical line, so as to bring the spindle A A towards C C; and this tendency will cease (in the case in which the second force is an impulse) on the spindle A A coinciding with C C, when the centrifugal forces will be balanced, and no longer inclined to the wheel. In the case of the perfect sphere, no unbalanced centrifugal forces arise to move the original axis into a new position; but the sphere turns about a new set or line of its component particles as an axis, and the pole of the original axis descends or moves in the direction of the force changing the direction of rotation.* But to return to the gyroscope and the diagram, fig. 5—a weight is attached to one end of the spindle A A, and the movement caused by the centrifugal force, being entirely in a horizontal direction, cannot *directly* cause the weight to move horizontally, though it might combine with the downward motion the weight would otherwise have, to give it an intermediate direction—

* Even with the Bohnenberger gyroscope the centrifugal resultant is not in all cases sufficient to carry the weight round horizontally. If a very slow rotation is imparted to the wheel, the weight will describe vertical curves, provided the instrument turns very freely on its pivots. With this form of instrument, however, there is in all cases a centrifugal resultant of the kind described, and this resultant causes any curves that may appear at starting to be gradually reduced to a horizontal line, as will be explained farther on. In the case of the sphere, on the other hand, there is no such centrifugal resultant under any circumstances; and if the rotation remains uniform, the weight will continue to describe equal vertical curves, if not influenced by the supporting mechanism. To simplify the explanation, it is at first assumed that the rotatory velocity of the body is such, that the centrifugal resultant arising is sufficient to carry the spindle round horizontally.

perhaps inclined downwards, at an angle of about 45°. In the gyroscope, however, the weight is actually carried round horizontally:—the explanation is therefore still incomplete. In proceeding to carry it a step farther, I must first observe, that as the application of a downward pressure on the end of the spindle A A gives it a tendency to turn round horizontally towards C C, if this movement is prevented—by making the spindle end move in a vertical groove, for example—a pressure corresponding to the weight, or to the horizontal or precessional motion it tends to produce, will obviously be exerted against the side of this groove—as may also be proved by experiment. The weight also moves down the groove, in consequence of the supporting power not being called into play, and carries the spindle of the gyroscope with it. Now, the action of the centrifugal resultant already pointed out, as tending to turn the spindle round horizontally, is precisely that of a separate external pressure, tending to turn the already rotating wheel about a vertical axis, and consequently, according to the principle of the composition of rotatory motion, the wheel will tend to turn about a new axis, lying between its original horizontal axis and the vertical axis. As in the case already considered, in which the weight constituted the external pressure, the spindle will tend to move towards this new axis—that is, the end of the spindle to which the weight is applied will tend to turn upwards. Now, if this upward motion were prevented by a horizontal groove, an upward pressure would be exerted against the groove, and the spindle would move horizontally. The weight itself obviously acts the part of the horizontal groove, and its downward pressure obviously meets or sustains the upward pressure, whilst the spindle consequently moves horizontally. Instead of saying that the weight sustains the upward pressure, we ought of course rather to say that the upward pressure derived from the unbalanced centrifugal force, or the centrifugal resultant called into play by the weight, sustains that weight, or prevents it from oscillating vertically as in the case of the perfect sphere.

The upward pressure due to the horizontal or precessional motion of the spindle is in proportion to that motion; and if an attempt is made to accelerate that motion, the upward pressure will be increased, and becoming greater than that of the weight, will lift the latter. If, on the other hand, the horizontal or precessional motion is retarded, the upward pressure will be diminished, and becoming less than the weight, the latter will fall. These results may be easily verified on the Bohnenberger instrument. The friction of the pivots of the outer ring retards the horizontal or precessional motion, and the weight gradually descends. It is not, as might be supposed, the diminution of the rotatory velocity of the wheel which causes the weight to gradually descend. The precessional motion actually increases as the rotatory velocity diminishes, because the ratio between this velocity and that which the weight tends to impart becomes more favourable to the latter. Of course, as the horizontal precessional motion increases, the friction and consequent retardation increase also, and the weight descends with gradually increasing rapidity.

It may perhaps be thought that having shown that the weight is sustained, my explanation is now complete, as far as regards the case under consideration. Not so—for I have still to show what becomes of the pressure of the weight. I have made out its removal, as it were, from one spot, but I have not shown where it is to be looked for. We cannot annihilate the weight, nor do we do so by removing it from a particular situation. In the case we are considering, the weight cannot really produce motion, for it does not descend, but retains its potential energy unimpaired. I have already shown that with the horizontal precessional motion there is a pressure tending to turn the spindle A A upwards. Referring to fig. 6, let a force (or, more correctly, a couple) act on the lever A G, tending to turn it about the centre F, so as to press the end A up against the obstacle W—one-half the pressure acting on each side the centre F. It will be obvious that a pressure equal to that pressing up against the obstacle W reacts downwards upon the centre F. Now, in the gyroscope, the weight applied to the spindle end acts as an obstacle to the upward pressure, which does not exceed it in amount, and there is obviously, in consequence, a reactionary downward pressure upon the point of support of the instrument, precisely equal in amount to the weight. We have thus at last ferreted out the whole of the effects involved in the phenomena (except, indeed, those due to friction and the resistance of the air). The weight tending to turn down the spindle of the rotating wheel occasions a horizontal angular or precessional motion, through which it is itself sustained, its downward pressure being, as it were, transferred to the point of support of the wheel. Simple as this last deduction may seem, and notwithstanding the facility with which it is derived from what precedes it, it is a very important element in the explanation. It is in fact the keystone of the theory, which without it would fall to pieces. The upward pressure which supports the weight cannot exist without a reactionary downward pressure on some point of resistance. If the theory were complete without this element, it would prove too much; for it is quite applicable to the case of an unsupported disc rotating about a horizontal axis; and were it applied to that case it would seem to prove that gravity ought to make it travel horizontally, instead of falling vertically. In reality, however, we pass to this case from that of the gyroscope, by first supposing the weight in the latter case to be gradually moved nearer the point of support. As this change takes place, the line of action of the upward pressure gradually approaches that of the reactionary downward pressure on the point of support, until, on the weight reaching the point of support, the two opposite pressures may be considered either as coinciding in their lines of action, and so neutralizing each other, or as vanishing—the original weight being left acting on the point of support, so that if that point of support were removed, it would make the instrument fall. In fig. 7, my apparatus is represented as arranged to show that the pressure of the weight actually does take effect on the point of support. The ring A of the fly-wheel can turn about a horizontal axis on pivots in the ring B, which last can turn about a vertical axis on pivots in the bowed end C, of a lever D, set free to oscillate on the point of a pillar E. A small weight F is fixed on the ring A, and a thread G, attached to the lower pivot of the ring B, is made to catch the side of the ring A, opposite to the point of attachment of the weight F. When the thread G is thrown off, and the fly-wheel is not rotating, the weight F falls down into the vertical line, about which the ring B turns, making the spindle of the fly-wheel vertical. In this position of the weight F the lever D is balanced in a horizontal position by means of the weight H. If now the weight F is kept up by means of the thread G, the weight H will be over or underbalanced accordingly as by turning the ring B the weight F is placed nearer to or farther from the fulcrum E, than the centre of the fly-wheel. If, however, the fly-wheel is set spinning, the thread G may be thrown off, and the weight F will be carried round horizontally by the precessional action, whilst the lever D will remain horizontal, the weight H being balanced precisely as if the weight F were acting at the centre of the fly-wheel. The thread G prevents the ring A from turning about its pivots in the ring B, just as if these pivots were fixed; if the precessional action did this in the same way, the leverage on the lever D, of the weight F, would vary as it moved round; but instead of this, it transfers the pressure to the centre of the fly-wheel, where it has no tendency to turn the ring A about its pivots, in the ring B. Again, the pressure of the weight F is not diminished in amount during the precessional action, for the weight H is balanced precisely as when the weight F hangs below the centre of the fly-wheel, the latter not rotating.

In the case of the sphere, if the axis of rotation is changed by an impressed impulse, the rotatory velocity is changed also,—but Airy demonstrates that when the axis changes continuously, in consequence of a pressure acting continually on the pole of the actual axis, the rotatory velocity does *not* change,—and this corresponds with the fact, that in the one case the force of the impulse is spent, being accounted for by the changed velocity, whilst in the other case the force is *not* spent. In the case of the continued pressure the wheel acts as though points on its periphery were continually coming in contact with fixed inclined guides, which have the effect of changing the courses of the points, and consequently altering the position of the axis about which they rotate.

It may occur to some one to ask if the pressure on the point of support exists also in the case of the earth? There would be such a pressure at right angles to the plane of the ecliptic, did the action on the earth, corresponding to that of the weight on the gyroscope, take effect on one side only of the centre. This action, however, takes effect on both sides in the case of the earth. Thus, if in fig. 6, I J represents the plane of the ecliptic, and G A a diameter of the earth; there is a force pressing at W, towards J, and another pressing at H, towards I. The precession, as I have shown, gives rise to counter pressures, A and G exactly balancing the pressures W and H respectively. If these pressures, W and H, are equal, there will obviously be no pressure on the centre F: for the pressures, W and G, pressing the centre one way, are equal to the pressures, A and H, pressing it the other way. I leave it to astronomers to decide if the forces at W and H are equal or not. When the sun is towards J, the force at W may possibly be slightly the greater of the two—if it is, there will be a slight pressure on the centre F, in the same direction; but this will be compensated for when the sun is towards I, by a like pressure in the opposite direction. If the pressure exists at all, it will merely amount to the difference between the forces at W and H.

I must now show how my explanation applies to the Fessel gyroscope, in which the weight of the entire instrument constitutes the downward pressure which changes the position of the axis. Referring to figs. 1 and 2,—if we remove from the sphere all but the segment shaded with vertical lines, and shown separately in figs. 8 and 9—we shall obtain a sufficiently close approximation for our purpose, the centre of the sphere, marked F in figs. 8 and 9, being still the point of support. The tendency of gravity to produce rotation about a horizontal axis at right angles to the axis A F, combines with the rotation of the wheel to produce rotation about an intermediate axis, C C, fig. 7, supposed to be very near A F. At the instant the change of axis takes place, the wheel is oblique to the line C C, but each material point in it immediately endeavours to rotate in a plane at right angles to this line, C C, and the horizontal components of the centrifugal forces due to the rotation consequently act in directions parallel to the arrows, E. The centrifugal forces being thus inclined to the wheel, tend to turn it round, so as to carry the end A of the spindle towards C, and the part F towards K. But the part F cannot move from the point of support, so that the reaction of the pressure towards K, along with the pressure on the end A, towards C, will tend to turn the wheel about the centre F, so as to bring its spindle F A to coincide with the line C C. In other words, the moment round the centre, F, resulting from the centrifugal forces on opposite sides of the wheel, carries the wheel round towards C. Beyond this point the explanation is identical with that already given of the action of the Bohnenberger apparatus. My adjustable apparatus can be arranged to show the transformation from the Bohnenberger to a modification of the Fessel apparatus, whilst in motion; the fly-wheel performing a portion of a precessional revolution about its own centre, and then moving round a centre at a short distance on one side.

I must now remind you that so far we have only considered cases in which the spindle of the gyroscope is in a horizontal position, the weight tending to turn it about another axis which is also horizontal. The resultant axis being in the same plane, the precessional motion is consequently in the horizontal plane. If, however, the spindle is, at starting, at all inclined to the horizon, the plane in which the two axes lie, will, of course, be inclined also, and the spindle will therefore *tend* to move in that inclined plane. Let A F, figs. 10 and 11, represent the inclined spindle, fig. 10 being an elevation, and fig. 11 a plan. The weight applied at A will tend to turn the wheel about the horizontal line L M, and L A M will be the plane passing through the two axes. The spindle A F will therefore tend to move towards C F, in the plane L A M; but the weight moves with the end A of the spindle, and as the action of the weight is continuous, no movement, however small, of the spindle, can take place towards C F, without altering the position of the horizontal line L M, about which the weight tends to turn the wheel. As the spindle A F moves towards C F, the imaginary axis, L M, moves towards O P, fig. 11, and the plane through the two axes consequently continually moves round. The result is, that the spindle A F actually moves on the surface of a cone, of which the vertical line N F, fig. 10, is the axis, whilst the end A of the spindle, carrying the weight, moves in the horizontal circle, A C R, forming the base of the cone. The weight is therefore carried round horizontally, whether the spindle of the gyroscope is at starting in a horizontal or in an inclined position.

The gyroscope does not in all cases present a complete example of the phenomena I have explained, and the action is generally very much modified by friction and by the resistance of the air. One way in which friction brings down the weight has already been alluded to: the resistance of the air, or friction, on the other hand, causes the weight to rise if the gyroscope is set in a certain position. I will speak more fully of some of these effects when discussing Mr. Elliot's paper.

In the course of my investigations it occurred to me to consider whether any difference would be produced in the phenomena exhibited by placing the gyroscope farther from the point of support. In comparing two cases with the view of ascertaining what difference arises from difference of position, with reference to the point of support, we must assume that the other conditions are precisely alike in both cases; that the form of wheel, and the original rotatory velocity are the same; and that gravitation tends to produce an equal amount of precessional motion in both cases. In fig. 5, which may represent one case, the point of support is supposed to coincide with the centre of the wheel, and a vertical plane passing through what may be termed the precessional axis, C C, divides the wheel into two equal halves. The centrifugal resultants represented by the arrows, E E, act on opposite sides of the point of support, and both in the same direction of rotation. Fig. 9 will represent the conditions of the second case we are now considering. Here the point of support, F, is away to one side of the wheel. The centrifugal resultants represented by the arrows, E E, both act on the same side of the point of support, and in opposite directions of rotation round that point. However, if they are equal to those in the first case, and to each other, they will have precisely the same effect as in the first case, for the conversion of one of them into a backward strain, is exactly compensated for by the increased leverage of the other. But *are* they equal to each other? The precessional axis, C C, must necessarily pass through the point of support, F; and it will be obvious on inspecting fig. 9, that a vertical plane through C C, divides the wheel into two *un*equal parts. It will also be easily seen that the final resultant in the direction of the precessional motion will be lessened in consequence of this unequal division, and it follows, that a gyroscope, under circumstances in which it would exhibit a horizontal precessional motion without undulations, if placed with its centre coinciding with the point of support, can be placed at such a distance from the point of support that the centrifugal resultant shall be insufficient to render the precessional motion horizontal. In such a case, the modified phenomena shown will resemble what I have said would be exhibited by a sphere in which no centrifugal resultant arises,—that is to say, the wheel will move along an undulatory curve. This phenomenon is shown in a very remarkable manner by a common gyroscope, A, set as represented in fig. 14, at ten or twelve inches' distance from the point of support, upon a light lever, B, free to turn in every direction about that point. It is necessary to put a weight on the opposite end of the lever to lessen the downward force of gravity on the gyroscope, so that the latter may not descend inconveniently low. The lever B can turn on horizontal pivots in a ring D fixed on the top of a tube E. The ring and tube turn freely round the fixed pillar F, resting on a point, close under the ring, whilst anti-friction wheels carried by the tube bear on the lower part of the pillar. The phenomena shown by the apparatus arranged in this way may be very beautifully varied. Thus, if the wheel is spun and then left free with the lever in a horizontal position, care being taken not to impart an impulse of any kind on removing the hand, we shall have a case of two forces—the rotatory momentum of the wheel, and the downward pressure of gravity. In this case, the centre of the wheel describes a curve, indicated by dotted lines in fig. 14, resembling the common cycloid, or more correctly, a spherical epicycloid, the cusps of the curve being directed upwards. If, at starting, a forward horizontal impulse is imparted by the hand, the case becomes one of three forces,—this impulse being added to the rotatory momentum of the wheel and the downward pressure of gravity—and the result is, that the curve described becomes prolate, the cusps disappearing. If this forward impulse is of a certain precise force, corresponding to the other two forces, it will cause the precessional motion to be quite horizontal. In a third case, a backward horizontal impulse is given by the hand, and has the effect of making the curve curtate or looped.

An insight is gained into the second and third cases by considering the effect of first compounding two of the three forces—the rotatory momentum of the wheel, and the horizontal impulse given by the hand, —and then as it were superadding the downward pressure of gravity. In the second case, the forward impulse, combining with the original rotation, would tend to produce rotation about an axis passing *above* the centre of the wheel, so that the superadded action of gravity would be the same as that of a weight attached to a point *below* the pole of original rotation of a sphere supported at its centre. Similarly in the third case, the backward impulse, combining with the original rotation, would tend to produce rotation about an axis passing *below* the centre of the wheel, and the superadded action of gravity would be the same as that of a weight attached to a point *above* the pole of original rotation of a sphere. It will thus be seen that the circumstances in the three cases are varied in a manner analogous to the variation of those under which the several forms of plane cycloids are described, by a point, carried by a disc, rolling along a straight line.

In the gyroscope the curves are prevented from being true spherical epicycloids by the varying leverage of the weight, and also by the action of the moving frame and details carrying the wheel. In the third experiment (with the backward impulse), it is necessary to place the wheel in an elevated position at starting, as the lower halves alone of the curves then formed are equal in size to the ordinary curves, the entire curves being deeper and requiring greater scope. When the gyroscope is moving along a curve, an impulsive acceleration acts like a backward impulse at starting, and similarly an impulsive retardation acts like a forward impulse at starting,—the former making the curve less prolate or more curtate, and the latter making it less curtate or more prolate.

I must now mention another phenomenon always shown in these experiments. Whatever curve is made by the instrument at starting, it gradually changes to a less curtate or more prolate curve, in a manner indicating, that in time, if the rotation of the wheel continued, it would ultimately become horizontal and without undulation. Several causes combine to produce these results, and it would be extremely difficult to assign to each the precise value due to it. The frictional and general resistances to the movements of the apparatus cause the wheel to rise to a less and less height at each succeeding undulation; and they must also, to some extent, modify the form of curve described. When the wheel is descending the curve (the common cusped cycloid, let us suppose), it is also imparting a horizontal motion to the apparatus, and the mass partaking of this horizontal motion having been just previously at rest, necessarily absorbs a corresponding amount of force. Then the centrifugal resultant, although unable to prevent some descent of the wheel, must tend to modify the curve by rendering it more prolate or more nearly a horizontal line than it would otherwise be. In the descending portion of the curve, the centrifugal resultant will assist in giving horizontal motion to the moving frame, and this part of the curve will be more nearly like what may be termed the true curve, than if either the centrifugal resultant acted alone, or the mass of the frame absorbed part of the force alone. The ascending portion, however, of the curve will be different, for as the wheel rises its horizontal motion diminishes, so that the forward momentum of the moving frame will tend to elongate the curve and render it more prolate, without being partly counteracted by the centrifugal resultant, which, on the contrary, now assists it rather than otherwise. The result is, that on the wheel arriving at the top of the curve, the horizontal motion is not wholly destroyed; and, on the next descent, the curve is more prolate and resembles what would be the result at starting, if a slight forward horizontal impulse were imparted to the wheel. An additional increment of horizontal motion is gained in this way at each undulation, and if the wheel spins long enough the curve will ultimately become a horizontal line. In my apparatus it is very noticeable that it is in the ascending portion of the curve that the change takes place most markedly.

I have made the gyroscope describe curves when placed with its centre at only five inches from the point of support, no counterweight being in this instance used. With an extremely low rotatory velocity the curves can even be shown with the point of support coinciding with the centre of the gyroscope; but in this and similar cases they very rapidly become prolate, and disappear in consequence of the rapid accumulation of the individually insufficient effects of the centrifugal resultant.*

I will now proceed to discuss some incomplete or erroneous explanations that have been published. Amongst these is one given by Poggendorff, in the volume of his *Annals*, in which Fessel's apparatus is described. This explanation is confessedly incomplete, and it would be tedious for me to enter into detail concerning it, although I had prepared some remarks upon it. Most continental writers on the subject appear to consider Poisson's explanation complete and accurate. The discussion of Poisson's theory is involved in that of Major Barnard; for, as the latter author says, "He follows the steps of Poisson, and arriving at his analytical results, he endeavours to develop fully their meaning, and to show that they are expressions not merely of a visible phenomenon, but that they contain within themselves the sole clue to its explanation."

In Major Barnard's application of the analytical method in the investigation of the gyroscopic phenomena, I understand him to assume, *first*, that the body is any solid of revolution; *second*, that its original rotation is about its geometric axis; *third*, that it is supported at a point in the geometric axis, at a given distance, from the centre of gravity; and, *fourth*, that at starting, the body is in such a position that gravitation tends to turn it about a horizontal axis in such a way as to bring its geometric axis into a vertical position.

Further, he does not appear in his investigation to have anticipated any alteration in the phenomena arising from mere change of position with respect to the point of support.

Having worked out his analytical results, the interpretation of them which he gives is to the effect (as I understand him) that the actual axis of rotation which also continues to be the geometric axis of the body, travels along a series of equal cycloidal curves, of which the cusps,

* The enlargement of the curves as the distance from the point of support is increased, may arise partly from the mass having to be moved an increased distance to obtain a given angular adjustment, as well as partly from the diminution of the centrifugal resultant.

directed upwards, are in a horizontal plane. He says that in experimenting with the gyroscope, the rotatory velocity usually given to the fly-wheel is so great that the cycloidal oscillations of the spindle are so *exceedingly minute, that, to the eye, the axis seems to move horizontally without any oscillation at all!* He does not, however, explain why we do not see these oscillations gradually increasing in amplitude, as they ought to do, according to his and Poisson's theory, as the rotatory motion gradually becomes less. With a well made Bohnenberger gyroscope, the weight continues sustained and moving round horizontally without oscillation when the rotatory velocity of the fly-wheel has diminished to a very low rate,—when the circumstances, indeed, become such, that, according to their theory, the weight ought to move through cycloidal curves almost lying in a vertical plane through the point of support. The assumption, that in the ordinary experiments, the cycloidal oscillations are present, but too minute to be noticed by the eye, will appear very unsatisfactory also, when we consider that by the theory the oscillations shown by a given instrument are greater or less accordingly as the rotatory velocity of the fly-wheel is less or greater; but the greater the rotatory velocity of the fly-wheel is, the less rapid is the precessional motion; and for the oscillations to be infinitely small, the rotatory velocity must be infinitely great, and the precessional motion *nil.* Now, the precessional motion usually exhibited indicates that the rotatory velocity is very far from being infinitely great, and therefore the oscillations must be far from being infinitely small. At the least, these considerations would lead us to expect that, if the theory is correct, the gyroscope could easily be arranged so as to show the oscillations in a marked and unmistakeable manner. I must here remark that oscillations can be produced in the Bohnenberger gyroscope even when the wheel rotates very rapidly,—namely, by fixing a small weight to one side of the wheel rim; but there is no mistaking these for the cycloidal oscillations, as they increase with an increase in the rotatory velocity and *vice versâ,* whilst the cycloidal oscillations should vary inversely as the rotatory velocity.

The analysis of Major Barnard is not of such general application as he seems to have supposed. The case considered by me at pages 135 and 136, fulfils the conditions assumed as the foundation of his analysis. The sphere is a solid of revolution; with a weight applied to the pole of the original rotation, the axis of that rotation passes through the point of support (the centre of the sphere) and the centre of gravity of the entire mass, and corresponds to the geometric axis; it is supported at a point in what corresponds to the geometric axis, at a given distance from the centre of gravity; and gravitation tends to turn the body so as to make the original axis vertical. In this case my investigation led me to the same result as Major Barnard's analysis; but this is not the case of the common gyroscope, as I have already shown. The gyroscope, however, fulfils the conditions contemplated by Major Barnard; but there is a difference between its conditions and those of the case treated at pages 135 and 136, which is not taken into account in his investigation. The analysis is not complete as applied to all cases fulfilling his various assumed conditions, and it would only have been so had the first condition been—that the body be a solid of revolution, such that the centrifugal forces are balanced about whatever axis passing through the point of support it may be turning; but the condition so worded excludes the common gyroscope.

Major Barnard's analysis shows at any instant the position of the line passing through the point of support and the centre of gravity, that is, the spindle of the instrument to the end of which the weight is applied. It does not however follow that this line is at every instant the actual axis of rotation, as is assumed by Major Barnard in his interpretation of the analytical results. By the first theorem of the composition of rotatory motions, the body cannot, under the given conditions, rotate about an axis *lower* than its original one,—that is, than the original position of that axis,—and, therefore, if the centre of gravity descends, the line through it ceases to be the actual axis of rotation. Indeed, the analytical results, if properly interpreted, show that the line through the centre of gravity is *not* continually the axis of rotation, for what is the movement of this line along the cycloidal curve but a motion of rotation about some other axis which has a horizontal progressive motion? It being indisputable that the body is continually revolving on a different axis, or at least tending to do so; the analysis is incomplete as far as regards its application to any body in which the centrifugal forces are not balanced about whatever axis it may be revolving. To make it applicable to the gyroscope, as commonly arranged, it will be necessary to introduce an element which will have the effect of showing how the results are modified by the occurrence of an unbalanced condition of the centrifugal forces when the body tends to rotate about an axis differing from its geometric axis. I have no doubt that the analysis corrected in this way, if it can be done, will show results coinciding with those I have obtained, by a different method of investigation.

Major Barnard seems to think that if the weight does not actually descend, the horizontal precessional motion cannot take place, except as an effect produced without a cause. But, viewing the matter in this way, what does he gain by making his weight descend—as long as he brings it up to the same level again? Any dynamical power its descent may give it is entirely reabsorbed by its reascent. Again, the mere pendulous action or oscillation would not account altogether for the pressure of the weight. What, according to Major Barnard's theory, becomes of the pressure corresponding to that of an ordinary pendulum upon its point of support—and which, in the gyroscope, acts on a point at some distance from the point of support?

Major Barnard makes some remarks on what he terms "the popular idea that a rotating body offers *direct* resistance to a change of its plane." As the supposed resistance is a phenomena of rotatory motion, it will not be out of place to introduce the subject here, particularly as very incomplete, if not erroneous notions about it appear to be prevalent. Major Barnard says, "If the extremity of the axis of rotation were confined in a vertical circular groove, in which it could move without friction, the rotating disc would vibrate in the vertical plane as if no rotation existed. What, then," he adds, "is the resistance to a change of plane of rotation so often alluded to and described? A misnomer entirely." Now, the application of the groove does not *quite* reduce the case of rotation to that of non-rotation; for in the former case, since the weight tends to produce a horizontal movement of the axis, it must exert a horizontal pressure against the side of the groove; whilst in the case of non-rotation there is of course no such horizontal pressure. Indeed, the pressure against the side of the groove, and consequently on the pivots of the fly-wheel, is so great as to considerably reduce the rotatory velocity of the wheel. My gyroscope will spin twelve minutes when no force is applied to change its plane; but with an equal velocity of starting it will not spin longer than three or three and a-half minutes, if a force acts on it tending to produce a precessional motion, which is prevented. However, notwithstanding that Major Barnard's remarks are unsatisfactory, the popular idea on the subject requires correction.

There is, in reality, no greater resistance connected with rotatory motion than with rectilineal motion. It is inaccurate to say, that a rotating body offers a greater resistance to a change of plane than a non-rotating body; but it is correct to say that *a rotating body offers a greater resistance than a non-rotating body to an attempt to make it rotate in a particular new plane, by a force directed parallel to, or in that new plane.* We should feel precisely the same resistance, under the same circumstances, in attempting to change the direction of rectilinear motion. If a body is moving rectilineally in one direction, and we wish to make it move in some other particular direction, we must apply an impulse to it, of such an intensity, and in such a direction, as when *compounded* with the original motion will give the desired result, on the principle of the parallelogram of forces. If we apply such an impulse as would have made a similar body, in a state of rest, move in the desired direction, it will not produce the desired result, for the body will move in a direction lying between that of the original motion, and that corresponding to the new impulse. Now, it is something very like this that occurs with a rotating body. In trying to change the plane of motion we endeavour to give new directions to the particles already in motion in other directions, and they will therefore *not* move in the directions in which the new impulse tends to move them, but in intermediate directions. In other words, the new impulse will not make the body rotate about the same axis that it would have done, had it been at rest. It will, however, make it rotate about a new axis different from its original one—and the plane of motion will really be changed to the full extent of the new impulse imparted.

Professor Piazzi Smyth read a paper before the Royal Scottish Society of Arts, in 1856, on the angular disturbances of ships, in which he described his admirable, ingenious, and correctly designed apparatus, to be used on shipboard to give perfect steadiness to a telescope and observer, notwithstanding the most violent movements of the ship. In an appendix to this paper, and in treating of the parallelism of the earth's axis, he appears to consider that the diurnal rotation of the earth is necessary to maintain the inclination of the axis—that it is the resistance due to the diurnal rotation that causes the axis to maintain a uniform inclination. Now, I think it is plain from what I have said, that the rotation would not maintain the inclination of the earth's axis, were any force applied to change that inclination—it would merely cause the change of inclination to take place in a different direction from that of the disturbing force. But as regards the earth itself, it seems to me that before we search for some power to maintain the inclination of its axis against the action of disturbing forces, we must first show the necessity of such a power by proving the existence of disturbing forces equal to the task of altering the inclination.*

Professor Smyth, referring in the same paper to an incorrect explanation of the gyroscope, says, "That the true explanation of the phenomena may be obtained by observing *everything* that we see, instead of confining our attention to *one* favourite point only out of many. Examining the experiment again," he continues, "in this spirit, we find that at the same time that the spinning of the wheel serves to restore the apparent balance, a horizontal motion of it about its central point of support takes place; and this, which escaped the attention of the paradox-finder,

* In the particular observations of Prof. Smyth, to which these remarks refer, I do not understand him to be considering anything connected with the precession of the equinoxes.

is the effect of the weight of the wheel compounded into the rotatory motion. The wheel is weighing just as much when spinning as when at rest; but the fact of its weight, or the attraction of gravitation on it, is not to be looked for in the downward direction, as with quiescent bodies, but in a direction at right angles to it, that is, in the horizontal. . . . In this horizontal motion, then, is the desired explanation of the mystery, which turns out after all to be no paradox, no upsetting of previously ascertained laws of matter." With all due deference to Professor Smyth, I must submit that his proposed explanation leaves the matter as paradoxical as before,—for he says, that the attraction of gravitation is not to be looked for in a downward direction—that is, he annihilates the downward tendency of gravity, and substitutes a horizontal motion for it. In his explanation, the Professor does not appear to have fully worked out his own very good rule of observing *everything*, otherwise he would have perceived that the attraction of gravitation *is* still to be looked for in a downward direction; but that it takes effect upon the point of support of the instrument, instead of acting as it would, were the wheel not spinning.

The report published of Mr. Elliot's discourse of the 9th April, 1855, shows that he then possessed a much greater knowledge of the subject of rotatory motions, than when he wrote the paper delivered the year before, and to which I referred at the commencement of this paper; but it does not appear from the report of his later discourse, that he corrected what was erroneous in his earlier paper, which I shall now proceed to discuss, premising that I admire, as much as any one, his exceedingly ingenious mechanical illustrations of some of the planetary motions; and that the following remarks refer solely to his explanation of the phenomena.*

As already mentioned, Mr. Elliot's explanation is peculiar to himself. He applies it, in the first instance, to the case of the peg top, the continued conical motion of which, without falling, when spinning in an inclined position, is precisely the same as the precessional motion of the earth and gyroscope. He says, that the fallacy of the popular idea that the top's not falling is due to centrifugal force, is well exposed by Dr. Arnott. Centrifugal force, however, as I have shown, has a great deal, —though not everything,—to do with the phenomena; but the popular idea refers the centrifugal force to the geometric axis of the top, whereas the centrifugal forces actually in operation have reference to another axis. Mr. Elliot next proceeds to show the insufficiency of Dr. Arnott's

* On reading this paper I was informed that the error of some of Mr. Elliot's explanations had been demonstrated when his paper was read at Glasgow. As, however, I have seen no published correction of his explanations, I have considered it useful to publish this portion of my paper entire as read.

own theory, according to which the top keeps up, and even rises to a vertical position in consequence of the frictional action of the rotating peg point on the table or floor. I can arrange my apparatus so as to act like a common peg top; and, in partial confirmation of Mr. Elliot, it shows the phenomenon without the peg point rotating at all.

In giving his own explanation, Mr. Elliot uses the diagrams which I copy in figs. 12 and 13, with some additions. The line C P, fig. 12, is the axis of the peg top; the ellipse A B is a perspective view of a ring, in which the mass of the top is supposed to be concentrated. The top being inclined, gravity tends to make it fall over and turn in a vertical plane round the point P. Mr. Elliot says, that every point in the lower half of the ring tends to fall, and every point in the other half to rise. This is incorrect, for all the points to the right of the vertical O P, tend to fall, and only the few points on the other side of that line to rise—whilst, if the top were a little more inclined, *every* point in it would tend to fall. What need is there to depart from the simple statement, applicable to any inclination of the top,—that every point in it tends to turn in the same direction round the point P? Mr. Elliot continues:—"But the point B, in beginning to fall, is, at the same time, carried forward from B to *b*, conveying the tendency to fall with it, so that the actual fall would take place at a point *b*, immediately in advance of the lowest; at the same time, the highest point A, beginning to rise, carries that rise forward to a point *a*, immediately in advance of the highest. Now, let us observe," he adds, "the effect which this has produced upon the top: the point *a* in advance of the highest is raised, and the point *b* in advance of the lowest is depressed; this change tilts the top over, if I may so express it, aside from its former inclination."

With all deference I must submit that this supposed tilting over in a direction at right angles to that in which gravity is soliciting the top, by no means follows from Mr. Elliot's premises. Observe, he does not say the particle at B *does not fall*, but that the actual fall takes place at a point *b*, in advance; that is, the fall must be measured from the position the particle would then have had by the rotation alone. The same effect would be produced as regards the point B if it were first turned about the axis C P, supposed fixed, and then moved through an angle round the point P, equal to, and in the direction of, the fall. Likewise, in the case of the opposite point A, the effect described rather vaguely by Mr. Elliot, would be obtained by turning that point about the axis C P, supposed fixed, and then moving it round the point P in the direction of the fall. Mr. Elliot gives no reason why the very same description should not apply to every other point of the top; and if it is correct, their positions, after a short interval of time, will all be an equal angular distance measured in the direction of the fall round the point P from the positions which the rotation alone would have given. In plain words, the top will have fallen through a certain distance; this result being the reverse of what Mr. Elliot tries to show. In proceeding with his explanation, he assumes that the particle at the lowest point B, is still the lowest point after it has moved to *b*. Could he prove this, he would certainly prove too much, for he would prove that one particular particle moves round in a horizontal plane, and is *always* the lowest point, under which circumstances the top would not rotate on its axis at all, but be merely moving in an inclined position round the vertical O P! Before assuming, however, that *b* is the new lowest point, it is necessary to prove that no other point is lower than it. This Mr. Elliot does not attempt to do, but proceeds to explain by means of his second diagram (fig. 13), how the actual rising or falling of the top depends on the velocity of rotation. The ellipse A B is the projection of the ring, in which the mass of the top is supposed to be concentrated, on a vertical plane touching its lowest point. The short verticals above the horizontal line D E, and extending from it to the ellipse, are intended to measure the heights through which the point at B would rise, during given intervals, by the rotation alone. The verticals below the horizontal line D E, extending to the parabolic curve F G, are intended to represent the heights through which the point B would fall in the same intervals by gravity alone. The pairs of verticals next the lowest point B, are all that are compared; and it is obvious that whilst the lower ones are always the same, the upper ones are longer or shorter according to the rotatory velocity of the ring. Mr. Elliot says if the rotatory velocity is such that the upper and lower verticals are equal, the top will not fall, because the forces represented by the pairs of verticals are opposite and equal; but this is only true of the ascending side. Thus the point B would not absolutely fall whilst on the ascending side of the ring; but if we consider a point behind it, and on the descending side, as at H, we find that the motions or forces represented by the verticals above and below the horizontal D E, have both the same direction; and, therefore, instead of opposing and neutralizing each other, as on the ascending side, they will be added together, and the point at H will move to a position below B; whereas, for the new point *b* in advance of the point B to be the new lowest point, the point at H should not have descended below B, nor even have reached as far! Nothing is gained by supposing half the ring to be concentrated in the point B, and the other half in the opposite point A; for if, when the point B is on the ascending side, gravity prevents it from ascending as far as it would otherwise have done, gravity will also make the point

A on the descending side descend farther than it would otherwise have done, and the centre of the line joining the two points will necessarily move to a lower position. Here, again, Mr. Elliot's method, if followed out, actually shows the reverse of what he would have it to do.

Mr. Elliot says that a top spinning in an inclined position will rise to a vertical position under certain circumstances, and he appears to consider the explanation which I have just discussed as superior to others, because it professes to explain this rising as well as the not falling. Now, I feel sure that a top can be made which will *not rise* in a vacuum when spinning under circumstances where friction of the point cannot make it rise. A top's rising under such circumstances (when not in a vacuum) is due to its action on the surrounding air. The case is very similar to that treated by Professor Magnus of Berlin, in a paper to be found in Taylor's *Scientific Memoirs* for 1853. In this paper the author, in discussing the cause of the deviation of projectiles, shows that if a body rotates, and has at the same time a motion of translation through the air, in a direction at right angles to its axis of rotation, it will experience a greater pressure of air on one side than on the other, in consequence of the opposition on that side of the rotatory and rectilinear or translatory currents, these currents being both in the same direction on the other side. Now, when a top spins in an inclined position, its axis moves on the surface of a cone round the vertical line passing through its point of support, and this conical motion corresponds to the motion of translation treated of by Professor Magnus. The side of the top farthest from the vertical line moves in the direction of the conical motion, so that on that side the rotatory current of air caused by the spinning motion is opposed to, and consequently increases the pressure resisting the conical motion, whilst, on the side nearest the vertical line, the rotatory current coincides in direction with, and reduces the pressure resisting the conical motion. A resultant pressure thus arises, which tends to lift the top into the vertical position.

Since the top is spinning, this uplifting pressure tends, by the composition of rotatory motions, to produce a backward conical motion, which cannot however take place in consequence of the forward conical motion which the top has already, and the effect of the air pressure is partly to reduce the forward conical motion, and partly to lift up the top. For the air pressure can only bear a small proportion to the pressure tending to make the top fall by gravity, and it can only reduce the forward conical motion in that small proportion; whilst, supposing the conical motion to be reduced to the full extent of that proportion, the causes producing the air pressure will still be in operation to an only slightly diminished extent, and the resulting pressure can have no other effect than that of making the top rise.*

According to this theory the top ought to rise with the greater rapidity as its rotatory speed decreases, as I find to be actually the case; because as the rotatory motion decreases, the conical motion, and with it the air pressure, increases. According to Mr. Elliot's theory, however, the lifting power decreases with the rotatory velocity.

In the case of the Bohnenberger gyroscope, the phenomena are very much modified by the action of the air, as in the case of the top, as well as in other ways; and also by the friction of the pivots. Thus when the weight is applied to the upper end of the inclined spindle, the air current produced by the rotation of the fly-wheel, and also the friction of the pivots, act on the rings in such a way as to tend to accelerate the precessional movement, and this has the effect of raising the weight. On the other hand, when the weight is applied to the lower end of the inclined spindle, the current of air, and the friction of the pivots act upon the rings in such a way as to tend to retard the precessional movement, and this has the effect of bringing the weight down. The great force acting in this way will be seen on the spindle becoming vertical. In the *first* case, the fly-wheel and its rings all spin round very rapidly in the direction of the precessional movement. In the *second* case, the fly-wheel and rings all spin round; but in the opposite direction to the precessional movement, and it is curious to observe the outer ring changing the direction of its motion, the moment the weight reaches its lowest position. To show this last experiment satisfactorily, the apparatus must be constructed with such accuracy that the ultimate spinning round of the outer ring gives no conical motion to the fly-wheel.

To return to Mr. Elliot's paper. Those who heard or have read it will remember that he applies precisely the same explanation to the stability of Saturn's rings as to that of the top. To fully expose the fallacy of the explanation of this particular phenomenon, would involve tedious repetition of what I have already said. Suffice it to say that Mr. Elliot attempts to show that a point of the ring which at one instant is the nearest to the centre of attraction, is still the nearest after a portion of a revolution has been made. Were this true, the

* The nutation of the earth's axis is probably caused in a somewhat similar way. One would at first expect that the change in the tilting force, caused by the change in position of the moon, would merely accelerate or retard the precessional motion without producing nutation; but, as in the case of the top, the two external forces interfere with each other. If the atmospheric pressure acted alternately on opposite sides of the top, a nutation of the top would result.

centre of the ring would move round the centre of attraction once for every revolution of the ring. In other words, the ring would revolve about the centre of attraction instead of about its own centre, and the centrifugal force would be least on the side nearest the centre of attraction, and greatest on the opposite side; and this would aid the attractive force in bringing the side of the ring nearer to the centre of attraction. Mr. Elliot says that the point of the ring nearest to the centre of attraction at one instant, will, after a portion of a revolution, be nearer to the centre than it would have been if not attracted to it; and he assumes that, in its second position, it is a new nearest point, without proving that a point following it is not nearer than it. It appears from Mr. Elliot's paper that he described or exhibited apparatus showing the motion of Saturn's ring on a small scale, the ring being represented by an iron ring, and the centre of attraction by a magnet. If, however, the construction of this apparatus is studied it will be found not by any means to exhibit the conditions of Saturn's ring. The apparatus is in fact a mere modification of the gyroscope or peg top, and it requires to be proved that Saturn's ring is really under similar conditions; but even if this were proved, the explanation which fails in the case of the peg top must also fail in that of the ring. In Mr. Elliot's apparatus the ring is placed upon a spinner which is supported upon a small pedestal. The lower part of the spinner reaches below the point of support, and is weighted to bring the centre of gravity of the spinner and ring into coincidence with the point of support, which is a short distance below the ring. The description does not say whether or not the ring is fixed to the spinner, but it does not much matter. The magnet is made to project downwards inside the ring, and when placed eccentrically of course attracts one side of the ring more than the other. If the ring is fixed to the spinner, the attraction of the magnet obviously tends to make the spinner turn about its point of support in a vertical plane, and this tendency combines with the original rotation to produce a modification of the precessional movement shown by the gyroscope. If the ring lies loosely on the top of the spinner, it will either tend to tilt over the spinner by its frictional adhesion, or if it slips on the top of the spinner, it will cause a preponderance of weight on one side, and in any case produce the same precessional movement. As in the gyroscope the ring would not be prevented from approaching the magnet were it not for the reaction on the point of support of the spinner, and unless something equivalent to that reaction, on the point of support in the model, can be shown to exist in the case of Saturn's ring, the latter cannot be considered as represented by the former. In the model the magnet tends to change the plane of motion of the ring, but in the case of Saturn's ring the centre of attraction is supposed to be in the plane of the ring, and must tend to move it in its plane. The attraction cannot tend to alter the plane of motion of the ring unless something exists to cause the ring to move about an external centre in the prolongation of its axis, as in the case of the model, and then it would move conically. Mr. Elliot admits that if Saturn's ring did not rotate, it would move in its own plane towards the centre of attraction. Supposing it solid and free to do this, Mr. Elliot's reasoning, if applied to the case of an unsupported disc rotating on a horizontal axis, would seem to prove that the action of gravity ought not to make the disc fall. Mr. Elliot says that Laplace omitted the rotation of the ring when calculating the attractive force upon it; but if the ring is solid and uniform, that rotation could not affect the result of the calculation in the slightest degree.

Mr. Elliot's remarks on the stability of Saturn's rings led me to consider the subject a little, but I have not been able to solve the problem. I cannot, however, conceive any way of accounting for their stability unless they are in a state of greater or less fluidity. If the rings are solid, their mere rotation cannot give them stability, and Laplace has demonstrated that they have no stability without the rotation. If they are fluid, however, the parts nearer the centre of attraction will move with increased velocity, and will have a greater centrifugal force than the more distant parts; whilst the latter, from their smaller velocity, will be accumulated in such a way that the section of the ring farthest from the centre of attraction will be greater than the opposite and nearest section; so that whilst the cohesion of the parts may prevent sufficient increase in the velocity and centrifugal force of the parts nearest the centre of attraction to prevent the ring from moving towards that centre, the preponderance of matter on the opposite side of the ring will cause the insufficient corrective force to be supplemented by the consequent increase of the attraction on the farthest side of the ring.*

December 16, 1857.—*The* PRESIDENT *in the Chair.*

The Hon. Andrew Galbraith, Lord Provost of the City, was admitted a member of the Society.

* I gave the above idea as a mere suggestion; it would require a difficult analytical calculation to determine whether the stability could be maintained in the way I have imagined. After my paper was read, I was informed that Professor Clerk Maxwell had solved the problem on the supposition that the rings consisted of perfectly independent particles. I have not, however, yet been able to see his solution.—E. H., *January*, 1858.

Mr. Alex. B. M'Gregor, Writer, was elected a member.

Mr. Robert Blackie moved that instead of the whole members of Council retiring every year, and eight of the number being re-eligible, only the four should retire whose names are at the bottom of the list, and be ineligible for one year.

The motion having been duly seconded, it was approved of unanimously by the first vote of the Society.

Mr. Bryce read a report "On the Recent Progress and Present State of the Sciences of Meteorology and Terrestrial Magnetism."

On the Recent Progress and Present State of the Sciences of Meteorology and Terrestrial Magnetism. Part I. By J. BRYCE, M.A., F.G.S.

GENERAL HISTORY.

(1.) THE last fifteen or twenty years have been distinguished above almost any period of the same duration, by the progress which scientific inquiry has made in almost every department. There has been a remarkable increase of knowledge among all classes; new sources of commercial enterprise have been opened up in all parts of the world; the facility of transit from place to place, and from country to country has been wonderfully increased; and there has thus been sent abroad, into every field, a multitude of observers, with whose active bands the inquirers of an earlier period can bear no comparison. Without stopping to point out the various causes which have led to this result, it will be sufficient to allude as bearing upon the subject now before us, to the efforts of the British Association, itself the product of aspirations and aims, which are among the very causes referred to. Dividing itself at length, after experience of several years, into sections which embraced all the departments of physical inquiry, this great body appointed men of the most eminent ability, specially conversant with particular branches, to prepare Reports upon the existing state of those branches, which, distinguishing the known from the unknown, the positive from the doubtful, should serve as a carefully measured base from which to advance, in fixing the doubtful and discovering the new. The path to be followed in this discovery was also indicated in many of the Reports to which we refer, and the particular line of inquiry most likely to prove fruitful of results suggested for the guidance of those who should attempt to consolidate the empire of science, or to enlarge its bounds.

(2.) In this recent advance, meteorology has so largely participated, that, as a science, it may almost be said to have originated within the period to which we now refer. Many of its phenomena, indeed, were matter of careful observation from the earliest times. In constant dependence on the earth's atmosphere, the scene in which the phenomena of meteorology are exhibited, in prosecuting those avocations on which life and health depend, man must have given himself to the observation of these phenomena so soon as he began to be "a keeper of sheep," and "a tiller of the ground," and "to eat bread in the sweat of his brow." In the Sacred Scriptures, and in ancient profane writers—as Hesiod's *Works and Days*, in Homer and Virgil, we have constant allusion to its real or supposed laws; and in Hesiod and Virgil many precepts for the guidance of the shepherd, the husbandman, and the mariner. Some such precepts indeed have been for ages established in all nations, and the phenomena connected with an agency emanating from the heavenly bodies; but most of them have no foundation in any scientific principle or careful induction of facts. Yet are they repeated from day to day by persons of intelligence among ourselves, and pass current as established laws. The opinion is still too common that meteorology has only for its object to record changes of weather, and enable us to construct weather almanacs; at least, the numerous registers which have been from time to time published, appear to have no higher aim. It seems never to have struck the observers that such loosely arranged collections of facts, made at stations fortuitously hit upon, would be useless for any purpose of science, or lead to any knowledge of great laws; while, on the other hand, it requires little scientific enlightenment to understand, that exact numerical results, obtained at stations well chosen, and collected for a series of years by means of instruments of a like construction, and carefully compared, would lead, when analyzed, to the discovery of general laws. Such great generalizations are always difficult, as we know from the history of every science,—those especially, like chemistry, physiology, and geology, in which the induction of facts leads to the discovery of laws. In the sciences to which mathematics is strictly applicable it is different. In astronomy, optics, and the various branches of mechanics, we have, in most cases, absolute certainty in the establishment of such laws; but in other sciences, how often has it happened that the generalizations of one age—or even decade of years—have been upset or largely modified by the more extended induction and wider range of experiment in the next age or decade. Now, meteorology deals with a subtile element—the gaseous envelope of our globe in its momentarily varying relations to the diffused moisture, to the all-pervading impalpable element of heat, and to that mysterious and powerful agent, the electric fluid. To estimate the mutual action of these, and to eliminate the effects due to each agent, must obviously require the closest observation, with instruments as perfect as possible, and having a correspondence in their indications of the various elements, established by a careful comparison with a standard instrument, and with one another. The data, or facts on which generalizations are to be built, have thus a manifest connection with the employment of accurate and correspondent instruments, and a wide spread association of observers.

(3.) It would be a mere waste of time to point out the vast importance of that simultaneity in the observations to which we have been referring, or to dwell on the selection of proper stations and accurate correspondent instruments. The great advance in meteorology, and the still greater anticipated progress which, there can be no doubt, the science will soon make, is entirely due to this and to the admirable contrivances by which photography has been applied to the *automatic registration* of phenomena during every moment of every day throughout the year. One of the greatest works which the British Association has accomplished is the establishment of a simultaneous system with improved instruments. This body was not the first, however, to organize such a system, so far at least as simultaneity and proper stations are concerned. The Meteorological Society of England, established in 1823, took the first step toward combined observations. In 1839 they published their first volume of papers. It is only within a few years, however, that they have encouraged, in every way, the use of approved instruments, and undertaken to supply such, with instructions to intending observers. They have now a great many stations over England, from which Reports are forwarded to Mr. James Glaisher of the Royal Observatory, whose important labours are well known. The complete accomplishment of the great work is due to the British Association, acting on the government through a standing committee of its leading men, and powerfully aided by a committee of the Royal Society. Important grants were obtained, and the hearty co-operation of enlightened official men at home, and in our widely extended colonial possessions. Observatories already in existence were improved and supplied with new means of observing, while a few additional observatories were set up for the special purposes pointed out by the Association. On their repeated earnest representation, the Antarctic Expedition under Captain, now Sir James Clark Ross, and Captain Crozier, was sent out in 1840–42 at the public expense; — the results of which may be set side by side with those of the most important and interesting voyages before undertaken by our nation, while the conduct of it has reflected the highest honour on the skill, courage, and indomitable energy and daring of the two commanders and their associates. Still more recently (in 1851) the Government was induced to grant the use of a disused inconvenient observatory in the old Richmond Deer Park, now called the Kew Observatory, to the Association. Here they conduct various scientific investigations bearing almost entirely on meteorology, and keep a set of standard instruments with which others sent there may be compared. They have supported it for several years by grants varying from £200 to £500 per annum, drawn entirely from their own funds. The working of this admirable institution, under the superintendence of Mr. Welsh, promises to be of the utmost service to the progress of meteorology. I spent a day at this observatory in July, 1856, and was beyond measure instructed and delighted by an inspection of the various arrangements and contrivances for making observations, and correcting and adjusting instruments. The Association has fostered it with the utmost care, with scarcely any aid from the Commissioners of Woods and Forests, who have charge of the park; indeed, a long correspondence was conducted, and much time lost before gas could be introduced, or a space of two acres be got enclosed with a wooden fence for the purposes of the observatory!

(4.) In 1852, Lieut. Maury, of the American Navy, and Dr. A. D. Bache, head of the Coast Survey of the United States, incited by the example of the British Association, induced the American Government to organize a system of combined observations in all ships both of the navy and mercantile marine. Lieut. Maury visited this country soon after; and on the invitation of his Government, seconded by our own, a conference was held at Brussels on the 23d August, 1853. Besides representatives from England and the United States, there attended those of France, Russia, Belgium, Holland, Denmark, Sweden, Norway, and Portugal. A plan of observations was agreed on, and recommended for all ships of friendly nations. In the year following, Prussia, Austria, Spain, Sardinia, the Pope, Hamburg and Bremen, Brazil, and Chili, offered their co-operation. In case of war between these powers, the treaty provides that the journal of the observations shall be held sacred on the capture of any vessel! May we not cherish the hope that such friendly co-operation in the pursuit of scientific objects will lessen the chances of war, bind these nations together with the bonds of a closer amity, and bring about those happy times,—

> "When each man's good shall be
> Each man's best rule, and universal peace
> Lie like a shaft of light across each land,
> And like a lane of beams across each sea."

Acted upon by the various influences above referred to, our Government, in 1854, created a new department, in connection with the Board of Trade, for the special purposes of meteorology. This has been placed under the charge of Captain Fitzroy, himself a distinguished navigator and man of science.

(5.) A main feature in this grand scheme is the perfect unity in the instrumental means and the objects of inquiry. After trial of the instruments constructed by various makers, Mr. Welsh of Kew selected those of Messrs. Negretti and Zambra, M. Casella & Co., Adie, Newman, and Barrow, as the best and cheapest. Some he constructs at the observatory. These are all compared with the standards, and carefully adjusted so as to give exactly similar indications. There have been thus verified each year for the last two or three years, about 3,000 thermometers, 250 barometers, and 1,300 hygrometers, for the United States, our own marine, and those of other nations. Kew, indeed, will soon be the great central observatory, whence the instruments of all nations will be sent forth. We may thus confidently reckon on obtaining, in a few years, an extensive series of really trustworthy results. The discussion and arrangement of the observations is to be effected partly in this country and partly under charge of the Smithsonian Institute at Washington—a noble institution, founded by an Englishman, the annual income of which by the bequest is about £6,500.* The observations already collected at our own Admiralty, and those which will in future be sent in, will all be discussed and arranged under Captain Fitzroy in the meteorological department of the Board of Trade. For the expense of this department, as well as for purchase of instruments, Parliament has for the last two years voted an annual sum.

(6.) Scotland has been long distinguished for her attention to meteorology, and in this important field her philosophers have reaped many honours. Sir David Brewster was the first, many years ago, to obtain an hourly series of observations running through several years, and to draw from them new and valuable deductions on the subject of atmospheric temperature and pressure, at varying heights, which later observers have but little modified. Sir John Leslie led the way in experimenting on the internal heat of the globe, and on the conducting power of its various strata, both in reference to the absorption of solar heat, and the transmission of the temperature proper to the interior; a subject afterwards taken up and largely extended, in a most philosophic spirit, by

* Mr. Smithson made the grant to the United States instead of this country out of pique, because a paper of his, read at the Royal Society, was refused a place in its *Transactions*. Mr. Smithson died in 1829, and the institution was founded in 1846, with the interest accrued. The handsome building is now completed, and contains large lecture rooms, museum, gallery of paintings and statuary, laboratory, &c., and the national collections are transferred to it from the Patent Office. Works on ethnology, antiquities, palæontology, &c., have been published by the Institute, and a serial work is in progress.

Professor James D. Forbes, his successor in the chair of natural philosophy at Edinburgh. But, not to follow the history of meteorology in Scotland in greater detail, I need only here mention, that during the meeting of the British Association in Glasgow in 1855, a meteorological society for Scotland was organized by the exertions of Mr. A. Keith Johnston, the distinguished geographer, and is now in healthy operation. It has many well chosen stations in different parts of the mainland and islands, where extended observations are carried on with instruments of a uniform construction. The results are forwarded to Dr. James Stark, the accomplished secretary, by whom they are discussed, arranged, and from time to time published at the Society's expense. Several members of our Society have joined the Scottish Meteorological, which is well deserving of the support of all who wish well to the cause of science in Scotland. The objects of this Society are somewhat wider than those of the London Society; they include all which could throw light on the climate of the island, and their observations at sea are already beginning to yield valuable fruit. After a visit last year to the Greenwich, Kew, and Oxford Observatories, and an interview with Mr. Glaisher, I was anxious that the Scottish Society should adopt the English instruments; and I urged this upon the council. Various objections, however, were made to them. The Secretary and the most experienced members prefer Scottish instruments; they consider them better, while certainly they are very much cheaper. By those who have used it, the registering barometer, invented by Mr. Thomas Stevenson, of the Northern Lights Board, is considered by far the best ever invented. Then, again, the registering thermometer of Negretti and Zambra, one of those adopted at Kew, is regarded by our Edinburgh friends as very defective; it is impossible, it seems, to know its index error, which varies with every change of temperature. A good barometer by the best Edinburgh makers, as Adie, Bryson, and others, can be had for £2 10s., while an English one, no better, cannot be had for less than £6 10s; a rain gauge costs £1; in London, £3 10s. The Lind gauge, too, is a great improvement on the English instrument, and no dearer. Some of the instruments they have adopted, and the above grounds are perhaps sufficient to justify the Society in departing from complete uniformity. Before sending out their instruments they are, of course, as at Kew, carefully adjusted and compared with the standards. In conjunction with Mr. Keith Johnston, I have earnestly urged on the Society to attempt the establishment of an *automatic registration* by means of photography. As yet, however, they have not seen their way to set such a system on foot; some doubt of its utility, while others are deterred by the expense which, in the first instance, it would certainly entail. A public subscription might, however, be got up; and perhaps the labours of the Society may soon so commend it to favour that the list of membership may be greatly enlarged, or the Board of Trade may be induced to aid the Society, for this as well as general purposes, by an annual grant.

Results.

(7.) Having given in the preceding brief and imperfect sketch, a history of the principal steps which have been taken within these few years to promote meteorology; and shortly alluded to the class of instruments in use, I must now call the attention of the Society to some of the results which have, under the favourable circumstances referred to, been already obtained. The difficulty here encountered is very great; the results are scattered through a multitude of journals, English, American, French, and German; the mere collecting and consulting of which alone imply a great amount of time and labour. Imperfections in the present Report, so far as these results are concerned, can be supplied on a future occasion, if health, and by favour of the Society, an opportunity be afforded to me. In the portion of the Report now submitted, I shall consider the subjects of Temperature, Rain and Clouds, and Terrestrial Magnetism, reserving the other branches of meteorology for a future occasion.

I.—*Temperature and Climate.*

(8.) The subject of atmospheric temperature, and the causes which produce our actual climates, have received considerable elucidation of late years. Much has been done in the various Arctic and Antarctic voyages, by travellers in various regions, especially among the high mountain ranges of Central Asia, and by balloon ascents conducted under the guidance of scientific men. The discussion of the multiplied observations of comparatively recent date, by Prof. Dové of Berlin, has led to a considerable modification of the maps of isothermal lines, formerly and first given by Humboldt. He has so extended the researches as to have produced a series of monthly isothermals for both hemispheres. Astronomy, also, has lent its aid in showing us that the sun himself, the great cause of atmospheric and terrestrial temperature, undergoes a periodicity in respect to the absolute quantity of heat radiated by it.—The extreme difficulty of arriving at laws capable of definite statement, or of being embraced in algebraic formulæ, will appear when we consider the constitution of our atmosphere, and the varied aspect of the basis or floor on which it rests. It consists of common air and aqueous vapour which have widely different relations to heat; both elastic and capable of sudden and immense dilatation; but one incapable of being condensed into a liquid by any degree yet known of cold or pressure; the other readily and by natural means reducible to a liquid. The mixture possesses the highest degree of mobility; so that a change of condition, originating in a particular tract, is propagated into portions widely remote, and masks the conditions there operating. Movements in the fluid mass of a most complicated kind are thus generated, which, though originating in the action of a known force, cannot be brought under the dominion of any calculus, or mathematical analysis. Indeed, such movements in elastic fluids are about the most difficult to grapple with, and bring into subjection to dynamic laws. The assumption that such laws and certain definite ratios existed, has led to many errors, now happily given up. Such are the so-called laws at one time attempted to be established for the dependence of temperature on latitude, and by a simple ratio on the altitude.—Then, further, the floor of the atmosphere varies everywhere; its seat on a fluid base, as that of the great ocean, must produce very different effects upon it through its whole mass, from those which would prevail if it were seated on a continental mass; and even continental masses of land vary in their physical conditions. Hence the vast difficulties attendant on the subject of atmospheric temperature, and the establishment of laws in this branch of meteorology.

(9.) Abstracting all consideration of the mixed aqueous vapour, it is clear that the atmosphere receives its heat in three ways, *first*, by direct radiation from the sun; *second*, by reflected rays of heat emanating from the heated ground; and *third*, by contact with the heated ground itself. Various recent experiments have been made on the direct heating power of a vertical sun. Sir J. Herschel found it, at the Cape of Good Hope, to be such as would melt ·00754 in. in thickness from a sheet of ice in 1^m, when the ice was exposed to it perpendicularly; or, which is the same thing, and perhaps more intelligible, $\frac{3}{4}$ in. in 1^h 40^m. Experiments at Paris have made it ·00703. The mean of the two, Sir J. Herschel thinks very near the truth, namely, ·007285 in. in 1^m, or ·7285 in 1^h 40^m. In a cloudy atmosphere nearly the whole is absorbed, going to heat the air or evaporate the clouds. With oblique sunshine the heating power would of course be much less; depending, in fact, upon the cosine of the obliquity, or zenith distance, of the ray,—the zenith distance being supposed under 80°. From several recent experiments, it has been concluded that about 33 per cent., or $\frac{1}{3}$ of a vertical sunbeam, is absorbed in its passage through a cloudless atmosphere, before reaching the sea level. This is expended in heating the air through its whole vertical extent, or in evaporating the clouds. As yet, I believe, we have no knowledge of any law, according to which, the density of, and power of transmitting heat by the air vary; and, hence, we cannot yet say in what ratio the absorbability varies as the rays penetrate deeper into the atmosphere. Neither do we know in what proportion the various rays are absorbable by the air. It is, however, well known that a given volume of dense air is more easily warmed than the same volume of rarer air—rarified air has, in fact, a greater specific heat; so that heat becomes latent by the process of rarefaction. Hence, the cold of the high regions of the atmosphere, and the explanation of the fact, that within the tropics perpetual snow lies all the year round, though exposed to the vertical rays of the sun. The air generally, but especially in the higher regions, has so great a degree of diathermancy, that the atmosphere derives almost all its heat from radiation, conduction, convection, and the conversion of vapours at various points throughout its extent into rain, snow, or hail. The observations bearing upon this point, made by Prof. C. Piazzi Smyth during his late residence on the Peak of Teneriffe, are very interesting and remarkable. On the 4th August, about noon, the black bulb thermometer, exposed to the direct rays of the sun, rose to 212°·4 F., the temperature of the air, in the shade, being then only 60°; so that the direct solar radiation exceeded the temperature by more than 150°! At $9\frac{1}{2}^{h}$ A.M., the direct solar radiation was 180°. So rapidly, indeed, does the direct radiation or heating power of the rays increase with the height, that the cochineal insect is killed by the heat at 3,000 ft., though thriving well and yielding a rich produce at Oratava, on the sea level, at the base of the Peak. The chemical power of the rays also increases greatly with the height, as shown by Saussure before photography was known. Prof. Smyth found the difference remarkable on his photographic pictures; they were more easily taken, and much more intense at great altitudes. The chemical rays are more dispersed and disturbed by the dense atmosphere below, than the luminous ones. He conjectures that at fifty miles up, usually regarded as the height of the atmosphere, the temperature of shade would be —50° F., while the effect of direct sunlight would be increased hundreds of degrees. The existence of perpetual snow, then, must be independent of radiation, and due to the temperature of the air and the non-conducting power of ice. The decrease of temperature with latitude is due to a different cause, namely, the sun's diminished altitude. The heating power of a beam which acts perpendicularly on a surface equal in area to a section of the beam, if acting obliquely is spread over a surface greater in the ratio of the sine of the obliquity to radius. The heating power on a *horizontal* surface is given, according to Sir John Herschel, by the expression ·01093 cos. z, where z is the zenith distance of the sun,—independently, of course, of the physical character of the surface. The heating power is thus greatly diminished at low altitudes of the sun. The changes of temperature have thus a certain general dependence on altitude, and on latitude; but no law of decrease has yet been established in either direction—the complex elements, indeed, seem to throw great obstacles in the way of our ever determining such a law,—we shall therefore state a few of the best ascertained facts, in order to give a general notion of the subject.

And, *first*, as regards the distribution of heat in latitude, the recent corrected isothermals of Dové show that the decrease is extremely different under different meridians; the decrease, as we advance from the equator, is least near this line, and becomes progressively greater to about lat. 45°; the temperature of the equator is 79°·8 F., but the warmest parallel does not coincide with the equator; it is that of about 10° N., and here May is the warmest month. At the equator the maxima temperatures fall in April and November, the minima in July and December. The mean temperature of the pole is 2°·2 F.; in summer (July), 3°·6; in winter (January), —26°·6. In July the equator is 48° warmer than the pole; in January, 106° warmer. From latitude 40° up to the pole, July is the warmest month; in latitude 30° August is the warmest; in latitude 20° the two are equal. From latitude 60° to the pole the temperature may be found with great exactness by the following empirical formula:—

$$t = + 3^\circ{\cdot}65 + 105{\cdot}75 \cos^2 x$$

x being the latitude, and t the mean temperature of the year in that latitude. . . . From the equator to latitude 40° S. the temperature of the southern hemisphere is lower than that of the northern. But Dové thinks that this may not be so in the higher latitudes. East of the meridian of Ferro the decrease of the temperature of January in going north is given, between lat. 0° and 30°, by the formula—

$$t = 32^\circ + 47^\circ{\cdot}5 \cos 2\,x,$$

and in the western hemisphere, between lat. 0° and 40°, by the formula—

$$t = 32^\circ + 48^\circ{\cdot}15 \cos (2\,x - 7^\circ);$$

for both hemispheres for north latitudes, both high and low,

$$t = - 23^\circ{\cdot}1 + 102{\cdot}4 \cos^2 x$$

and still nearer the truth for low latitudes—

$$t = - 22^\circ + 101{\cdot}25 \cos^2 x.$$

For the eastern half of the southern hemisphere, the formula

$$t = 20^\circ{\cdot}8 + 59^\circ \cos^2 (x - 5^\circ),$$

will do very well for January. To show how completely other causes modify those depending on latitude merely, we may mention, as striking facts, that the isothermal of 23° F. in April passes from latitude 52° in Canada across Labrador, up to latitude 75° or 80° in Greenland, bends E. to touch Spitzbergen in latitude 80°, and then descends steeply to the mouth of the White Sea in latitude 68°. In January we may pass from the Shetland Islands to the English Channel without changing the temperature; while, if we pass W. of this isothermal, we have a higher temperature, as in Cornwall and Ireland. The line of 32° F. passes from Philadelphia (latitude 40°) across Newfoundland, touches the S. of Iceland, and reaches the polar circle (latitude 66½°) on the meridian of Brussels; it then descends perpendicularly, and crosses central Europe to the Balkan mountains; thence it runs due E. to the east of China. These remarkable inflections point to the action of other causes than the sun's declination merely, and on the west of Europe are now universally ascribed to the Gulf Stream, that immense body of tepid water which passes to the coasts of France, Britain, and Norway, from the great heated and constantly overflowing caldron, the Mexican Gulf. Other ocean currents, the varying floor of the atmosphere, and the diffusion of vapour by the winds are also modifying causes. Some exceptional phenomena are yet waiting for explanation. The existence of a "polar basin," that is, an unfrozen sea about the pole, is strongly suspected. A party of Kane's expedition remained for thirty hours on lofty cliffs on the west coast of Greenland, in latitude 81½°, and looked down upon an open sea, with its waves "trooping tumultuously from the pole" under a N.E. breeze, and yet no drift ice was to be seen. Farther south the cold was the most fearful ever encountered. The mercury froze at about —68° F., and when solid, indicated by its contraction still lower, but undetermined degrees of cold. What a grand object it would be to solve this great mystery, and reach the pole upon an open summer sea from the N.W. point of Greenland.*

The researches of Dové have led him to abandon the old notion of Brewster, Kaëmtz, Mahlmann, and Berghaus, that two poles of maximum cold existed in the northern hemisphere. He does not recognize their existence at all, and even goes so far as to say that "Brewster, by confounding the polar with the equatorial map-projection, was led to suppose that the isothermals of lowest temperature curved in separate branches round two such poles of maximum cold." In North America

* Dr. Rink of Greenland, in a paper lately laid before the Royal Geographical Society, endeavours to show that these observations of Kane's companions are not trustworthy, and doubts the existence of such open water as they have described.—(*April* 24, 1858.)

grain will scarcely ripen, except in sheltered spots, beyond latitude 50°; here the cold winds are from the N.W., and trees cease before latitude 60° is reached. In Asia the warm and moist currents brought up from the south over Central Asia by the floor or basis being extremely heated in summer, "cause an arboreal vegetation to flourish up to latitude 72° over ground perpetually frozen at the depth of a few feet." Here the cold winds are from the N.E.

(10.) It has been long the practice among physicists to assume, on the ground of loosely collected records of mountain ascents, that there is a direct simple ratio between height and temperature in the atmosphere as we ascend. Recent observations seem to show that all these are incorrect, but no simple ratio has yet been grasped. It would appear that Laplace's law, though not exact, gives a less error when compared with balloon ascents than any other,—namely, that there is a *uniform* fall of temperature when we ascend through heights increasing in an arithmetical series. The balloon ascents in 1852 at Kew, under Mr. Welsh's care, to heights of 19,510 feet, 19,100 feet, 12,640 feet, and 22,930 feet, were conducted with the greatest nicety as to instrumental contrivances. The temperatures were carefully observed in correspondence with the heights of the quicksilver in the barometer; but it was from these barometric indications that the height was determined, *according to Laplace's formula*, in which his hypothesis of a decrease in temperature is an element. Hence these temperatures, as observed by Mr. Welsh, are exposed to doubt; because, if Laplace's law is incorrect, the heights are incorrect. The perfection of observation of course would be that the heights of the balloons should be determined by *trigonometry*, not by the *barometer*; then we should have the observed temperatures freed from every source of error, and perhaps some new exact law of decrease might be deduced. It is not easy to see, however, in what way this is to be attained. In the balloon ascents of Mr. Welsh, strata of cloud were frequently passed through; the temperature, before decreasing, then rose; after passing some distance above the clouds the decrease was resumed, but the *rate* of decrease was greater *below* the stratum than above it. The disturbing causes of this character being allowed for, Mr. Welsh considers that the observations countenance no other hypothesis of decrease than that "this decrement is uniform with the height." The average of all the ascents gives a rate of 1° F. for 386 feet. The fall in ascending *along the surface*, as up a mountain side, is much more rapid (see Article 14). In some of the ascents, clouds, in the form of a cirrous haze, were seen far above the highest points reached. Half of the whole atmosphere is passed through when the altitude of 18,500 feet is reached; and air collected at the greatest heights in no way varied in its proportion of oxygen and nitrogen from its state at the surface; it did not vary in composition in the four ascents more than if collected at various points on the surface. The lowest observed temperature was about 11° F. below zero. Reasoning from these observations it may be concluded, according to Sir John Herschel, that at the top of the atmosphere over the equator, the temperature may be taken at —$77\frac{1}{2}$°, and over the pole at —$119\frac{1}{2}$°, supposing the surface temperatures to be respectively 82° F., and 0° F.

(11.) With regard to the temperature of the celestial spaces, I am not able to find that anything has been recently added to what has been left us by Fourier, except some late speculations of Mr. Hopkins of Cambridge. Fourier placed the temperature of space somewhere about —60° F., but has, I believe, left no memorandum of the reasoning by which he was led to this conclusion. We know that the earth has either a fluid nucleus, or concentric fluid layers at an inconsiderable depth; that of about 10,000 feet, or two miles, would give us the temperature of boiling water; the increase downward would soon become so great, that at a depth of twenty-four miles, we should meet with a temperature equal that at which iron melts, or 2,786° F.—a heat sufficient to fuse all known substances. Below this there may be a solid nucleus; the melted matter being arranged in concentric spheroidal layers.* Upon any hypothesis we may adopt, conduction and dissipation must be going on; but the passage of heat is so slow through stoney substances that the internal heat now annually dissipated is thought not greater than $\frac{1}{17}$th of 1° F., or such as would in one year melt $\frac{1}{40}$th of an inch of ice. The earth has arrived at this stationary condition. This heat is dissipated in space, and the radiation of the solar heat received is also constantly going on, but at what rate we are without exact data to fix. The stars and planets may also radiate heat into the planetary spaces, which may, by the combined causes, have some proper temperature of their own. In a late paper read to the Cambridge Philosophical Society, of which I have seen an abstract only, Mr. Hopkins, by a process of reasoning into which I cannot now enter, attempts to show that a minimum temperature exists within the earth's

* Such is the estimate hitherto formed. A different one, however, has been very recently made by Mr. Hopkins. From reasonings founded upon the results of the "Experimental Researches on the Conductive Powers of Various Substances," undertaken by request, and at the expense of, the British Association, he draws the conclusion that the rate of increase of temperature downwards has been taken too great, and that the solid crust is not so thin as geologists have hitherto supposed.—(Abstract of Paper read to Royal Society, in *Philosophical Magazine*, April, 1858).

atmosphere, but at a great altitude; and that just on the limit of the atmosphere the temperature will be intermediate between this minimum and that of planetary space, which he would make higher than either, the thermometer being of course supposed to be placed in shelter of all solar radiation, but open to every other influence. The paper is a speculation upon the degrees of heat which may exist on the surfaces of the planets; and the matter now referred to is introduced somewhat incidentally. He does not attempt to fix any temperature for the celestial spaces.

(12.) The sun, it is now considered highly probable, may act as an agent in meteorological phenomena in another way than by the direct radiation before described. There seems to be a periodicity in its emission of heat, in connection with the number of spots at any time visible on the disc. The year 1856 has been remarkable for an almost total absence of spots; a like phenomenon was noticed about eleven years ago; and, in fact, from continued observations, it would seem that the spots recur in the same order and magnitude in ten or eleven years, giving about nine periods to a century—that is, from the *minimum* display to the *minimum* again is ten or eleven years. The spots are now universally agreed to be owing to vast openings in the luminous envelope, which display dark clouds within, or the opaque substance of a solid globe. This theory was first proposed by Dr. Alexander Wilson of the Glasgow Observatory and College in 1774, and adopted by Sir W. Herschel, without, however, any reference to the source whence it was derived. The paper appeared in the *Philosophical Transactions*, and must have been known to Sir William. We do not know that his son has anywhere acknowledged Dr. Wilson, or explained the omission of his father in adopting the hypothesis without mentioning Dr. Wilson's name. Most probably he took it for granted that all interested in the subject would know the source; and it seems to have been his constant practice in all his papers to refrain from allusions to the past history of the inquiries, and to record merely his own observations, leaving it to others afterwards to weave the whole into a connected history. Arago, in his late work, has done ample justice to Dr. Wilson, and imputes no blame to either Herschel. Solar spots have been observed many times larger than the whole surface of the earth, some even as great as one-tenth the sun's diameter. The least that could be seen by our existing instruments, must have a diameter of 461 miles, and an area of 167,000 square miles. It is obvious, therefore, that a great development of spots may considerably diminish the amount of heat emitted by the photosphere of the sun. Respecting the *mechanical value* of sunlight, according to the principles of the dynamical theory of heat lately developed by Joule, Professor W. Thomson remarks,—"Some idea of the actual amount of mechanical energy of the luminiferous motions and forces within our own atmosphere may be given by stating that the mechanical value of a cubic mile of sunlight is 12,050 foot pounds, equivalent to the work of one horse power for the third of a minute."—(On the Density of the Luminiferous Medium, *Transactions of the Royal Society of Edinburgh*, vol. xxi., Part I). We shall again recur to the solar influence when speaking of terrestrial magnetism.

(13.) Some very curious facts regarding atmospheric temperature have been made known to us within a few years by scientific travellers, among whom two townsmen of our own are distinguished—Dr. Joseph D. Hooker, and Dr. Thomas Thomson. These relate chiefly to the situation of the snow line in Central Asia, and show us how dependent the elevation of this line is upon other causes than latitude merely. While the mean level of the snow line on the equator in S. America is from 15,200 to 15,800 feet, it rises on the inner ranges of the Tibetan mountains, about lat. 28° to 30°, and on the Karakorum mountains, lat. 33° to 35°, to about 20,000 feet! In the outer ranges of the Himalaya about Sikim, the level ranges from 13,000 to 18,000 feet, the mean being about 16,000 feet. In the same latitude in Spain, the snow line is 9,500 feet. The mean at lat. 0° being thus 15,500 feet, and at lat. 28° 16,000 feet, or 500 feet higher, the remarkable difference has no relation to latitude. The cause no doubt is the greater heating of the atmosphere from the larger extent of land in the latitude of Sikim, while in South America the land is narrower, covered with moist forests, and the Andes press close on the vast body of waters in the Pacific Ocean. In Bhotan, on the southern Himalaya, towards the head of the Bay of Bengal, where the mountains are open to the influence of the moist currents of the monsoon, and are protected from direct solar radiation by the fogs and mists thus generated, the snow line sinks to 13,000 feet. As we advance northwards, the line rises uniformly, reaching, as already stated, 20,000 feet. This remarkable anomaly arises from the small supply of moisture, the lofty spurs of the chain towards the Indian plains intercepting the greater part of it, by the clearer sky permitting a more fervid radiation, by the great amount of heat reflected from the bare arid plains, and by the dry winds sweeping over these elevated tracts, under whose influence snow and ice evaporate without melting. Facts of exactly the same significancy have been made known to us regarding Norway by Professor James D. Forbes. Here, in lat. 60°, the snow line is at 4,450 feet near the coast; inland it rises 1,000 feet, or to 5,500;

at lat. 66°, the respective elevations are 3,250 and 3,700 feet; and at lat. 70°, 2,900 and 3,350 feet. Here, as in the Himalaya, the rainfall decreases rapidly inland, the quantity deposited and the consequent prevalence of a cloudy state of the atmosphere having, in both cases, a manifest relation to the depression of the line of perpetual congelation. In Scandinavia the climate towards the coast has the insular type; that of Bergen is equable and damp: the heads of the larger fiords have less rain and a higher mean temperature; while the climate of the interior from Christiania northwards tends to approach the excessive or continental character. How influential are other causes besides distance from the equator, is strikingly shown by the circumstances of South Georgia, South Shetland, and Cockburn island in the southern hemisphere. These, though in a latitude varying from that of the mouth of the Tees to that of the Orkneys, are clad in snow to the sea level during most of the year; and produce among them but two herbaceous plants and one grass; the rest of the vegetation being of mosses and lichens.

(14.) The only observations that we know of as yet recorded regarding the temperatures on high mountains in these kingdoms, are those made within the last few years, by the late lamented Mr. Miller of Whitehaven. The minima given in a former memoir by this author (*Philosophical Transactions*, 1852), are stated in a paper in the Edinburgh *Transactions* for 1853–54, to have been found quite erroneous, owing to a change in the instruments, not discovered at the time. The mean difference between the absolute minima at Seathwaite, and the top of Scafell Pike, varies from 12°·7 to 13°·8 in a difference of altitude of 2,798 feet. The average fall of temperature, as we ascend *on the surface*, may be taken here at about 1° in 215 feet. The details will be found in the latter paper. The instruments were placed upon Scafell Pike, the highest mountain in England, elevation 3,166 feet; and the monthly minima are as follows:—For the year 1853 in order, 10°, 8°, 11°, 11°, 20°, 35°, 37°, 35°, 29°, 27°, 23°, 12°. In the Seathwaite valley, adjoining on the N.E., at a station 368 feet above the sea level, the minima of the several months, in order, were as follows:—27°, 20°, 22°, 33°, 36°, 47°, 50°, 45°, 42°·5, 35°, 31°, 19°. The winter mean at Whitehaven, deduced from a long series of observations, by Mr. Miller, is 44°·7 F. These temperatures are in no way remarkable; much greater degrees of cold having been experienced in Lancashire, Yorkshire, the Midland Counties, and at London, during the months of December and January, than on these mountains. While Seathwaite shows but 19° and 18° F., the minima in the other places just named, ranged from 10° to —4° F. In fact these mountain valleys, and even mountain tops have a comparatively mild and equable climate. The high minima on Scafell and the other mountains is, however, in great part due to the thermometers being covered with snow in the coldest months. They show a minimum of only 8° to 10° F.; while, there can be no doubt, that *in the air*, a temperature considerably below zero would have been indicated.

(15.) The temperatures of a great many stations in India, are given in a long and elaborate paper by Col. Sykes, in the *Philosophical Transactions* for 1850, to which we can only now allude. Reference will again be made to it under the head of "Atmospheric Pressure."

(16.) From a comparison of registers, kept for more than thirty years at Berlin, with others in various places, Mäedler concluded that a general depression of temperature took place over the whole globe, on the 11th, 12th, and 13th of May. To this view a discussion of the Toronto observations lends no countenance; and Major-General Sabine considers that, as a general law, the theory is by no means established, though true as regards Berlin. From the same discussion, it appears that the summers in N. America have not a greater degree of warmth than is due to the latitude; but that the winters are much below the mean temperature due to it. The mean is, in fact, for this season, about 7° F. below the normal temperature of the latitude. At Toronto, it is even more than this; the *thermic anomaly*,—that is, the difference between the temperature actually experienced and that due to the latitude being there 11° F. The mean annual range, or the difference between the hottest and the coldest months (July and February), is 42°·7. The hottest day is the 28th July; the coldest the 14th of February; and the mean temperature, 44°·23, is passed through on the 19th of April and 15th of October. A paper on the climate of North America, containing some new and very remarkable views, will be found in the Report of the Glasgow meeting of the British Association. The discussion of the Toronto temperature observations is given at length in the *Philosophical Transactions* for 1853, Part I.

(17.) Much attention has been given of late to the important subject of a change in the zero point of thermometers. Such a change has an obvious connection with the trustworthy character of instruments long in use, or exposed to new conditions, and is thus worthy of the closest attention. It is suspected that such a change may have taken place in the earth thermometers at the Edinburgh Observatory; and the subject is now engaging the earnest attention of Prof. C. Piazzi Smyth. Mr. Welsh of the Kew Observatory has also investigated the subject, and has recently put forth some important views in a paper, of which an abstract is contained in the Report of the Hull meeting of the British Association, 1853. An important mathematical paper, by Mr.

J. J. Waterston, bearing on the same subject, will be found in the *Philosophical Magazine* for March, 1858.

Clouds and Rain.

(18.) To this department of our subject some important additions have been made of late years. Meteorologists have long been divided in their views regarding the internal constitution of clouds, and the nature of fogs and vapour. These are all of the same integrant structure—that is, they consist of minute spherules, suspended at greater or less heights in the air. We call them fogs or mist, when resting on the surface of the earth; when raised aloft, and viewed *en masse*, we name them clouds. It is obvious, however, that there are differences in the state of aggregation, or the degree of closeness among the particles; and these different states of density may develop peculiar forces among the component molecules. Now, some hold that the spherules are hollow, and that the water serves only as an envelope, as in the case of a soap-bubble; others maintain that they are without internal cavity, and resemble globules of quicksilver. Kaëmtz inclines to the former view (*Meteorology Translated*, by Walker, p. 109, 1845). In his first report to the British Association (Vol. I. of Reports, 1833), Prof. J. D. Forbes does not directly consider this branch of the subject. In his second report (*Report of Tenth Meeting*, 1840), he merely alludes to it in a short paragraph, and seems to incline to the view that the component particles are vesicular (Note, p. 111). Professor Stevelly, of Belfast, who has long given special attention to this part of the subject, adopts the view that "the constituent particles are minute spherules, but not vesicles." He refers their suspension to two causes—"the extreme slowness of descent through the air of such exceedingly minute particles, and the repulsive action of the electrical atmospheres of these particles upon the ambient air (*Fourth Report British Association*, 1834). The idea of electrical atmospheres originated, we believe, with Mr. Henry Eeles, of Lismore, in Ireland, about the year 1750. His views on this and other collateral subjects were communicated to the Royal Society (*Philosophical Transactions*, 1752), and afterwards published in a small octavo volume, under the title of *Philosophical Essays*, Dublin, 1771. He supposed that the vapour ascended in vesicles, enveloped by such an atmosphere, but descended in drops, receiving accretions as they fell. This branch of meteorology is still involved in great obscurity—as well the internal structure, mutual dependence of the parts, and mode of suspension of clouds, as the entire subject of atmospheric electricity. There can hardly be a doubt that some such agency as Mr. Eeles suggested is actively at work in the production of rain and hail, especially the latter. It has been lately detected in many cases by Mr. Manuel J. Johnson, at the Oxford Observatory, by means of the admirable contrivances there adopted for *automatic* registration by photography. But these have been so recently established that we must await the result of more extended observations before attempting to generalize. Sir John Herschel has expressed his decided opinion (*Encyclopædia Britannica*, new edition, vol. xiv.), in opposition to most meteorologists, that lightning is a consequence and not a cause of sudden precipitation of large quantities of rain and hail. "The utmost amount of electrical agency which we can conceive influential in determining precipitation is the sudden relief of tension, that is density, on the discharge of a flash, which, aided by the vibration of the thunder-clap, may favour the coalescence of globules into drops, which otherwise would have been kept asunder by their mutual repulsion. As a chemical and magnetic agent, electricity is important; but it can only produce such atmospheric movements as are merely molecular." The negative electricity produced during rainfalls, Faraday has shown to be caused by the friction of water-drops against the substance rubbed. The same is found in the spray of waterfalls, even at several hundred feet distance. Respecting clouds, Mr. Drew, in his late excellent little work on *Practical Meteorology* (Van Voorst, 1855), thus writes—"We are told by some that they are vesicular vapour; this is simply a hypothesis; we can only affirm with certainty that they consist of particles of aqueous vapour in a peculiar state of aggregation, and that they float in the lower regions of the atmosphere. That electricity affects their state is pretty certain; but facts are wanting on which to found a theory as to its mode of operation."

(19.) In this state of uncertainty, the observations and experiments of Dr. A. Waller, of Kensington (*Philosophical Transactions*, 1847. Part I.), are a welcome gift to meteorologists. He appears to have succeeded in showing that vapour consists of globules or spherules, without any internal cavity; that the minutest component molecules are not vesicular, but water to the centre. He examined the globules by the microscope in various ways. The ova-bearing filaments of the spider's web, and the cocoon of the silkworm, were exposed to the steam of boiling water, which was condensed upon them. In fogs also the web, covered with globules, was removed, and fixed between small glass plates. Another method employed was to cover a slip of glass with a thin coating of Canada balsam, and to breathe on it. The moisture was found to remain for many hours in minute globules on the balsam, and also to sink into it below the surface. The forms were irregular—not perfect spheres. In both cases the globules coalesced, and formed larger ones, in exact proportion to the *solid* globules united. The diameters of the original globules were estimated at ·001 to ·003 of a millemètre, or ·000039 to ·000118 of an inch! Those condensed from boiling water were also irregular in form, and from ·02 to ·03 of a millemètre, or from ·000787 to ·001181 of an inch in diameter. When the glass slip, with its balsam coating, was laid upon grass covered with hoar frost, globules gradually formed on the surface. These were estimated at less than ·0001 of a millemètre, or ·000003937 or 4-millionths of an inch in diameter!! Water at 167° F. gave globules of the same size as those from the breath. A further proof of the non-vesicular character of the globules was their permanency when enclosed between the glass plates. Besides, globules of air or other gases were found to be very different from these; they were larger and darker. On one of them, from ·01 to ·02$^{mm.}$ in diameter, an extensive landscape of trees, houses, &c., was projected. Bright objects, viewed through the water globules of ·001 to ·003$^{mm.}$ in diameter, were surrounded by a halo, like those seen around the sun and moon.—But it is unnecessary to abstract this paper in greater detail. It is well worthy of a careful perusal by those who are interested in the subject, and will be found very curious and instructive. The views put forward do not lessen the difficulties attendant on an explanation of the cause of the suspension of clouds. But so little definite knowledge is possessed by us as yet on this subject, so far as I am aware, that I must content myself by a reference to the works already quoted for the prevalent notions. No change has been introduced into the nomenclature of clouds; that of Mr. Luke Howard, proposed in 1802, is still used by meteorologists. Many new and curious observations on the subject of clouds and ærial currents will be found scattered through the instructive and fascinating work already referred to, Prof. C. P. Smyth's *Residence Above the Clouds.*

A series of very ingenious experiments has recently been contrived by Mr. Jevons, of the Royal Mint at Sydney, N.S.W., to illustrate the mode of formation of the different varieties of cloud. By peculiar apparatus of his own devising, liquids of different specific gravities, specially adjusted, are mixed, one liquid being injected into the other. The effects produced exhibit to the eye a close resemblance to those observed in the atmosphere; and he uses these as proofs of a theory of the origin of clouds, differing in some respects from that generally received, and described in works on meteorology. The papers will be found in the *Philosophical Magazine* for July, 1857, and April, 1858.

(20.) Very little progress has been made of late years towards the construction of a theory of rain, founded on the true basis of a careful induction of facts. The observations of Professor Phillips, so admirably worked out theoretically, were a great step in this direction; but many more will be required, at various altitudes, and under different climates, before a general law can be deduced, expressing the decrease of the quantity of rain from the surface of the soil perpendicularly upwards. The views which he has developed are well known to meteorologists, and have met with general acceptance. An account of them will be found in the third, fourth, and fifth Reports of the British Association, also in Professor Forbes's second Report to the British Association, 1840, where they are spoken of with high approval. They were not put forward as complete, but merely as a partial solution of a most difficult problem, awaiting further and extended observations for its complete solution. In this state it still remains, receiving, however, occasional illustration from registers kept in various places.

(21.) While the quantity of rain is thus known to increase from moderate altitudes downwards—most probably from the drop gathering fresh vapour upon its surface, in consequence of its having a lower temperature than the vapour through which it successively passes in its descent, just as a decanter of cold water, brought into a warm room, becomes covered with dew—it must be borne in mind that the absolute quantity of rain which falls on high grounds is greater than that received on low surfaces towards the sea level. Hills attract and cool vapour, and cause a deposition of moisture, which might otherwise be borne away, or re-dissolved into steam on meeting with warmer currents. Hills near the sea have a much greater quantity on their south-west than on their north-east sides, and *that* in Asia as well as in Europe. The case of Norway and Sweden has been mentioned already. Towards the mouth of the Frith of Clyde, as at Greenock and Dunoon, and among the hills northward, as at Lochgoilhead and Arrochar, the rainfall is from fifty to sixty inches; at Glasgow and Paisley, no more than 35·27 inches. The lake mountains of Cumberland and Westmoreland, rising abruptly from the Irish Sea, towards which three principal valleys open out, have the greatest rainfall yet known in Great Britain, or perhaps in Europe. The latest results of Mr. Miller's long continued inquiries on this subject are given in the *Philosophical Transactions* for 1852, Part I. The wettest spot in the district is 100 yards south of the top of Styehead Pass, elevated 948 feet above the sea, and 580 feet above Seathwaite. In 1850 the rainfall at this spot was 189·5 inches. But 1848 was a wetter year; and if the ratio of increase in that year was the same at this spot where a gauge had not then been established as at the other stations, he reckons that the amount would have been 211·62 inches. At Seathwaite the amount varies from 144 to 161 inches in the different years, or 50·62 inches less than on the Styehead Pass, distant a mile and a-half. Passing from the sea level up the valleys above mentioned, the quantity of rain increases rapidly, and at the heads of the valleys augments immensely (*Philosophical Transactions*, 1849, Part II). Thus the quantity is one-fourth greater at the head of Eskdale than in the middle of the valley; at Ennerdale it is nearly double the amount at a farm house three miles west. As the heads of the valleys are reached, a few hundred yards make a remarkable difference. The amount goes on increasing up to 2,000 feet, and then begins to diminish, the air at this altitude being about saturation; getting colder upwards, it holds a less quantity of vapour in solution.

(22.) Not less remarkable are the prodigious quantities of rain which have been recently ascertained to fall in some parts of India, exposed to the full influence of the south-west Monsoon. The meteorology of India is fully considered by Colonel Sykes, in a long paper in the *Philosophical Transactions* for 1850, Part II. We have here only to consider the rainfall. The amount annually deposited on the West Ghauts, against which the warm winds, loaded with moisture, first impinge, is very great. The quantity which falls at Cape Comorin—a low point—is very slight; but a few miles north, where hills rise to 2,000 feet, it is 112 inches annually. Colonel Sykes considers that the chief rain-bearing current is seldom much higher than 2,000 feet; for, standing on heights greater than this, he has often seen the rain-clouds below; but, when driven by the west winds they strike against the steep wall-like barrier fronting in that direction, they rise to heights very much greater, and suddenly cooled by the lofty summits rising above the general level of the Range, deposit a prodigious quantity. The maximum fall yet recorded on the West Ghauts takes place at Uttray Mullay in Travancore, latitude 9°, where the amount was 263·21 inches, the mean of two years. At Mahabuleshwar, latitude 18°, the rainfall was 254·84 inches, the mean of fifteen years; and of this quantity 134·2 inches fell in the month of July alone. The mountains here attain an elevation of 4,500 to 4,700 feet, 2,300 higher than the Deccan plateau inside the Range. At places where valleys, or rather gullies, opening from the low tract seaward, cut the Range deeply, the quantity is much less, because the rain-clouds escape eastward across the Deccan, and deposit their load of moisture gradually. The maximum fall he places at about 4,500 feet; the quantity above and below this plane being less. Thus at different elevations on the Travancore Range, the quantities are as follows:—At 500 feet, base of Range, 99 inches; at 2,200 feet, 170 inches; at 4,500 feet, 250 inches; at 6,200 feet, 194 inches. The fall at Bombay is 76·08 inches, the mean of thirty years; and at other stations on the coast near the sea level, ranges from this amount to 82 inches; at heights varying from 150 to 900 feet, the fall varies from 115 to 135 inches; at 1,740 feet on the Kundalla Pass, leading from Bombay to Poonah, 142 inches; and on the highest points, ranging from 6,000 to 8,640 feet, the highest of the West Ghauts, the quantity deposited varies from 82 to 101 inches; the maximum being always about 4,500 feet. We have already alluded (Art. 10, 14) to the different conditions under which the air is placed as regards temperature and humidity, when in contact with a mountain slope, from those which prevail within its mass, when we ascend vertically over any space removed from such disturbing influences. The balloon ascents also illustrate this difference. In open situations above the level surface of the ground, the law of Professor Phillips, stated in Article 20, is said to hold good for altitudes in India not passing a few hundred feet.

Great as is the rainfall here recorded, a still more remarkable case remains,—that, namely, of the Khasia Mountains at the head of the Bay of Bengal, between Assam and Burmah. We learn from Dr. J. D. Hooker that the south fronts of these hills, which attain a maximum elevation of 6,662 feet, with a general level of 4,000 to 5,000, arrest the cloud-bearing current brought up by the Monsoon from the Bay of Bengal, and cause a deposition of the moisture along their cool fronts to the enormous amount of 540 inches, and sometimes 610 inches in the year,—a quantity which, if not evaporated from day to day, absorbed, or run off, would cover the surface to the depth of fifty feet. A portion of the cloud-bearing current, however, passes over these hills, and is caught by the higher ranges of the Bhotan Himalaya, which, while arid and treeless below 6,000 feet, above that level are well watered, and nourish a luxuriant vegetation (see Art. 13.)

Reserving the remaining portions of Meteorology proper, as Pressure of the Air, Radiation, Meteors, &c., for a second Report, we shall pass on now to the collateral subject of Terrestrial Magnetism.

TERRESTRIAL MAGNETISM.

(23.) The various branches of physical science have so close a connection with one another, that it is difficult to adopt a classification of them which shall be quite satisfactory. To explain the phenomena of one branch, the laws of another must constantly be referred to. This is especially true of Meteorology, whose multiplied objects and many complex problems ally it to geography, astronomy, chemistry, optics, and pure physics, and require the aid of the higher mathematical analysis. As referring to the great physical agencies at work in the earth's atmosphere, or operating through this medium, Terrestrial Magnetism may in this view be regarded as a branch of Meteorology. It is certainly not an inapt classification to regard it as such, in the state to which the science has now arrived. Without entering fully into the subject here, we shall merely set forth a few of the more striking results lately established; a full detail is impossible, as perhaps no other branch of this great subject has made so much progress, been so systematically and ably pursued, or called forth an equal refinement and skill in the construction of instruments and methods of observing. The credit is mainly due to the Norwegian Parliament and the British Association—the latter at length liberally aided by her Majesty's Government. The chief actors in this great undertaking were Hansteen of Christiania and Major-General Sabine of the Royal Artillery. The mathematical theory has been most ably developed by M. Gauss of Göttingen and our distinguished president, Professor W. Thomson—the latter, in a series of papers read before the Royal Society, beginning in 1851. We believe that the first suggestion of combined and continuous observations on certain days, previously fixed, is due to Baron Humboldt, whose appeal to the Royal Society on the subject led to the adoption, on the part of our Government, of those extensive inquiries which Major-General Sabine has conducted to so successful an issue. For the investigation of certain formulæ, necessary to the right conduct of the inquiries, he acknowledges his obligations to Mr. Archibald Smith of Jordanhill. The most important instruments by which the inquiries have been conducted are due to the ingenuity of M. Gauss, and Professor H. Lloyd, of Trinity College, Dublin.—Other Governments lent a willing assistance, especially that of Russia, whose vast territories are celebrated for the most striking displays of magnetic phenomena.

(24.) The King of Sweden, in 1829, requested a grant of money from the Norwegian Storthing to build a new palace at Christiania; the parliament resolved that the king could wait, and granted a sum of the same amount to send Hansteen to Siberia, to determine the position of the eastern magnetic pole, and for collateral magnetical objects. The western magnetic pole had been already fixed by Commander Ross, now Sir James Clark Ross, off the north-west of America. The celebrated voyage which Ross made to the antarctic regions, in 1840-2, already referred to, was undertaken at the public expense, on the representation of the British Association. Observatories were also established at Hobart town, the Cape, St. Helena, and Toronto—critical stations pointed out by our men of science. Officers on foreign stations or on voyages in various seas, were instructed how and what to observe. The magnetic elements and their changes were the chief subjects of research, coupled, of course, with those of temperature and pressure. General Sabine discussed, arranged, and published the results.

It is now pretty clearly ascertained that there are four magnetic poles, that is, four points on the earth's surface, where the dipping needle stands in a vertical position, and which (for distinction's sake), we may call poles of verticity. The west pole was fixed in Boothia Felix, in lat. 70° 5′ 17″ N., long. 96° 45′ 48″ W. Another pole lies in the north of Siberia, in lat. 82° 3′, long. 114° 33′ E. In the southern hemisphere the poles of verticity have been placed, by the researches of Ross, in lat. 68° 51′, long. 131° 33′ E.; and south of the American continent nearer the pole of the earth, namely, in lat. 76° 7′, long. 143° 34′ W. The latter he was unable exactly to reach, on account of the magnificent barrier of ice, which presented lofty cliffs seaward, in front of Victoria Land, through a distance, nearly east and west, of 1,000 miles. Most persons will remember the striking descriptions which Ross gives of this wondrous region—the ice covered land with its lofty volcanoes rivalling Mont Blanc in altitude, and its high icy cliffs presenting a crystal barrier to the roll of the antarctic waves. Here, amid volcanoes and glaciers, lies unapproachable the western magnetic pole of the southern hemisphere.

(25.) Besides these poles of verticity in both hemispheres, there are also poles of *maximum intensity*, distinct, and considerably removed from the poles of verticity. The intensity of the force is estimated in the same way as that of the force of gravity in different latitudes, by means of the oscillations of a pendulum—a freely suspended needle is withdrawn from the meridian, and oscillates a certain number of times in resuming its original position. This being done at different points, the intensities at those points are in the ratio of the squares of the numbers of oscillations. Thus, if at two points the number of oscillations are 24 and 25, the intensities at those points are as 576 : 625, or 1·000 : 1·085. These intensities have been estimated with great care in so many parts of the globe, that lines can be laid down upon a map connecting them. These are the isodynamic lines, or lines of equal intensity. They form at first regular ellipses around the poles of intensity, and change into various forms, chiefly looped curves, like the figure *eight*. The position of these "intensity poles" has been accurately determined within the last four years for the northern hemisphere; the western most recently. It is situated near the south-west corner of Hudson's Bay, in lat. 52° 19′, long. 92° W. Here, and at Toronto, the inclination is about $75\frac{1}{4}$°. Another pole of less intensity is in Siberia, about long. 120° E. The total force has clearly two components—that which produces declination, or variation east and west, and that producing dip, or inclination. The inclination is properly the angular amount of dip. Now these have been separated, and estimated as the *horizontal* and *vertical* components of the force. An admirable contrivance for the purpose is due to the ingenuity of Dr. H. Lloyd of Dublin. The total force is estimated in numbers, the unit being 1 grain in weight, 1″ in time, and 1 foot in space; or the force is such as in 1″ would generate in 1 grain a velocity of 1 foot—just as the force of gravity is $32\frac{1}{6}$, though in the first second $16\frac{1}{12}$ feet is the space passed over. Estimated thus, the force at the point of maximum intensity in Canada is 14·21; at Toronto, 13·896; at Greenwich, 10·388. In the southern hemisphere, it is 15·600—the point of maximum intensity there best ascertained being about lat. 60° S., long. 135° E. Another intensity pole is in lat. 20° S., lon. 36° W. These four foci or intensity points are constantly changing their positions—the two northern shifting eastwards, and the two southern westwards; the weaker, or eastern pole, in Eastern Siberia, moving much faster than the stronger or western, in Canada; so that they are approaching one another in a line, crossing from Siberia, through Russian America, towards the south of Hudson's Bay. In this intermediate space the total force is increasing.—To other determinations and results I cannot now allude, and shall further only state a few facts, very recently ascertained, bearing closely on the theory of terrestrial magnetism, and tending to withdraw the science from the category of terrestrial agencies, and to place it in the class of the "great cosmical phenomena."

(26.) A horizontal magnet has variation with the hours of the day, so that, running through several changes in the advance of the hours, from sunrise to sunrise, it returns to its former position at the expiry of the time, to begin a new set of variations. It attains its maximum when the sun is 2^h past the meridian of the place of observation,—say anywhere in Europe.—With us this would be 2^h p.m.; but at Constantinople it would be 4 p.m. of our time; and at the Azores 10^h a.m. of our time. This change, then, is clearly dependent on the sun's passage of the *meridian of the observer*. Now, *this diurnal* variation is not the same at all times of the year,—it runs through a series of changes, the period of which is one year; so that the *diurnal* variation has an *annual* period; the same condition of things being again established on the expiry of the year, and coming round again the next year in like order. But the variations are not the same in *each* of the *half-years* forming the *annual* period. They differ with the lapse of the two semi-annual periods from April to September, and from October to March. These changes, however, have no relation to summer and winter, or to the seasons of the year; for they correspond most remarkably at the three stations of Toronto, St. Helena, and Hobart town, the former having summer while the latter has winter; and St. Helena scarcely any distinction at all. The epoch of change at all the stations, from one class of phenomena to the other, is the sun's passage across the equinoctial. This clearly points to an effect of the sun upon the magnetism of *the earth* AS A MASS. It has been found, too, that the changes of variation in the two half-yearly periods almost coincide with the day of the equinox; but it requires some time to complete the change, and bring round a marked difference in the variations. Gen. Sabine states that this may be compared to the change in the induced magnetism of a ship, by a change in geographical position; it is not accomplished at once. The greater proximity of the sun in December than in June, has also been shown to produce an effect on the intensity of the force; but by no more than ·002 of the whole. This also is the same at all the stations—clearly pointing to solar influence on the whole earth. Now, it is remarkable, as showing how erroneous were our former ideas, in regarding these variations as due to terrestrial *temperature*, that M. Dové has proved that, at this very period, namely, in the months between October and February, when the *inclination* and *total* force are *greatest*, and the sun *nearest* us, the aggregate temperature of the whole earth is *less* than at the opposite season—a diminished temperature clearly due to the smaller quantity of land in the southern hemisphere. This most emphatically points to great *cosmical* influences, quite beyond the earth and its atmosphere, and indicates the sun as a vast magnet. But conclusions still more interesting and remarkable, regarding a connection with, and dependence upon the sun have been established. I have already referred to the solar spots, and their periods of abundance and paucity—in these, also, we now detect a relation to magnetic disturbance. When the spots are at a minimum state of exhibition, only 30 or 40 appear in a year; but when at a maximum state, 300 or 400. The period from minimum to minimum is ten or eleven years. Now, it has been found that unusual magnetic disturbances or *storms*, as they are called, coincide with the period of abundant spots, and that these storms run through a decennial period, or recur, after ten years, of similar character and intensity. The year 1843 was a year of minimum in the spots; 1848, a year of maximum. From the former to the latter, the magnetic disturbances increased in frequency and aggregate values; the aggregate in 1848 being three times greater than in 1843. The relation being thus suspected, calculations for previous dates of maximum and minimum among the spots, and of magnetic disturbances, were entered into, and the results have shown that, so far back as the accurate system of observations has gone (about twenty-six years), the correspondence is truly remarkable. To put this striking connection almost beyond a doubt, Gen. Sabine found that the *mean* diurnal variation exhibited a change in different years, and had a maximum and minimum correspondence with the solar spots; and that 1843 and 1848 were two such periods. On calculating backwards for previous epochs of the spots, there was found an exact correspondence.

The moon, also, has been recognized, first by M. Kreil, director of the Austrian observatories, and since by Gen. Sabine, as slightly influencing the variations of the magnetic elements; but here there is no trace whatever of a decennial period.

These late results are extremely striking, and open up to us new views regarding the great cosmical phenomena, as well those relating to the earth and its magnetism, as to the constitution and action of the great photosphere of the sun himself.—They seem to point to vast secular changes in the magnetism of the sun; and, in connection with the highly probable existence of a magnetic medium, pervading all space, suggest new relations among the imponderable agents,—heat, light, electricity, and magnetism, which play so important a part in the economy of the universe.

January 13, 1858.—*The* President *in the Chair.*

Mr. William Gilmour was elected a member.

Mr. Thomas Nicolson, Writer, 20 Buchanan Street, was proposed as a member by Mr. James Young, Mr. John Ure, and Mr. Keddie.

Mr. Edmund Hunt gave further illustrations of his paper "On certain Phenomena connected with Rotatory Motion."

Professor William Thomson showed, by a series of experiments, the different conductivity of various samples of Copper Wire. The inquiry was suggested by circumstances which arose in connection with the construction of the Atlantic Telegraph Cable; and the results which have come out are very surprising, and such as no one had anticipated. The power of transmitting an electric current differed extremely in different specimens of wire, though these were manufactured in the same way and at the same establishment. Chemical analysis showed no difference in composition; and that the state of crystalline aggregation had no effect, was proved by the circumstance that stretching, twisting, or compression in no way affected the conductivity. The cause of the difference must be held as still entirely unexplained; yet so great is this diversity of conducting power, that the use of the best conducting wire in place of the worst, would make a difference in the cost of the Atlantic Cable of £100,000 sterling. The result has been, that now, in the actual construction of the Cable, a testing apparatus has been put up, and all those specimens of wire are rejected which do not come up to the standard maximum of conductivity. The Professor exhibited a similar apparatus, and illustrated his views by experiments with different samples of wire.

In the conversation which followed the reading of the paper, Dr. Francis Thomson and Mr. James Bryce suggested certain theoretical considerations towards an explanation of these singular phenomena; but the Professor seemed to have anticipated them, and did not appear to regard them as satisfactory. The cause, he held, was still involved in complete mystery, while the facts were undoubted, and of the utmost practical value.

Mr. James Young described a new method of constructing Submarine Tunnels.

January 27, 1858.—*The* PRESIDENT *in the Chair.*

Mr. Thomas Nicolson was elected a member.

Mr. Bryce, in absence of Mr. Keddie, exhibited a fragment of one of the turrets of the tower of Glencairn Parish Church, which had been struck by lightning, and showed that the siliceous particles of the sandstone had been fused in the course of the electric current.

Dr. Anderson, the Librarian, announced the presentation to the Library of the following Books, viz.:—

Transactions of the Historic Society of Lancashire and Cheshire, vol. ix., Session 1856-57.

Memoirs of the Literary and Philosophical Society of Manchester, vol. xiv.

Proceedings of the Literary and Philosophical Society of Liverpool, Session 1856-57.

Journal of the Royal Institution, Part VII., 1857.

Transactions of the Philosophical Institute of Victoria, vol. i., 1857; and Part I., vol. ii., *Laws of the Philosophical Institute of Victoria.*

Report of the Committee of Management of the Melbourne Mechanics' Institution and School of Arts, for the year 1856.

Proceedings of the Natural History Society of Dublin, Session 1856-57.

Dr. Thomas Anderson read a "Report on the recent Progress of our Knowledge of the Chemical Elements."

Report on the Recent Progress of our Knowledge of the Chemical Elements. By Dr. Thomas Anderson.

He commenced by observing that the progress of a science is rarely uniform in all its departments, but that now one portion and then another claims the special attention of its cultivators, and advances with more than ordinary rapidity. The truth of this statement is well illustrated by our knowledge of the chemical elements, a subject which within the last few years has been studied with remarkable activity, and has given a rich harvest of new and unexpected results. After the brilliant discoveries which marked the end of the last and beginning of the present century, among which it is scarcely necessary to refer to the isolation of the alkaline metals by Davy, and the discovery in France of iodine and bromine, a long period elapsed during which scarcely anything was added to our knowledge of the elements, and in fact the dearth of novelty was so great that the belief gained ground that this department of chemistry had been completely exhausted. The fallacy of this idea was demonstrated, and a new epoch of progress in this branch of science commenced by Mosander's discovery of Lantanium in the year 1839, a discovery of peculiar interest, because it indicated a method of inquiry by which great additions to the number of the elements have since been made.

In the year 1803, Berzelius and Hisinger discovered a metal to which they gave the name of Cerium, and which had remained without further examination until it was again investigated by Mosander, who found it to be really a mixture, as he at first believed, of two, but as he subsequently showed, in 1841, of three different metals. For one of these he retained the name of Cerium, and the other two he called Lantanium and Didymium. These substances had escaped the notice of Berzelius and Hisinger, because they operated on a very small scale, and as the metals, though unequivocally different, are very similar in many of their properties, it is easy to understand how they came to be overlooked. Of the metals themselves very little is yet known, but the oxides are readily distinguishable; thus, for instance, the oxide of cerium is yellow or buff, that of lantanium white, and that of didymium dark brown. Their separation is very difficult and depends mainly on the difference of their affinity for acids. The result of his investigation led Mosander in 1843 to examine the metal Yttrium, which was discovered by Gadolin in 1794, and it also proved to contain three different substances, which are now known by the names of Yttrium, Erbium, and Terbium; all derived from Ytterby, the name of the place where the mineral containing them is chiefly found. The separation is effected in a manner similar to that of the Cerium and Lantanium. Owing to the rarity of the minerals containing these substances, very little is yet known regarding their properties; indeed, the metals themselves have not yet been separated, and even their oxides have been most imperfectly examined.

Shortly afterwards, Svanberg was induced to examine Zirconia, being led to anticipate the possibility of different substances being found in the zircon of different localities, from the conspicuous differences, and their specific gravity, which varies at between 4·0 and 4·7, and he believes that the Zirconia of Berzelius contains three different substances. To one of these, which gives a readily crystallizable sulphate, he has assigned the name of Noria, and to its metal Norium. It is found most abundantly in the Norwegian Zircon. Eudialyte, according to Svanberg, also contains two new earths, one resembling Yttria, the other yellow. It is right, however, to mention that considerable doubt still attaches to these substances, and Berlin has failed to confirm Svanberg's results.

In the year 1801, Hattchett discovered in an American mineral a metal which he called Columbium, and in 1802 Ekeberg found in a Swedish mineral another which he named Tantalum; and in 1809, Wollaston declared these substances to be identical. Rose was led to re-examine this subject in 1846, by observing the great difference in specific gravity of the Tautalites of different kinds, the black variety from Bodenmais having a specific gravity of 6·39, while the reddish-brown from the same locality is 5·69, and the American 5·70, and he found them to contain a metal distinct from Skeberg's Tantalum, to which he gave the name of Niobium. He also at the same time stated that they contained a third metal which he called Pelopium, but subsequent experiments satisfied him that it was not a distinct substance. The metals, Tantalum and Niobium, are scarcely known, but they both form acid compounds with oxygen, which are distinguished by very marked differences. One of the most curious is the effect of heat in modifying their specific gravity, Tantalic acid in its ordinary state having a specific gravity of 7·284, which is *increased* by a strong heat to 7·99, while Niobic acid is reduced by heat from 5·12 to 4·60.

A mineral, very similar in properties to Yttrotantalite, has been found in the Ilmen mountains in Siberia, to which the name of Yttroilmenite has been given. Herman, who has examined this mineral, believes it to contain a metal which he calls Ilmenium, but Rose considers this to be merely niobium contaminated with a little tungstic acid.

The residues obtained during the purification of platinum have also yielded a new metal, which its discoverer, Claus, calls Ruthenium. It is infusible in the highest heat of a furnace, and has a stronger affinity for oxygen than any of the platinum metals except osmium.

It thus appears that the number of elements has, during the last twenty years, been increased by certainly seven or eight, and, if we include the doubtful substances, by not less than a dozen. And these have been discovered by a revision of the earlier investigations of chemists of the highest eminence. They have all been detected in minerals of great rarity, and owing to the difficulty of obtaining the raw materials from which they are extracted, their properties are still very imperfectly known, and offer an extensive field for further inquiry.

But if the additions to the number of the elements are remarkable, the increased information obtained regarding those of older discovery is even more striking. The atomic weights of the greater number have been determined with additional care, and all the refinements of the improved analytical chemistry have been brought to bear upon the experiments; and while the result of these inquiries has been to confirm in most instances the numbers given by Berzelius, some not unimportant corrections have been introduced.

The tendency has been to show that the atomic weights of most of the elements are multiples of that of hydrogen, although some remarkable exceptions to this rule have been observed. This is particularly the case with chlorine, whose atomic weight is now universally admitted to be 35·5, and not 35.

The progress which has been made in the study of the properties of the known elements is equally great, and has led to most important discoveries. Perhaps the most interesting of these is the possibility of obtaining an element in two different forms, in which its properties are conspicuously distinct. Of these the most remarkable is that form of oxygen in which it acquires a pungent and irritating odour, and the property of decomposing many compounds which resist its action in its ordinary state. In this form oxygen is known by the name of Ozone, which was applied to it by Schönbein. He obtained it chiefly by the action of the electric spark and moist air, but a French chemist, M. Houzeau, has lately shown that it is obtained by the action of sulphuric acid on peroxide of barium at a sufficiently low temperature. By no process yet known is it possible to convert oxygen entirely into ozone, and hence considerable difficulty attends the determination of all the properties of the latter; but it would appear from the recent researches of Andrews, that its specific gravity is four times that of ordinary oxygen. It has been long known that sulphur varies greatly in its properties, and in addition to its two crystalline forms can be obtained also as a soft black substance, but it appears that it is capable of still further variations, and can be obtained as a white or yellowish matter insoluble in bisulphuret of carbon. Deville, Schrötter, and Magnus have made a large number of curious observations on these points.

Selenium, which in its usual condition is an amorphous and glassy substance, can also be converted by heat into a crystalline mass insoluble in bisulphuret of carbon, and into another kind of crystals soluble in that re-agent.

But probably the most remarkable among these changes is that offered by Boron, which has been long known amorphous, but which Deville has recently obtained in a crystalline form, in which it can scarcely be distinguished from the diamond, and in another state in which it resembles graphite. The diamond boron is obtained by heating amorphous boron or boracic acid in contact with aluminium to a high temperature, and then dissolving the aluminium in potash, when the boron is left in colourless or reddish crystals belonging to the square prismatic system, having a specific gravity of 2·68. It is quite infusible and almost as hard as the diamond, indeed, M. Deville entertains the expectation that it may possibly be economically employed for jewelling watches, and some similar purposes. Graphitic boron perfectly resembles graphite in colour and crystalline form.

Silicon is capable of existing in similar forms. The graphite form is obtained by heating silico-fluoride of potassium with aluminium, and then dissolving out the latter with hydrochloric acid, when the silicon is left in six-sided plates. By a modification of this process, and by the use of zinc it can be obtained, in regular octohedrons, sometimes of considerable size. Silicon appears to have a very remarkable tendency to combine with copper, and confers upon it a great degree of hardness, so great indeed that the alloy is to copper what steel is to iron, and may even be used for making cutting instruments.

A large number of the more oxidizable metals have recently been separated and more minutely examined, and their properties found to be very different from those previously attributed to them. Their examination has been greatly facilitated by the improvement in the processes for making sodium, which can now be obtained in very large quantities. It is scarcely necessary to refer to Aluminium, which is now so familiar. But Lithium, Barium, Strontium, Calcium, may be mentioned as metals previously almost unknown, and which have recently been more minutely examined. Lithium is remarkable as being the lightest solid known; its specific gravity is 0·589, being less than that of any known liquid, so that it floats on naphtha, and must be preserved in a vessel free from air. Barium, Strontium, and Calcium have all a yellowish colour, resembling an alloy of gold and silver. They are all rapidly oxidized in the air.

Glucinium has been obtained by the action of Sodium upon its chloride, and Magnesium by a similar process. They are both quite permanent in the air, and can be drawn into wires and otherwise worked. Many of the other metals have been recently obtained by improved processes, but their properties are less remarkable than those already mentioned.

Although the progress which has recently been made in the separation of the metals from their compounds is great, much still remains to be accomplished, and the greater number of them are still scarce and can be obtained only with great difficulty.

Mr. Hennedy exhibited a collection of Crustaceans from the Shores of Millport.

February 10, 1858.—*The* PRESIDENT *in the Chair.*

Professor William Thomson gave an account of experiments on the Elasticity of Metals.

Professor Allen Thomson exhibited and described several skulls from ancient burial places,—viz.:—1. Two skulls from catacombs near the Great Pyramid in Lower Egypt,—one of them apparently Pelasgic, the other Egyptian; 2. A skull from an ancient tomb in Malta, probably Phœnician; 3. A skull from the excavations at Kertch, very regularly formed, and fully developed; 4. A skull from an old burial place in New Zealand. Professor Thomson compared the forms of these skulls with those of more modern races of mankind.

Professor William Thomson showed an improved Apparatus for Testing the Electric Conductivity of Metallic Wires.

February 24, 1858.—MR. BRYCE, *Vice-President, in the Chair.*

Mr. James Napier read a paper "On Incrustations upon Steam Boilers."

On Incrustations in Steam Boilers. By MR. JAMES NAPIER.

INCRUSTATION upon steam boilers is an effect so universal, that it seems to be considered a necessary consequence connected with all steam boilers, and therefore borne with as an incurable evil; and it is only when the evil is very great, and as a matter of sheer desperation, remedies are sought after and tried: and hence nostrums of all kinds, like quack medicines, have been poured indiscriminately into the steam boiler, as a certain cure, without the slightest reference to the nature of the evil further than the general fact, that there was a cake or crust upon the boiler or tubes.

Sometimes the chemist has been called in to prescribe, and various cures have been suggested, some of which are certainly in themselves effective in preventing certain kinds of incrustation; but from subsequent reactions, which were not foreseen, the cure in many cases became worse than the disease. I will, in the first place, refer briefly to the cause of incrustations, their nature and composition, and then to some of the remedies that have been tried and suggested, pointing out what I consider the best and most economical.

If rain or distilled water alone be used for boilers, there would be no incrustation, because such water contains no salt in solution. But river and spring water always contain matters in solution, and these yield incrustation. The ordinary ingredients held in solution, in river and spring waters, are bicarbonate and sulphate of lime, iron, and magnesia, with salts of pôtash and soda. In some water the sulphates prevail, and in others the carbonate, depending altogether upon the soil or rock over and through which the water flows. Rivers at a distance from towns may be very regular in composition, but near manufacturing towns the water will vary very much in quality, owing to the various soluble refuse matters let into the river. The quantity of the different salts generally found in water which can be held in solution, when the water is cold, and when boiling, is as follows, reckoning ounces of salt per gallon of water:—

	Cold.	Boiling.
Sulphate of potash, . .	10 oz.	40 oz.
Chloride of sodium, . .	32	32
Chloride of magnesium, .	266	580
Carbonate of magnesia, .	$3\frac{1}{2}$	—
Chloride of calcium, . .	540	any quantity.
Nitrate of lime, . . .	500	—
Sulphate of lime, . . .	$\frac{1}{3}$	—
Bicarbonate of lime, . .	$\frac{1}{3}$	none.
Carbonate of lime, . .	trace	—
Silica, ...	$\frac{1}{6}$	—
Bicarbonate of iron, . .	—	none.
Sulphate of magnesia, . .	53	120

I may remark, that some of these salts are more soluble in a solution of other salts than they are in pure water. As, for example, sulphate of lime is more soluble in a solution of common salt than it is in distilled water; and so also is common salt in solution of other salts. The quantity of sulphate of lime which boiling sea water will dissolve is not, so far as I am aware, ascertained; but from a quantity of water drawn from a boiler at Ailsa Craig, that had been fed with sea water, I found it to contain 203 grains of sulphate of lime per gallon, nearly half an ounce.

Sulphate of lime is said not to be soluble in water at 300° Fah.; but whether this would be the case in water containing salt in solution, I do not know. Bicarbonate of lime in solution in water suffers decomposition; as the water is heated to boiling, it loses an equivalent of carbonic acid, and passes into the state of carbonate, which, not being soluble, falls as a precipitate. In boilers where water containing carbonates exist, and that are allowed to stand over night, this precipitate settles on the boiler, hardens, and forms a crust. Such crusts are generally composed of thin layers, or laminæ, each representing a day's work. Bicarbonate of iron in water undergoes a similar decomposition when the water is brought to boil. Carbonic acid is evolved, and carbonate of iron is precipitated, which is shortly after decomposed. The iron is converted into a peroxide, and the remaining carbonic acid liberated. This salt is generally in very small proportion to the lime, and only imparts to the crust formed a brownish tint. I have seen, however, a highly chalybeate water used in a boiler, which in a few weeks, when blown off the boiler, was a red colour, and gave the engineman the impression that it was blood. A portion taken from the boiler, and allowed to settle, deposited 190 grains per gallon, containing 130 grains peroxide of iron; still no caking had taken place, nor ever took place with these waters; but care was taken to blow off the red sediment from time to time, and regularly.

Sulphate of lime in water has a different action—is not precipitated but as the water is evaporated—after it has got its maximum quantity of salt in solution—the sulphate of lime crystallizes upon the surface of the boiler, and forms that hard, crystalline cake, or scale, which adheres so tenaciously to the boiler plates. This salt constitutes three-fourths of the incrustation upon stationary or land boilers, and is the cake on all marine boilers. This sort of crust cannot be avoided by care or mechanical means, except by keeping the salt in the water under its crystallizing quantity, which would necessitate such an amount of blowing off and supply as would render it expensive; but with the carbonates, or such salts that are precipitated, a little attention and blowing off at particular times will prevent entirely the formation of a cake or crust upon the boiler. The other salts held in solution in water are never found as crusts upon boilers; for example, I have never found a crust composed of magnesia; but when magnesia had existed in the water, I have never found a crust free of that earth. The crust or cake upon fresh water boilers have generally more of a mixed composition than from marine boilers. I will add a few of these as illustration.

Carbonate from Fresh Water.

Carbonate of lime,	79·0	Silica,	5·5
Sulphate of lime,	6·3	Water, at 212°,	4·0
Peroxide of iron,	3·5		
Magnesia,	2·1		100·4

Another, from using water having sulphates in excess or carbonates—

Sulphate of lime,	58·4	Silica,	2·0
Carbonate of lime,	27·3	Carbonaceous matters,	4·0
Carbonate of magnesia,	5·2		
Peroxide iron and alumina,	3·2		100·1

From a marine boiler, upon the iron plate, where care was taken in blowing off regularly, running between Aberdeen and London. This is a very hard, tenacious crust—

Sulphate of lime,	79·2	Water,	6·0
— magnesia,	6·8	Chlorine and common salt,	2·4
Peroxide iron and alumina,	4·8		100·0

The next is from boiler tubes running between Glasgow and Liverpool. In this little or no care had been taken by the engineer to prevent formation of crusts, which are composed of two distinct layers—the one next the tube a pure crystalline cake; that upon it was soft and granular. The two measured from $\frac{1}{4}$ to $\frac{3}{8}$ of an inch thick. These two layers separately gave—

	Crystalline Cake.	Granular Crust.
Sulphate of lime,	81·6	51·0
Magnesia,	4·2	14·6
Silica,	2·8	2·4
Peroxide iron and alumina,	2·4	1·6
Water,	7·5	15·0
Alumina,	—	8·4
Common salt,	7	2·4
Carbonic acid,	6	4·6
	99·8	100·0

The next is from the same boiler tubes, working the same length of time, but every precaution and care taken by engineer. The crust was only $\frac{1}{8}$ inch thick, and crystalline.

Sulphate of lime,	94·5	Water,	2·4
Magnesia,	1·5	Salt, &c.,	1·1
Peroxide of iron,	·5		100·0

This shows what may be done by care; but I may mention that there was a constant blow off from the boiler to an extent of three-fourths of that boiled off as steam. So that this cake may be looked upon as being only one-fourth of that which would have been formed without blowing off.

It will be seen from the specimens that the sulphate cake is crystalline. The water, by evaporation, becomes saturated with the salt when it crystallizes; and this saturation being kept up by the supply water, these crystals grow up, not in an isolated form, but as a plate over the whole surface of the boiler, and more on those surfaces exposed to fire; and the thickening of this plate is the extension of the crystals, which stand upon their points or axes—that is, the crystals of the plate arrange themselves in a line with the heat current, in the same manner as fused solids crystallize under the influence of rapid cooling.

I will now glance at a few of the remedies proposed to prevent incrustation. The first is adding to the boiler a little muriatic acid. This acid will act upon carbonate of lime, and produce a very soluble salt, chloride of calcium, which will not form a cake; but it has no action upon sulphate of lime, which is the principal ingredient of boiler cake; and besides, this remedy must be used with the utmost caution, as any excess of acid over the quantity required for the carbonate of lime will act upon the boiler, and also pass off with the steam, and corrode joints and stuffings. Indeed this remedy cannot be used with safety even under the constant superintendence of a chemist.

Another universal remedy was suggested by Ritterbrandt, namely, SALAMMONIA. This salt, put into a boiler with sulphate of lime, has no action further than rendering the sulphate a little more soluble, making it a little longer before crystallization begins; but salammonia decomposes carbonate of lime, producing carbonate of ammonia and chloride of calcium, both soluble salts. Should there exist any sulphates in the water, this reaction will be immediate, followed by another; the carbonate of ammonia will decompose the sulphate of lime, and form carbonate of lime and sulphate of ammonia; but the practical defect in this case is, that whenever the carbonate of ammonia is formed it volatilizes with the steam, and destroys the buskings, and everything containing copper, and is hurtful to the tubes of tubular boilers, which are composed of copper and zinc.

Carbonate of soda has been tried, which decomposes the sulphate of lime, producing sulphate of soda and carbonate of lime. As a precipitate the difficulty in applying this salt is the regulating the quantity; the practice has been to throw in from time to time large quantities of soda, which formed an alkaline ley in the boiler, and as soda passes freely off with steam, this practice has frustrated the object, as the alkaline steam hurt the stuffings, &c., of the engine. In a boiler treated thus, without any attention being paid afterwards, there was found at the bottom, after several months, the soda having been only thrown in once or twice at first and left to work a perpetual cure, a hard incrusted studge half an inch thick, composed of 100 parts:—

Silica,	2·6	Common salt,	1·7
Carbonate of lime,	28·2	Oxide, and iron, and alum,	1·2
Sulphate of lime,	18·5	Water,	10·7
Sulphate of magnesia,	12·6		
Crystal sulphate of soda,	24·5		100·0

This had lain exposed for several weeks to the air before being analyzed.

Soap has been tried, and is found to decompose both the carbonates and sulphates of lime. The tallow of the soap being rendered insoluble, or rather combines with some of the lime, and forms an earthy soap, which sometimes floats upon the surface of the water, forming a solid scum, preventing the escape of the steam, or causing priming, and when combined with much lime, it occasionally deposits and forms a very nasty crust upon the boiler. Means could be adopted to carry off the scum and recover the tallow, but its action being dependent upon the alkali it contains, it will be better to use the alkali pure. When soap is used in larger quantity than is necessary to decompose the salts in the water, priming is sure to follow.

Soda and gallic acid, and tannin prenite of soda, is recently patented. Besides these, which have some chemical principle in them, I will name over the following as a proof of the haphazard system of remedies, not only suggested, but tried and advocated, and even patented:—Sawdust, potatoes, potato skins, sugar, glucose, mixture of coal tar and linseed, Castile soap and plumbago, ground dyewoods, gum, catechu, oak bark, and green vegetable matters. Such is a list of what has been tried.

The effect which incrustations have upon boilers is matter of dispute. Some have boldly declared that they are not detrimental, either to the boiler or its economical production of steam; but there having been such a general feeling after a remedy, indicated by the list just given, is, I think, a practical answer to the economical question. The difficulty experienced in keeping up the steam when the boiler was covered over with a crust, has evidently led men to try anything in hopes of removing the evil; and I know that the burning of holes in boilers are often ascribed to that cause. I will not take up your time discussing the theoretical views how crusts of lime or gypsum lining the inside of a boiler must affect the transmission of the heat, but in respect to such crusts affecting a boiler, hastening its destruction, and causing danger, I refer to the recent report of the Society for the Prevention of Boiler Explosions, in which it is shown that incrustation affects the boiler. The report goes on to say—

"And lastly, I may mention among the causes of fracture, the formation of a scale or certain kinds of deposits, which, by retarding the transmission of heat, also allow the plates to become overheated. The nature of these deposits, so far as regards their powers of conducting heat, appears to vary greatly; for while some boilers, although thickly covered with scale, continue uninjured for years, others of similar construction, and under like conditions, with only a slight deposit, but of a different kind, require frequent repairs. On this subject there is, evidently, need of further investigation. For the prevention and removal of such deposits, various compositions have been employed with more or less success; but in the use of any composition it is preferable to effect precipitation in a tank or reservoir previous to the water entering the boiler. The employment of sediment collectors and frequent blowing off is beneficial, and should not be neglected."

Few things could show more fully the necessity of such associations than this part of the report; and we trust that the next report will not contain a statement that *certain* deposits, though very thick, will do no harm, while other *certain* deposits, though very thin, will destroy a boiler, but will be able to say what these certain deposits are, whether belonging to the sulphates or carbonates.

I have lately had my attention drawn to the whole subject as a matter requiring a little investigation, and have got a few samples of crusts to analyze, some of which I have given. Where the crust was carbonate I have found little difficulty in preventing its formation—only a little care on the part of the engineer. As we have seen, this falls as a precipitate by the mere boiling of the water. If, every night after the fire is damped down, and a little time allowed for this precipitate to subside, it be then blown off from the bottom, little or no incrustation will ever form upon the boiler. Such crust as the sample shown is always seen in nightly layers, the result of a deposit upon the boiler, which hardens and cakes by standing, and could all be removed by mechanical means and attention. And I have been told by engineers who have adopted this system of blowing off, that they do not require to clean their boilers over once a-year; while other parties, using the same water, require to clean and chip off the crust every three months, at least. The sulphate crust, as already stated, is a crystallization upon the surface of the boiler, and cannot be removed by mechanical means. It is, however, easily and thoroughly decomposed by carbonated alkalies, the cheapest is soda. It has been already stated that the only defect in soda was its being added indiscriminately and in too large quantity—a circumstance easily avoided. I make the matter a chemical question, analyze the feed water to ascertain the amount of sulphate of lime which is present in the gallon, take the size of the boiler and quantity of feed water added per day. I then calculate the amount of carbonate of soda that will exactly neutralize the sulphate of lime in the quantity of feed water taken per day, which is dissolved in a small iron tank placed above the boiler. If the engine works twelve hours, I form a syphon that will run this soda liquor in the feed water in that time, so that at no time is there an excess of soda in the boiler, and thus the lime is converted into the state of carbonate, which precipitates, and may be removed by mechanical means of judicious blowing off, as I have described. I have only had the opportunity of trying this one boiler, using the filthy water of the Kelvin. The blowing off was not carefully attended to; nevertheless, after six weeks, the usual time of cleansing and scaling, which generally gave a crust of $\frac{3}{16}$, there was nothing but a loose sludgy deposit, which was brushed off by a hard hair brush.

In marine boilers using sea water, as already stated, the cake is always the sulphate crystals, although where there is no mechanical care, carbonate crusts will also form. The use of soda in this way would be very simple, and possibly, from their constant blowing off from the surface this carbonate of lime might be, like the salt, carried to the surface, in the first instance, and blown away while working, and would not cake upon the tubes; but its application and effects upon sea going vessels I have had no means of testing. An analysis of sea water will not require to be made for each vessel, as with land boilers, but an average analysis may be taken. I say an average, because in different localities of the sea, and even on different days, or probably seasons of the year, the sulphate of lime in sea water varies very much. However, this is a subject I am not yet prepared to enter into. Instead of adding the precipitate to the boiler, if mechanical means cannot throw off the precipitate entirely, then a pair of tanks in which the precipitate may be made and the boiler filled from the clear, would not be a very expensive nor unwieldy piece of apparatus, which I do not consider, however, necessary, as mechanical means can be got for blowing off any accumulation of loose precipitates.

I have now done what I had intended in my own mind, namely, to bring the subject before the Society, in hopes of drawing the attention of those more immediately concerned with the working of boilers. The whole subject is yet to investigate, and science, economy, and common humanity, all urge the necessity of beginning without delay.

A paper was read "On a Method of Voting at Limited Liability Companies more Uniform than the present, and its Expression by a Mathematical Formula," by James R. Napier.

On a Method of Voting at Limited Liability Companies more Uniform than the present, and its Expression by a Mathematical Formula. By JAMES R. NAPIER.

IN the Joint-Stock Company's Act, 19 and 20 Victoria, cap. 47, the thirty-eighth clause of Table B refers to the votes of shareholders as follows:—

"Every shareholder shall have one vote for every share up to ten; he shall have an additional vote for every five shares beyond the first ten shares up to 100, and an additional vote for every ten shares held by him beyond the first 100 shares."

I failed in my endeavours to discover any other reason for the adoption of this scale of votes than that of limiting the influence of the larger shareholders; the limitation, however, has been done too abruptly. To make the scale vary more uniformly is the object of the present paper. The accompanying sketch shows the scale of the "Act," and the proposed modifications.

The number of shares is marked along a base line according to a scale; the corresponding number of votes according to the Act is represented by the ordinates to the *dotted* lines; and the proposed modifications, by the ordinates to the *full* lines.

The shares are supposed to be divided into an equi-different series, whose common difference is 4: thus, 4, 8, 12, 16, 20, 24, 28, &c., shares; and to each term of the series four votes are allotted. The sum of any number of the terms, therefore, commencing at the first, represents a number of shares, and the last term represents the number of votes. Thus, in the example above, the third term 12 represents the number of votes corresponding to the sum of the three terms, 4, 8, 12; or, in general, n being the number of terms, the number of votes will be represented by $4n$, corresponding to the number of shares represented by four times the sum of the series $(1 + 2 + 3 + 4, \&c., n) = 2n(n + 1)$. This expression will probably be considered by the shareholders of public companies as no simplification of the present scale, but it can easily be reduced to plainer English, and nearly to the same words as those of the Act referred to, thus:—

Every Shareholder shall have 1 Vote for 1 Share, and an additional Vote for every 1 Share beyond the first 1, up to 4 Shares.
— — — 4 Votes for 4 Shares, — — — 2 Shares, — 4 — 12 —
— — — 8 — 12 — — — — 3 — — 12 — 24 —
— — — 12 — 24 — — — — 4 — — 24 — 40 —
— — — 16 — 40 — — — — 5 — — 40 — 60 —
— — — 20 — 60 — — — — 6 — — 60 — 84 —
— — — 24 — 84 — — — — 7 — — 84 — 112 —
— — — 28 — 112 — — — — 8 — — 112 — 144 —
— — — 32 — 144 — — — — 9 — — 144 — 180 —
— — — 36 — 180 — — — — 10 — — 180 — 220 —
— — — 40 — 220 — — — — 11 — — 220 — 264 —
&c. &c.

And generally, every Shareholder shall have

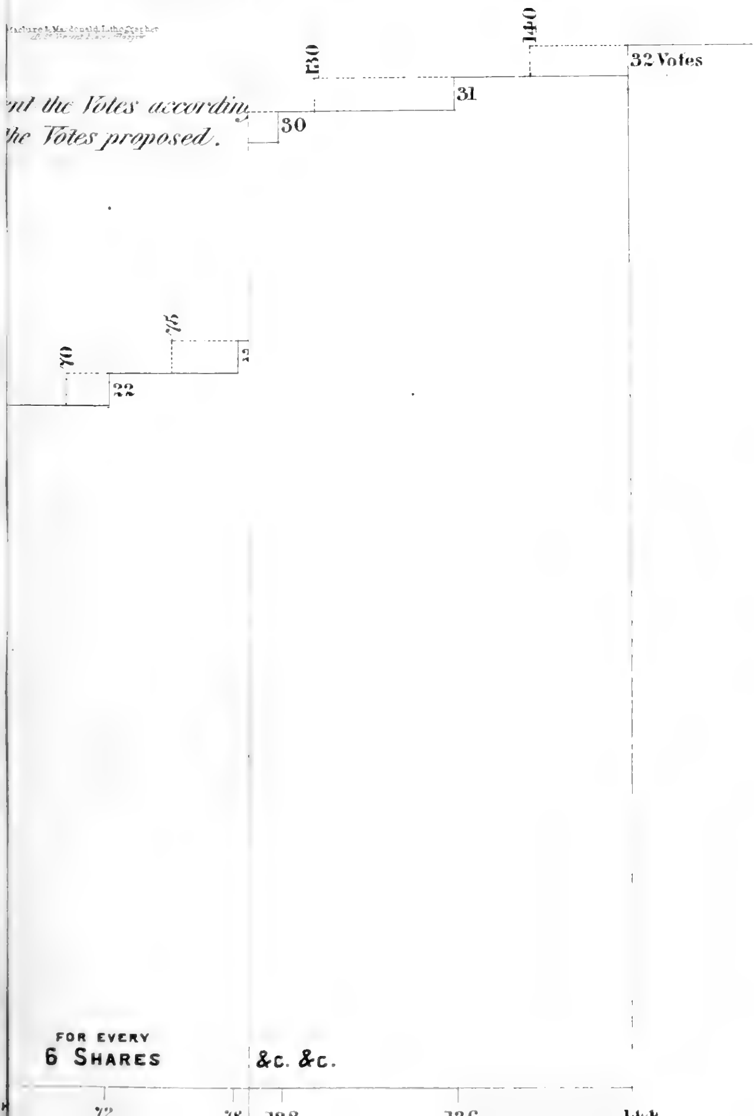
$4(n-1)$ Votes for $2n(n-1)$ Shares, and an additional Vote for every (n) Shares beyond the first $2n(n-1)$, up to $2n(n+1)$ Shares; (n) being the number of terms in the series 1, 2, 3, 4, &c.

I adopted the common difference 4, because it made the least difference on the scale of the "Act." It makes the scale the same from 1 to 4, from 40 to 60, and from 180 to 220, as the Act, and varies uniformly.

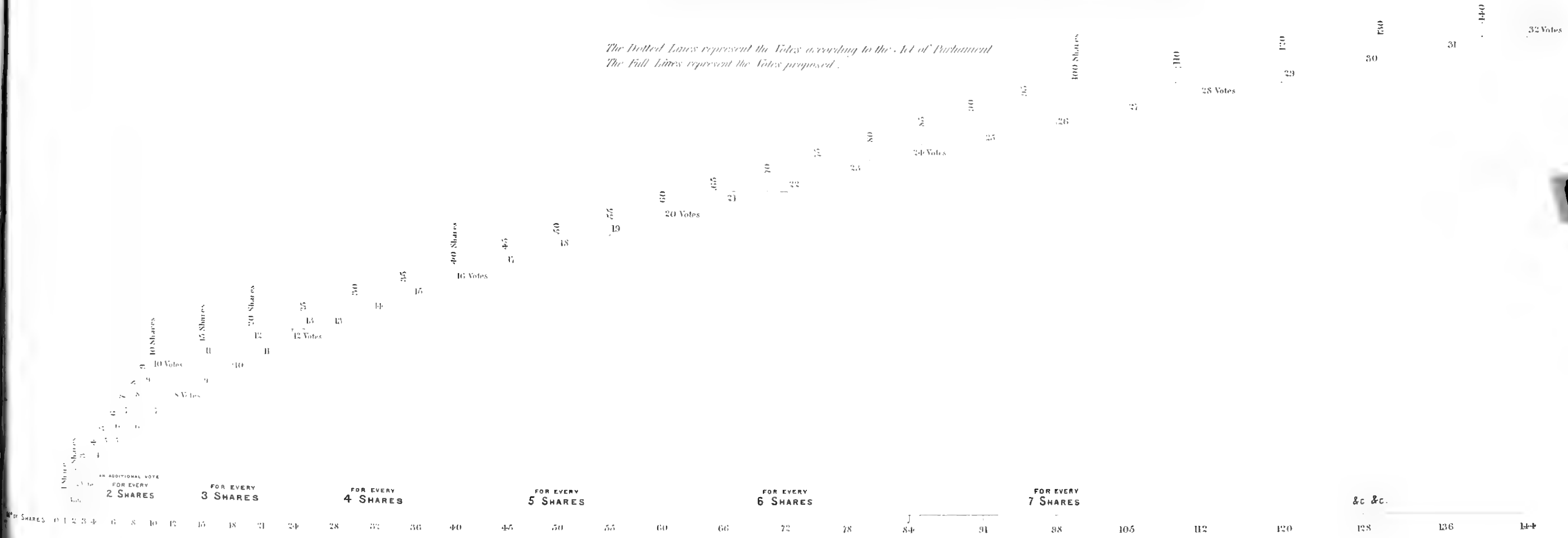
ON VOTIN

Maclure & Macdonald, Lithographers

...nt the Votes according
...he Votes proposed.



MR. JAMES R. NAPIER'S PAPER ON VOTING AT JOINT STOCK COMPANIES.



March 10, 1858.—Mr. Bryce, *Vice-President, in the Chair.*

The following papers were read, with illustrations, by the President:—

"On the Interference of two adjacent Organ Pipes tuned to the same, or nearly the same, note."

"On the Vibrations of Rotating Bodies."

Mr. Hunt exhibited an experiment illustrative of his paper "On Rotatory Motion;" but in consequence of the lateness of the hour, deferred till next meeting reading Notes in continuation of that paper.

March 24, 1858.—*The* President *in the Chair.*

Mr. John Dickie and Mr. John Dougan were elected members.

Mr. Hart described some appearances of the Eclipse of the Sun on the 15th, which were not generally seen by observers in this quarter. Mr. Hart was fortunate enough to catch a momentary glimpse of the sun's disc at the completion of the phenomenon.

Mr. Edmund Hunt read, and illustrated by experiment, Notes in continuation of his paper on Rotatory Motion, which was brought before the Society on the 2d of December last.

Additional Notes on Rotatory Motion. By Edmund Hunt.

When a peg top spins on a point which experiences friction upon the supporting surface, that friction will cause the top to rise if inclined, and with the greater rapidity the blunter the point is. This effect takes place by means of a tendency to accelerate the top's precessional motion. Supposing the top to be spinning in an inclined position upon a horizontal surface, the friction tends to make the peg roll along that surface, and this tendency acts as a rectilinear force tending to carry the top bodily along in a direction such that, if it moved fast enough the point would roll instead of rubbing on the surface. This rectilinear pressure being applied to the point of the peg, instead of the top's centre of gravity, causes such a translation of the top combined with a rotation about its centre of gravity, that its peg moves in advance. Consequently, supposing the top to be at first inclined up towards the north, and its point to move towards the west, it will in a short time be inclined up towards the east. The rolling action will then tend to carry the top towards the north, and after a second interval it will be inclined up towards the south, and so on. In other words, the top describes a circle, and is inclined in towards the centre thereof. So far the precessional action is not taken into account. Supposing the top to be rotating, so as to move (in the absence of precessional action) as just described, but with its peg point fixed, the precessional action would cause its centre of gravity to move round in the direction north, east, south, &c. This direction is the same as that of the change of inclination which the rolling tendency of the point would cause (the mere translation of the entire top not affecting the precessional action), therefore the rolling tendency must tend to accelerate the precessional motion, and consequently cause the top to rise. If the point of the top *fits* a hollow in the supporting surface, its friction in the hollow cannot make the top rise; but if the hollow is somewhat larger than the point, the latter will rise up the side of the hollow and move round at a determinate level; and the friction will act as on a level surface.

I exhibit a curious experiment to show that much caution is necessary in experimenting on the effects of friction. The gyroscope in its single ring has a bent peg fixed to the ring close to one end of the spindle. When set spinning, the instrument supports itself on the peg, the ring not turning with the fly-wheel, but merely partaking of the conical precessional motion. The friction of the pivots acting on the ring tends to accelerate the precessional motion, and thereby cause the instrument to rise; the friction of the peg point on the horizontal supporting surface tends to retard the precessional motion, and thereby cause the instrument to fall. If the peg rests on a soft substance, such as soft deal or caoutchouc, the instrument falls; if it rests on a hard surface, such as glass, the instrument rises.

Referring to fig. 14 in the plate illustrating my former paper:—If a weight be fixed to the underside of the lever B, below the axis crossing the ring D, so as to lower the centre of gravity of the whole, a great variety of experiments can be shown by starting the instrument in different ways. If the weight C is adjusted, so that the whole is in equilibrium with the lever horizontal; then if the gyroscope A is raised or lowered and started with a suitable determinate impulse, its path will be a species of oval with its longest diameter vertical. The other experiments are too numerous to detail.

In my former paper, I mentioned that a demonstration of the fundamental theorem of the composition of rotatory motions was given in Airy's *Mathematical Tracts*. There are other demonstrations extant, but most of them are complicated, and need the aid of spherical trigonometry. Poinsot's method of couples perhaps affords the simplest and most elegant demonstration, but it necessitates a tedious wading through numerous preparatory propositions. I beg to offer the following theorem as enabling us to directly apply to the case, the well known "Parallelogram of Rectilinear Velocities." It is capable of being put in a general form, but for the sake of simplicity, I will here give it as applicable to a sphere free to turn about any axis passing through its centre. "If a plane passes through a given axis of rotation the orthographic projection on that or a parallel plane, of a line representing the tangential velocity of a given point on the surface, will be equal to $V \cdot \sin \theta$; V representing the tangential velocity of a point on the equator, and θ the angle formed with the plane, by a line from the given point to the centre of the sphere." It follows as a corollary that, if in a sphere two or more diametrical axes of rotation lie in a plane, the relative velocities of any point about such axes will be represented as orthographically projected on such plane by lines at right angles to the respective axes, and having the ratios to each other of the respective angular velocities; for each projection is as the corresponding equatorial or angular velocity multiplied by sin θ—that is, the projections are equimultiples of the angular velocities, and having therefore the same ratios to each other that such velocities have.

Since my first paper was read, I have seen a second article by Major Barnard in *Silliman's Journal* for January, 1858; and as in this paper the mode of showing the enlarged "cycloidal" motions is described, I think it proper to mention that I wrote three several times to the editors of *Silliman's Journal* respecting my paper, the last time on 4th December, 1857, describing the "cycloidal" experiments. I have received answers to every letter but this last and most important one. The parts of *Silliman's Journal* generally reach here about the 20th of the month they are for; but that for January, 1858, was not received until the 3d March. I have thus reason to think that an account of *my* experiments was in America before that of the Major's was published; however, as far as I can learn, the experiments I exhibited before the Society on the 2d December, 1857, had not then been shown elsewhere.

Major Barnard's first paper conveys the impression that in practice, as well as theory, the gyroscope never moves horizontally—that there are always undulations, but that with high velocities they are "too rapid and too minute to be perceived." In the second paper, however, we are told that the undulations speedily vanish, and that the gyroscope moves horizontally, or nearly so! We are not told *how* the undulations are made larger on mounting the gyroscope farther from the point of support, nor why they are not sensible with the gyroscope arranged in the common way, as they ought to be, by the Major's theory. He attributes the gradual change in the form of the curve mainly to the decreasing rotatory velocity of the fly-wheel. To test the correctness of this, arrange the apparatus, fig. 14, with the centre of gravity of the lever, wheel, and weight at the centre of the ring D, and set the wheel spinning, with the lever horizontal. If now a vertical impulse is imparted to one end of the lever, the wheel will describe a circle; if the Major's view is right, this circle should become larger and larger; on the contrary, however, the circle becomes less and less, owing to the action of the centrifugal resultant. I believe the decrease in the rotatory velocity of the fly-wheel would of itself tend to make the curves more prolate, but not in the way shown by Major Barnard, nor to anything like the extent actually seen in practice.

In his first paper Major Barnard endeavours to show that the undulatory motion is such as would be produced by the combined action of gravity, and what he terms a *deflecting* force. Supposing there is such a deflecting force, it will be directed to a point travelling along the level of the cusp of the cycloidal curve; in the supposed case in which the rotatory velocity continues uniform, and the cusped cycloid is described, this point travels at such a rate as to coincide with the point describing the curve at each cusp; but when the rotatory velocity decreases, the point travels faster; so that on its reaching the point at which the cusp would have occurred, the gyroscope is below it, instead of coincident with it, and the curve is deflected, as shown at a_1 (fig. 1, Major Barnard's second paper). The mean motion along the curve is in a certain sense independent of the mean horizontal angular motion—that is, the motion of the point to which I have supposed the "deflecting force" to be referred. If the motion along the curve is retarded (which can be done by imparting a forward horizontal impulse), the motion of the "deflection" point is more rapid in comparison, and the curve described is prolate. On the other hand, if the motion along the curve is sufficiently accelerated, the gyroscope will get in advance of the "deflection" point, rise above it, and form a loop round it. The introduction of the idea of a "deflecting force" facilitates the conception of the way in which the curves are modified; but I think Major Barnard unnecessarily mystifies it. This deflecting force simply corresponds to the radial pressure on the point of support in the case of the ordinary pendulum. What corresponds to the point of support in the common pendulum is in the gyroscope what I have termed the precessional axis, which is continually moving round. In the common pendulum, the bob is at each instant moving in a direction at right angles to the line between it and the point of support; and similarly the gyroscope is at each instant moving at right angles to the plane between it and the imaginary precessional axis.

In my former paper I have endeavoured to explain actions having a much greater influence on the form of the curve than the mere decrease in the rotatory velocity of the fly-wheel.

At page 70, Major Barnard says—"This sustaining power being directly proportional to the rotatory velocity of the disc, as well as to the angular velocity of the axis, diminishes with the former; and as it diminishes, the axis must descend, acquiring angular velocity due to the height of fall; hence the rapid gyration and the descending spiral motion which accompanies the loss of rotatory velocity." This sentence contains several errors: in the first place, theoretically, the sustaining power is absolute for all rotatory velocities—that is, the gyroscope always retains or recovers its original elevation, whatever the rotatory velocity may be; secondly, the descent of the axis is entirely due to the resistance experienced to the precessional motion; thirdly, the angular or precessional velocity increases as the rotatory velocity decreases, and there cannot be any increase of it due to the descent; if an undulatory curve is being described, the descent will make it more prolate; but any tendency to increase the precessional motion will immediately check the descent.

At page 75, Major Barnard speaking of the top, says—"This rolling speedily imparts an angular motion to the axis, greater than the horizontal gyration due to gravity"—(there is a *tendency* to increase the gyratory motion, but it takes effect in lifting up the top; the gyratory or precessional motion *cannot* be increased, unless the top is in some way *prevented* from rising). "The deflecting force becomes in excess and the top rises." Also, page 71,—"The *addition* to this gyratory velocity, caused by friction, when the axis is inclined *upwards*, puts the deflecting force in *excess*, and the axis is raised." Here we have the mystical "deflecting" force figuring in quite a new way. If we do assume that a "deflecting force" acts in producing the undulatory motion, we cannot consider it as doing more than altering the direction of motion, just as the connection between the pendulum bob and its point of support makes the former move in a curve. If an undulatory curve is being described, any additional forward impulse merely makes the curve more prolate; if the gyroscope or top is moving horizontally there is no "deflecting force" in action, so that it cannot be excess of that which causes a rise. In either case, the rise is derived from the horizontal impulse in precisely the same way as the horizontal gyratory or precessional motion is derived from the downward pressure of gravity.

At page 74, Major Barnard says—"But these little undulations speedily disappear, through the retarding influence of friction and resistance of the air." In the case in which the top point is so free from friction that the centre of gravity remains always in the same vertical line, *that friction* must be quite unable to make the undulations disappear. As to the resistance of the air doing so, the top may be so proportioned as, *cæteris paribus,* to increase that resistance, and to make the rotatory velocity decrease more rapidly (namely, by, amongst other alterations, placing the rotating mass at a greater distance from the point), but the curves will be larger and continue longer—instead of the reverse, as Major Barnard would lead one to expect.

Specimens of Silicon, Boron, and some other rare elements, were exhibited by Dr. Anderson.

Mr. Keddie read the following analysis by Mr. James Napier, chemist, of a small portion of the stone fused by lightning, in May, 1854, exhibited at the meeting of the 27th January. The stone, which was a fragment of one of the turrets of the tower of Glencairn Parish Church, was given to Mr. Keddie by Robert M'Turk, Esq. of Hastings Hall, Glencairn, and is now deposited in the Museum of the Andersonian University:—

"I took a small sample of the fused stone, and also a piece of the stone not fused, and submitting them to analysi,s obtained the following results:—

Original Stone.

"Silica,	88·5
Peroxide of iron,	2·5
Alumina,	4·5
Carbonate of lime,	2·5
Magnesia,	1·0
Moisture,	1·0
	100·0

"The *fused stone* was a fair glass, opaque and brittle, indicative of rapid cooling.

"The analysis gave—

"Silica,	84·3
Protoxide of iron,	2·9
Alumina,	4·8
Lime,	3·2
Magnesia,	1·6
	100·0

"The only change is the reduction of the peroxide of iron to the state of protoxide. There is also more lime, iron, and magnesia; but this may be accounted for by the sample of the stone that I took, being from the *outside,* having lost these ingredients from being exposed to moisture or rain,—these being the matters that would be dissolved out of stone by the access of water. The analysis is interesting as showing *how rapidly chemical action must have taken place.*"

April 7, 1858.—MR. BRYCE, *Vice-President, in the Chair.*

A Report was read from the Committee "On Applied Mechanics," consisting of Mr. James Robert Napier, Mr. Walter Neilson, and Professor W. J. Macquorn Rankine.

Report on the Progress and State of Applied Mechanics. By JAMES ROBERT NAPIER, *Iron Shipbuilder;* WALTER NEILSON, *Mechanical Engineer; and* W. J. MACQUORN RANKINE, LL.D., *Civil Engineer.*

1. THE subject of Applied Mechanics, including, as it does, every application of the laws of force and motion to works of human art, is so extensive and multiform, that a mere enumeration of all its branches and subdivisions, and of the various objects to which they relate, would, if complete and fully detailed in every respect, occupy more time than can be devoted to a Report like the present. All that your Reporters can pretend to accomplish, is to give to the best of their ability a general view of the recent progress and present state of this vast division of human knowledge and practice, with such illustrations and examples as their own experience and study may most readily suggest to their minds.

2. The objects to which Applied Mechanics relate may, in the first place, be divided into two great classes: STRUCTURES and MACHINES;—Structures, whose parts are intended to remain fixed relatively to each other, and whose requisites are—*Stability*, which preserves the relative positions of the parts of a structure, and *Strength*, which preserves their figures, connection, and continuity; and Machines, whose parts are intended to move, and to perform work, and whose requisites are, not only strength in each separate moving piece, and stability in the frame (which is itself a structure); but *Efficiency*, which consists in the adaptation of the moving power to the work to be performed.

3. Certain objects, such as carriages and ships, may be considered to belong to both classes—being regarded as structures with respect to the connection of their parts, and as machines with respect to their means of propulsion.

4. Each separate part of a machine, being required to preserve its figure and continuity under the forces to which it is exposed, is itself a structure, and subject to the principles which regulate strength and stability.

5. Thus, Applied Mechanics, regarded as a science, may be divided into TECTONICS and ENERGETICS, corresponding respectively to the two

divisions of CONSTRUCTION and MECHANISM, of which it consists when regarded as an art.

6. In the perfecting of Applied Mechanics, whether as a science or as an art, the end aimed at, and the criterion by which true is to be distinguished from false progress, may be expressed by the word ECONOMY; that is, the production of every desired effect by those means which are exactly adequate to produce it, and no more. Whether in structures or in machines, the proportion borne by the means exactly adequate to produce an effect, and the means actually employed, can be expressed by numerical ratio. For PERFECT ECONOMY, that ratio is UNITY; but perfect economy never is, nor can be attained in human works; and in them the economy realized is expressed by some fraction, falling short of unity by a quantity which expresses the *waste of means*. Theory strives to ascertain, by experiment and by reasoning, the exact amount and causes of waste, and how it is to be reduced; and practice strives, by continually improving skill, to effect that reduction; and both tend to bring the fraction that denotes actual economy, continually nearer and nearer to that UNIT, which expresses the unattainable, though not unapproachable, limit of the result of human efforts.

7. In a *Structure* three things are to be considered; its materials,—the mode of putting them together,—and the purposes for which the structure is to be used.

8. The *materials* of structures are inorganic and organic. Inorganic materials are for the most part either stony or metallic. Organic materials are of vegetable or animal origin.

9. With regard to *natural stone*, the chief improvements which have of late years been made, have been in the art of separating it from its native rock by blasting. Much skill is employed in the placing of mines so as to detach large masses of it with the least possible waste of powder and of stone; and the heat generated by currents of electricity in metallic wires, has for many years been advantageously employed to fire the charges at one instant. Some of the most remarkable operations of this kind, of recent date, are described in a paper read by Mr. Sim (manager of the granite quarries at Furnace) to the British Association at Glasgow, in 1855.

10. The transport of good building stone from a distance is a matter of importance to those places where it is deficient. Thus, in those parts of the south of England where the formation is chalk, and the only stones fit for building that are found on the spot are the flints imbedded in the chalk, a valuable article of commerce is the oolite which is imported from quarries in Normandy, and which though soft when first quarried, and capable of taking the most delicate carving

from carpenters' tools, hardens by exposure to the air, so as to become strong and durable. The beautiful parish churches of Kent and Sussex, in whose walls a concrete of flints fills the intervals between the carved stone quoins and arches, show that at an early date the Normans imported the stone of their province into the south of England; but that importation ceased for a long time, and has only been of late years revived.

11. Of *Artificial Stones*, the most useful, though not the most costly, are BRICKS. The art of making bricks, of regular figure and great strength and durability, was brought to great perfection by the Romans, and subsequently to their time it appears to have been much neglected and forgotten, until of late years skill has been devoted to it with much success. Bricks have been moulded by hand or by mechanism, of various, convenient, and ornamental shapes; they have been made of great strength and accuracy of figure, by compressing dry clay; but the most useful improvements are those which have been made in the strength and durability of common bricks, by good materials and careful workmanship; and of this some of the most remarkable examples are to be found in Glasgow and its neighbourhood, where the frequent occurrence of large and lofty structures of brick, and especially of furnace chimneys, (one of which, that of St. Rollox, is, with three exceptions, the highest building in the world), renders strength and durability absolutely necessary in bricks.

12. Connected with the manufacture of bricks, is that of *clay* and *earthenware pipes*, for drainage and water-supply; an art of recent origin, and very beneficial, by its enabling small channels for the conveyance of water, to be executed at a cost proportionate to their size.

13. Amongst artificial stones may be classed *mortars* and *cements;* and of these the most important are such as harden readily in a moist atmosphere, and under water. *Hydraulic Limes* and *Cements*, as they are called, though much used by the ancients, especially the Romans, were in former times comparatively rare and costly, because the quantity in which they could be produced depended on the finding of certain natural stones; but now the researches of Pasley and Vicat have furnished us with the means of producing artificially, by the combination of lime with silica and alumina, or with oxide of iron, in proper proportions, hydraulic mortar and cement in any quantity that may be required.

14. One of the most useful artificial stones is *concrete:* a mixture of lime with gravel, and with fragments of stone. Though much employed by the Romans, and by Mediæval builders, its proper composition and use appear to have fallen for a time into neglect, until of late years it again received the attention of engineers. The great sea-wall at

Brighton, built wholly of a concrete of lime and flints, has for many years stood exposed to the full force of the waves of the English Channel. Blocks of concrete, hardened in boxes, have been used for the building of piers and breakwaters. Many bridges have had their piers founded in difficult positions, on platforms of concrete, which possess in some respects the properties of large flat blocks of solid stone; and, in particular the new bridge of Westminster, designed by Mr. Page, and now approaching completion, has the foundation and lower portion of each of its piers formed of a mass of concrete, contained in a cast iron casing.

15. Amongst various artificial stones, too numerous to specify in detail, mention may be made of the artificial sandstone of Mr. Ransome, composed of grains of sand cemented together by a sort of glass, and very useful in places at a distance from good natural sandstone, and also of a method invented by Mr. Kuhlmann, of hardening soft stones by infiltration with a solution of silica.

15 (A). GLASS itself is a kind of artificial stone. Its employment as the principal part of the covering of a building, originated with the great Exhibition of 1851. Its use for such purposes has been much facilitated by the invention of processes for easily manufacturing it in large flat sheets.

16. *Bituminous* or *Asphaltic Cements,* which, though of organic origin, are not organized, appear to have been used in Western and Central Asia, in ages beyond the range of history. The most remarkable use which has been found for them in modern times, is the binding together of the broken stone, gravel, sand, or other hard materials, with which roadways are covered. This art has hitherto been brought to greater perfection in France than in Britain; but it is to be hoped that by perseverance, we shall in time be enabled to equal or to excel our neighbours.

17. Amongst the METALS, the first place for abundance, for utility, and for strength, belongs to IRON. The progress which has in recent times been made in its production, has been in quantity rather than in quality. In times, and by nations, that we consider barbarous, iron and steel have been produced of a strength, toughness, and elasticity, which we should find it difficult to equal. Our present superiority consists mainly in the power of producing iron in abundance, sufficient to meet any demand which its rapidly increasing use in every kind of structure and machine may cause; and the great improvements which, in the course of the present century have taken place in the manufacture of iron, have tended chiefly to increase the rapidity and diminish the cost of its production.

18. Nevertheless some inventions have been carried into effect, whose tendency is to improve the quality of iron by increasing its strength, such as the smelting of iron by coke deprived of sulphur by the process of Mr. Calvert, whereby one of the most weakening impurities is removed,—and the mixing of wrought iron with cast iron, to produce a metal tougher than ordinary cast iron, invented by Mr. Morries Stirling. The effect of repeated meltings on the strength of cast iron, has been tested by Mr. Fairbairn, who found the iron increased both in tenacity and in hardness, by each melting up to the twelfth; while, for meltings beyond the twelfth, the iron, though its hardness is increased, becomes brittle.

19. The process of Mr. Bessemer, for puddling iron by a blast of air, although it has been found to answer perfectly with the iron of Nova Scotia, has not hitherto succeeded with that of Scotland and of Staffordshire; and until further experiments have been made, it is impossible to state what its results in most cases may be.

20. One of the greatest improvements ever made in the manufacture of STEEL, was that effected by the use of carburet of manganese, or of carbon and manganese separately added: a source of immense benefit to all manufacturers and users of steel,—but of ruin to its inventor, the late Mr. Heath.

21. Various improvements, too numerous to mention in detail, have of late years been made in converting iron into steel, case-hardening, moulding, casting, shingling, rolling, forging, welding, rivetting, and other processes applicable to cast and wrought iron, and to steel. An important instrument in those improvements which relate to the manufacture and forging of wrought iron, has been the steam hammer: whether the original steam hammer of Nasmyth, in which the hammer is attached to the piston, or the later steam hammer of Condie, in which the piston is fixed and the cylinder carries the hammer. It is by such an implement alone that such forgings can be executed as the engine, paddle, and screw-shafts of the Great Eastern.

22. Next to iron in abundance and utility, and also in strength, is COPPER; along with which may be considered its alloy with zinc, the ordinary *brass*, and with tin, also known as brass, but more properly called *bronze*, and classed, according to the proportion of its constituents, into gun-metal, bell-metal, and speculum-metal; the first, which contains most copper, being the softest and toughest; and the last, which contains most tin, being as brittle as glass. Modern chemistry has shown the necessity of combining the constituents of each of those alloys in *atomic proportions*, in order that the compound metal produced may be uniform in structure, and free from flaws, and that according to its purposes, it may be strong, sonorous, or brilliant.

23. *Organic materials* of construction are of vegetable or of animal origin, and are generally fibrous, like wood and leather; but exceptions to this are found in caoutchouc and gutta-percha.

24. The available sources of TIMBER have of late been much increased by the discovery of the useful properties of the trees of various distant and lately settled countries,—such as the various Eucalypti of Australia, some of which are remarkable for size and strength. Central and South America also,—Africa, Ceylon, and other tropical regions, possess many timber trees remarkable for strength, durability, and beauty, whose properties have only recently become known to Europeans. On these points, interesting information may be obtained from the report of Captain Fowke, R.E., on the specimens of timber at the Paris Exhibition of 1855.

25. In the *treatment of timber*, the points of principal importance are seasoning and preservation. SEASONING, which consists in the evaporation or extraction of the moisture contained in the timber, to such an extent as to prevent warping or decay from the presence of that moisture, used formerly to be effected by spontaneous drying in the open air, and occupied from two to four years: and when attempts were made to hasten the process, or to render it more effective by artificial means, these consisted in steeping, boiling, or steaming, which saved but little time, and weakened the timber. But within the last few years it has been discovered, that by exposing timber to hot air in an oven, it can be as completely dried in a few days as formerly in two, three, or four years. An example of this process may be seen at the yard of Messrs. R. Napier & Sons, at Govan. It is unnecessary to enlarge upon the economy which it effects in time and money.

26. The PRESERVATION OF TIMBER, by filling its pores with antiseptic fluids, has occupied the attention of various inquirers for nearly half a century. Amongst the earliest substances employed with success, was a solution of sulphate of iron; more recently, a solution of bichloride of mercury was employed, as well as various other metallic salts. The saturation was at first effected by simple steeping, then by producing a partial vacuum by the condensation of steam in a receiver at one end of the log, while the pressure of the atmosphere forced the solution into the vessels at the other end; and lately, a method has been invented of forcing the solution by hydrostatic pressure into the vessels at one end of the log, so as to expel the sap at the other end, and saturate the log with the solution. Good success has attended the use, as a fluid for preserving timber, of a kind of pitch-oil, called in commerce "creosote," (although differing from the creosote of chemists), which not only prevents decay, but repels the various animals commonly

called "sea-worms," whose burrowing would otherwise reduce most immersed pieces of timber to the condition of a honeycomb.

27. The discovery of new FIBROUS VEGETABLE SUBSTANCES, in addition to those already known, occupies the attention of many naturalists.

28. Few materials have contributed more, by their discovery, to the advancement of practical mechanics than INDIA-RUBBER and GUTTA-PERCHA; and especially the compound of the former substance with sulphur, called VULCANIZED INDIA-RUBBER, which, by the perfection of its elasticity, the great variations of form that it is capable of undergoing, and its preservation of those properties throughout a great range of temperature, is equally well adapted to act as an extensible spring, and as a compressible cushion, to prevent shocks between hard surfaces. GUTTA-PERCHA, though softened by a moderate degree of heat, possesses a strength and an elasticity, at ordinary temperatures, which enable it to be employed as a substitute for leather belts in machinery. Its recent application to the coating and insulating of telegraph-wires, is well known.

29. A new process of *dressing leather* was introduced a few years ago, by which its strength is rendered much greater than it formerly was; and it is better fitted for supporting heavy loads, and transmitting intense forces in machinery.

30. As an artificial substitute for natural fibrous material, may be noted the WIRE-ROPES of Smith and of Newall; and the wire-cables, applied to suspension-bridges, by Roebling and other engineers, in which the flexibility of a fibrous material is combined with strength greater than is possessed by any animal or vegetable fibre. In most suspension-bridge cables, the wires are parallel; but in wire-ropes, they are spun into a spiral form, by an apparatus which makes them revolve round each other without turning about their own axes,—so that each wire, although it is *bent* into a screw, is *not twisted*,—a condition essential to the preservation of the strength of the wires unimpaired.

31. The ART OF PUTTING TOGETHER the materials of structures, requires for its accomplishment the observance of two kinds of principles,—those of STABILITY and those of STRENGTH. Stability insures that the pieces, of which the structure is made up, shall preserve their proper positions, without being upset or dislocated;—strength, that each piece shall preserve its figure, and remain whole under the utmost load that is to be laid on it. The theory of stability forms a branch of the science of statics, depending for its advancement on the application of mathematics to questions whose experimental data are few and simple, such as the weights of bodies, and the friction between their surfaces; the theory of strength, depending on mathematical investigation also,

is based on experimental data, in some cases of great intricacy and obscurity, of which our knowledge is in many respects imperfect, and which are in the course of being augmented every day.

32. The principles of stability, especially as regards masonry, were well understood by the Romans and by the Mediæval architects. The beauty of architecture depends, to a great extent, upon their observance. Amongst the contributions that have of late been made to our knowledge of them, may be mentioned the researches of Mr. Moseley, on the Stability of Structures; and those of Mr. Yvon-Villarceaux, on the Stability of the Arch (published in the *Memoires des Savants Etrangers*, vol. xii). The latter paper contains the first complete mathematical investigation of the conditions of equilibrium of an arch, under fluid pressure, which are also those of many arches, under a solid pressure; and the manner in which the solution is obtained by means of elliptic functions, is such as must inspire every mathematician with admiration. The results, when applied to practice, are likely to conduce materially to the stability, economy, and beauty of large stone bridges. The theory of the stability and pressure of earth has recently been reduced to a system based on the sole law of the proportionality of the friction to the pressure, without any of the "mathematical artifices" hitherto employed; and a principle, called that "*of the transformation of structures*," by means of which, when a structure possessing stability has been designed, the figures of an indefinite number of other structures, also possessing stability, can be deduced from it by projection, may be expected to prove of some utility.

33. A mere catalogue of the names of those who have contributed, by their labours, to our knowledge either of the mathematical theory of the STRENGTH OF MATERIALS, or of its experimental data, would occupy a considerable time in being read. Your Reporters, mentioning only those who at present occur to their remembrance, have to name Galileo, Leibnitz, Huyghens, Hooke, Boyle, Newton, the Bernouillis, Euler, Boscovich, Coulomb, Belidor, Vince, Dupin, Marriotte, Smeaton, Robison, Musschenbroek, Young, Rennie, Bevan, Tredgold, Rondelet, Telford, Brewster, Fresnel, Gauss, Savart, Chladni, Navier, Poisson, Oersted, Colladon, Sturm, Mossotti, Cauchy, Lamé, Clapeyron, Grassi, Regnault, Wertheim, Chevandier, Carillion, Kirwan, St. Venant, Poncelet, Yvon-Villarceaux, Morin, Green, Stokes, M'Cullagh, Haughton, Kelland, Dunlop, Fincham, Mushet, Pasley, Brown, Brunel, Hodgkinson, Fairbairn, Stephenson, Clark, P. Barlow, P. W. Barlow, W. H. Barlow, Couch, Smith, Dobson, Galton, James, Daniell, Wheatstone, Watson, Kupfer, Forbes, Gordon, William Thomson, James Thomson, Jellett, Maxwell, Mallet, Russell, Fowke, Mendis.

34. THE MATHEMATICAL THEORY OF STRENGTH is a branch of the general theory of elasticity; and when that general theory is strictly applied to such problems as occur in practice, the mathematical expressions arrived at are so complex, that they have been exactly solved in but a few cases, and are in general too elaborate for practical use. It therefore becomes one of the functions of mathematicians who study this branch of mechanics, to seek for approximate solutions of the problems that it presents, which shall be sufficiently simple to be used as practical rules, without incurring too great a sacrifice of exactness. A remarkable example of success in this, is furnished by M. de St. Venant's investigations upon the torsion of bars, other than circular in section.

35. Amongst recent experiments on the *strength of stone* which have been made generally public, are those of Messrs. Wheatstone and Daniell, on specimens of stone prepared for the building of the Palace of Westminster. It is the practice of many architects and engineers—and it ought to be the practice of all—to test, by experiments, the stone proposed to be used in every building of importance. Mr. Alexander J. Adie's experiments on the expansion of stone and brick by heat, published some years ago in the *Transactions of the Royal Society of Edinburgh*, furnished data which are indirectly of importance as regards the strength of structures.

36. The principal sources of information respecting the *strength of timber*, and especially of those kinds which are most commonly employed in Europe, continue to be the experiments of Professor Barlow, as recorded in his work on the *Strength of Materials*, and (with the addition of some experiments by Tredgold and others), in *Tredgold's Principles of Carpentry*. The most important additions recently made to the information afforded by these works, have been the experiments of Mr. Hodgkinson on the resistance of timber to crushing,—those of Captain Fowke, on the specimens of timber at the Paris Exhibition of 1855,—and those of Mr. Adrian Mendis, on the Timber Trees of Ceylon.

37. The information collected in the standard work of Tredgold, on the STRENGTH OF IRON, received, a few years ago, most valuable additions from the experiments of Mr. Hodgkinson, who ascertained the great difference which exists between the strength of cast iron to resist direct crushing and direct tearing—the former being about six times the latter—a fact of the highest practical importance. Mr. Hodgkinson also ascertained the mode of variation of the resistance of cast and wrought iron pillars to a vertical load, and represented its law by a formula. Mr. Lewis Gordon has since shown, in a paper read to the Philosophical Society of Glasgow, that the results of Mr. Hodgkin-

son's experiments are capable of being accurately represented by suitably modifying the constant multipliers in a formula originally proposed by Tredgold; and this formula indicates the fact, that for a pillar whose length is less than twenty-seven or twenty-eight times its diameter, cast iron is the stronger material,—while, for a pillar whose length is greater in proportion to its diameter, wrought-iron is the stronger. To Mr. Hodgkinson is due the experimental investigation of the resistance of wrought iron tubes to a direct longitudinal thrust, and of the manner in which all granular substances give way to a direct crushing force, by splitting into wedges, cones, and pyramids, of a certain inclination for each material.

38. The resistance of wrought iron rivets to shearing, has been determined by Mr. Doyne (who commanded the Army Works Corps in the Crimea), and found to be nearly equal to the tenacity of boiler-plate.

39. The experiments which have recently contributed most to the advancement of our knowledge of the strength of iron, are those of Mr. Fairbairn. By him was invented that cellular construction, which enables wrought iron plates to withstand a thrust, and is essential to the practicability of those tubular girders large enough to transmit a train, the original idea of which was the invention of Mr. Stephenson. Mr. Fairbairn has determined the strength of iron at different temperatures (showing it not to be impaired at 600° F.), the strength of cast iron, after repeated meltings,—the strength of various kinds of plate iron, along and across the grain,—of various forms of plate and bar iron beams,—of different forms of boilers,—and of the different parts upon which the strength of a boiler depends, so that the giving them their proper proportions is now a matter of calculation. Many of Mr. Fairbairn's experiments have been made at the instance of the British Association; and, amongst others, those which have just been completed upon the resistance of thin tubes, such as the flues of boilers, to a pressure from without, tending to make them collapse.

40. Mr. W. H. Barlow, experimenting on the resistance of CAST AND WROUGHT IRON BEAMS to a TRANSVERSE LOAD, has recently found that resistance to be greater than that which corresponds to the direct tenacity of the material, in a proportion depending on the figure of the cross-section of the beam,—being greater as that figure becomes more compact, and approaches a solid rectangular shape. When a solid rectangular cast iron beam is broken under a transverse load, Mr. Barlow finds that the tension upon those particles which are most strained, viz.,—those at the middle of the lower side of the beam, is about two-and-a-half times as intense as the tension which tears a bar

of the same cast iron asunder directly. Mr. Barlow calls the additional resistance which he has discovered, *resistance of flexure*, and has framed an ingenious theory of the manner in which it is produced. It is possible, however, that it may arise altogether from the superior strength of the *skin* of the iron, as compared with that of the interior of the mass; for experiments on direct tension shew the tenacity of the interior, in the very centre of the mass, where it is weakest, while experiments on the cross-breaking of beams show the tenacity of parts of the mass, either at or near the skin. But be the cause of the additional resistance what it may, its discovery is one of the highest importance. It is described in two papers, published in the *Philosophical Transactions for* 1856 *and* 1857.

41. Dr. William Thomson, in the course of the present year, with the assistance of two students of his class, discovered a kind of resistance in elastic solids, analogous to friction, inasmuch as it retards, without finally preventing, both the strain produced by the application of a load, and the recovery from that strain when the load is removed.

42. The PROCESSES OF CONSTRUCTION, employed in the making of structures, depend on the nature of the material, and may be classed into *Earthwork, Masonry, Carpentry, and Metal-work.*

43. The unparalleled magnitude of the EARTHWORKS, including excavations, embankments, shafts, and tunnels, required for the Railways, which for more than a quarter of a century have been extending over the world, have naturally led to an increase of skill in the practical details of the operations by which they are executed; but it would be difficult to point out many specific inventions by which those operations have been improved, except some ingenious machines for digging earth and tunnelling in rock, which have been introduced to a limited extent. It may be mentioned as an interesting fact, that the cost of the ordinary earthwork of Railways, per cubic yard, is nearly the same all over the world, the differences in the wages of the excavators being compensated by the differences in their efficiency. For example, it is stated, that on the East Indian Railway, where the excavators' wages are about one-twelfth of the wages in Britain, twelve times as many excavators are required to do the same quantity of work, and the result is, that the cost of the earthwork is nearly equal in both regions.

44. Connected with the subject of earthwork, is that of FOUNDATIONS. The gradual extension of the use of concrete, in foundations on soft ground and under water, has already been referred to. A useful method of making foundations for heavy structures, such as viaducts, on soft ground, of great depth, is to sink cylindrical wells, lined with brickwork or ashlar masonry, resting on a drum-curb, which is lowered

by undermining it from within, while the building of the lining is continued at the top, until a firm stratum is reached, when the well is filled with concrete, or arched over; so that each well forms a pillar, resting on solid ground; and on a sufficient number of such pillars, suitably placed, the superstructure can be erected. This method has been followed with success on the Indian railways.

45. A method of making FOUNDATIONS IN WATER AND MUD, first introduced at the new bridge over the Medway at Rochester, is now coming into extensive use. A vertical cast iron pipe, extending from the bottom to about nine feet above the surface of the water, and large enough for men to work in, is bolted together in lengths, with internal flanges; and on the top is bolted a cast iron bell, having within it a box with double doors for entrance and exit, and a windlass and platform. A steam engine forces air into the bell until all the water is expelled from the vertical pipe, and continues to force in a supply sufficient for the workmen, who excavate the materials at the bottom, so as to undermine the pipe and allow it to sink,—passing themselves in and out, and removing the materials, when required, through the box, which is so contrived that only one box-full of compressed air escapes at each time when the box and its doors are used. When the tube has sunk, so that the lower edge of the bell is near the water, the compressed air is blown off, the bell removed, a new length of pipe bolted on, the bell replaced, and air again forced in; and the operation proceeds as before, till a firm stratum is reached, when the pipe is filled with concrete or with masonry, so as to form a pillar to support the superstructure. This method has recently been applied on a very great scale in Mr. Brunel's viaduct at Saltash.

46. The STEAM HAMMER has facilitated the making of foundations, by its use in driving piles.

47. For founding and building in deep water, improvements have been made in DIVING-BELLS or DIVING-BOATS, by Dr. Payerne and by Mr. Hallett, which enable those machines to rise, sink, move from place to place, and otherwise manœuvre under water, at the pleasure of those within them.

48. In MASONRY and BRICKWORK, the greatest works which have been executed of late years, are remarkable rather in an architectural than in a mechanical point of view, if we except some bridges, such as the two principal bridges of Glasgow,—some large viaducts, such as that of Ballochmyle,—some great towers, such as those of Westminster Palace,—some tall chimneys, such as that of St. Rollox and that of Mr. Townsend's works at Port-Dundas,—and the piers of some iron bridges, of which the most remarkable for the magnitude of the undertaking are

those which are now in progress for the purpose of supporting Mr. Stephenson's tubular bridge across the St. Lawrence at Montreal,—the largest viaduct in the world.

49. The most remarkable examples of originality in CARPENTRY occur in America, where the comparative abundance of timber makes it the leading material for bridges and viaducts. The feature by which the carpentry of the present day is chiefly distinguished from that of former times, is the profuse use of iron in the form of bolts, straps, tie-rods, and sockets. Machine tools have of late been extensively applied to the shaping of timber in various ways.

50. METAL-WORK is the branch of construction, by whose advancement the present time is chiefly distinguished. The processes by which metals of all kinds, and especially iron, are formed into various shapes and put together, such as casting, rolling, welding, forging, wiredrawing, punching, boring, planing, turning, screw-cutting, rivetting, &c., are every day being improved, and the use of machinery to perform them is becoming more and more general. One of the most striking features of the progress in metal-work which is now going on, is the improvement in accurate workmanship, due to a greater or less extent to a long series of mechanical engineers, past and present, and especially to Mr. Whitworth, who, by means of instruments for mechanically magnifying small distances, enables a degree of accuracy to be achieved by means of the sense of touch, which no existing microscope would enable the sense of sight to attain. Accurate workmanship in machines is the most effectual means of diminishing friction, wear, and breakage, of obtaining economy of time, money, and materials, and of insuring efficiency of action. The success of Mr. Whitworth's well known improvements in fire-arms and projectiles is in the main due to accurate workmanship.

51. When structures are classed according to their PURPOSES, they may be distinguished, for the most part, into Mines, Houses, Lines of Conveyance, Harbours, and Vehicles, including Ships, which last class partakes of the character of machines.

52. On the subject of MINES, we shall say little, as being a special branch of engineering, which would be treated of in a more satisfactory way by a mining engineer. We may only remark, that great progress has been made for some time past in the art of providing for the health and safety of miners, by causing an adequate supply of air to circulate in the workings.

52 (A). In the same manner, we pass over the subject of HOUSES of all kinds, as being the province of the Architect more than of the Engineer.

53. Amongst lines of conveyance, we shall first mention ROADS. The

art of making roads of broken stone, with or without a rubble foundation, was brought in the present century, by Macadam and Telford, to a perfection which it would be difficult to surpass. Some of the finest examples of Telford's roads exist in the neighbourhood of this city; and it is worthy of remark, that that engineer never hesitated to take a circuitous course when it was conducive to easy gradients and economy of works. Paved carriage ways have been rendered more smooth, less slippery, and less costly, by the use of smaller paving-stones than it was formerly the practice to employ,—being cubes of granite, of about four inches each way, made from fragments too small to be used for other purposes, and laid on a gravel foundation. Bituminous pavements have already been mentioned. The art of making wooden plank-roads, so essential in newly settled countries, has been much improved by experience.

54. The immense extension of Railways has been the most conspicuous feature in the engineering of the last quarter century. During the whole of that period, a continual increase has been going on in the speed of the traffic and weight of the engines and vehicles; and a corresponding increase in the strength and stability of the roadway has been required. This has led to a gradual increase in the weight of rails, chairs, and sleepers, and to the exertion of much ingenuity, on the part of inventors, to devise a sufficiently strong, stable, and durable construction of permanent way.

55. In the selection of the course of a Railway, the judgment of the engineer is exercised to find the line which best combines economy in construction and economy in working. Economy of construction alone may require steep gradients and sharp curves, which are adverse to economy of working. In the great trunk lines of Railway, which were laid out at the commencement of the formation of the general network of Railways, economy of working appears to have been chiefly considered; in the lines now projected and in progress, economy of construction is more studied. The solution of the question of the best combination of those two kinds of economy, depends on the amount of traffic, and must be different in every different case; but experience has proved, as might have been expected, that a weak and perishable style of construction is never truly economical.

56. Amongst the great structures which the construction of lines of Railway has rendered necessary, perhaps the most remarkable are Viaducts. Those of stone and brick resemble, in most respects, the aqueducts of the ancients, and the viaducts of turnpike roads, except in being on a larger scale: the Ballochmyle Bridge, a semicircular stone arch of 240 feet span, has already been mentioned. Those of timber

have also been referred to; they comprise examples of carpentry, unparalleled for magnitude. But the most characteristic of the time are those of iron, the designing and construction of which is almost a new art, called into existence by the requirements of Railways. To this remark some exceptions have to be made; first, as regards cast iron arches, of which several remarkable examples, such as that at Sunderland over the Wear, and those of Southwark Bridge over the Thames, were constructed before the development of the Railway system; and, secondly, as regards Suspension Bridges, of which the Menai Bridge of Telford, on the Holyhead Road, long remained an unrivalled example, and whose use on lines of road has extended over all civilized countries. But the various forms of the wrought iron bridge, known as the Tubular Bridge, the Bow-string Bridge, and the Lattice Bridge, have been invented in succession, for the purpose of carrying Railways across wide spans and at great heights. The Tubular Bridge of Stephenson has already been referred to, and is too well known to require lengthened explanation; but it may be mentioned, that although the Conway and Britannia Bridges were the earliest examples of tubular girders, large enough to allow trains to pass through them, and stiffened by cells, still wrought iron rectangular hollow beams, or *box-beams* as they are called, after having long been used on the platforms of blast furnaces, were first employed in Railway construction, about 1834, by Andrew Thomson, of Glasgow, in the Bridge by which the Butterbiggins Road is carried over the Pollok and Govan Railway. One of the finest examples of the *bow-string* girder, is Mr. Stephenson's celebrated "High-Level Bridge" at Newcastle. A well known example of the use of Trellis-work or Lattice girders, is the Viaduct over the Boyne at Drogheda; it was designed and executed by Mr. Barton, for a line of which Sir John Macneill was chief engineer, and is a striking instance of the combination of strength with lightness, and of the exact verification of theoretical calculations in practice. The most simple of all Lattice girders, is that invented by Captain Warren, and known by his name; it has been used in what is in some respects the most remarkable bridge in the world, the Crumlin Viaduct in South Wales, of which the honour is shared between Captain Warren, the inventor of the girders, Messrs. Liddell & Gordon, the engineers, and the Messrs. Kennard, the contractors. The piers are skeleton frames of cast iron, and rise to the enormous height of 220 feet above the valley of the Taff; yet this gigantic structure has cost about one-half of the sum, per cubic yard covered, that had been considered cheap for previous Viaducts. Mr. Brunel has designed some very peculiar iron Viaducts, of immense size, such as that over the Wye at Chepstow, and that over the Tamar at

Saltash, of a class intermediate between tubular, bow-string, and suspension bridges.

57. The use of Suspension Bridges on Railways has been delayed and limited by their flexibility, which might give rise to dangerous oscillations during the passage of trains at high speeds. Were it not for this objection, their lightness and economy would render them preferable to all other structures for crossing wide spans. Nevertheless, they have in some cases been used, the speed of the trains being moderated in passing over them. The celebrated Niagara Railway Suspension Bridge, designed by Roebling, is of the immense span of 822 feet, and has two platforms, the upper for the Railway and the lower for a road. In the case of a structure so large, the weight of the wire cables, suspension rods, and platform, is so great in proportion to that of a train, that the oscillation produced is but small: it would not be so in a suspension bridge of less magnitude. It has long been the practice to stiffen suspension bridges, to a certain extent, by means of a lattice framework; but when it has been proposed to stiffen them thoroughly by that means, it has been objected, that auxiliary girders would have to be used strong enough to carry the load by themselves, and that the chains would be superfluous. Some experiments by Mr. P. W. Barlow, on models, have shown that this objection was founded in error; and that auxiliary girders, extremely light in comparison to what had been supposed to be necessary, will be found sufficient to stiffen a suspension bridge, and fit for Railway traffic at high speeds. A theoretical calculation, undertaken since Mr. Barlow's experiments were made, has shown that mathematicians might have anticipated this result, had they turned their attention to the subject, and that girders of four-twenty-seventh parts of the strength required to support the entire load will sufficiently stiffen a suspension bridge. That conclusion will be tested in practice by the execution of a bridge, designed by Mr. Barlow, at Londonderry.

58. Although the success of Railways has diverted the public attention from Canals, these continue to be the most economical lines of conveyance for all articles in whose transport speed is of little importance. Amongst the structures whose use on Canals is recent, may be mentioned *inclined planes*, for transporting boats from one level to another, to save the expenditure of water at locks, and *suspension aqueducts*, hung by wire cables,—a kind of structure first introduced in America, by Mr. Roebling. The continual and undisturbed uniformity of the distribution of the weight in canals, renders the mode of support by suspension from chains or cables peculiarly well suited to their aqueducts; and it is remarkable that so obvious a principle

should not have been discovered until so late a period in the history of canals.

59. Canals form a connecting link between lines of conveyance for passengers and goods, and Lines of Conveyance for Water. These are either for drainage or for water supply.

60. The principles of the drainage of large districts of country have been studied and applied from a very remote period; and their progress has been so gradual, that it is difficult to fix on great leading events in it. Perhaps the most striking work for that object in Britain is the Great Bedford Level—a large and straight canal, which acts at once as a channel and as a reservoir—collecting the waters of the district during the intervals between low tides, and discharging them rapidly at low water, through great flood-gates.

61. The Drainage of Towns has for some years been making rapid progress, both as to the extension of its use, and as to improvements in the art of laying out and constructing the drains. There is still, however, much room for further improvement.

62. Along with the branches of sanitary engineering, that which relates to Water supply has recently made great progress, not so much in the magnitude of the works and of the quantities of water supplied by them, in which the ancient Romans are still unsurpassed, as in the art of providing large supplies of pure water at a moderate cost, whether by pumping engines, by the collection of water in artificial reservoirs, or by drawing it from a natural reservoir, such as Loch Katrine,—a source of supply for this city originally proposed by Messrs. Gordon and Hill.

63. Lines of Conveyance for Gas belong to a special branch of engineering, so intimately connected with practical chemistry, that we leave it to those who may report on that branch of applied science.

64. Of Lines of Conveyance for Signals, that which has superseded all others is the Electric Telegraph. The construction of telegraphic lines on land is simple and well known, and has not recently been marked by any great improvement. In long lines of Submarine Telegraph, a difficulty in making signals, arising from the electrostatic charge of the conductor, was predicted from a theoretical investigation by Professor William Thomson, and means of overcoming that difficulty were invented by Mr. Whitehouse. For such lines, batteries of great power, and receiving instruments of extraordinary delicacy, are required; and in both these respects, the latest step in the march of improvement has been made by Professor William Thomson, as is shown by his instruments having succeeded in transmitting intelligible messages through the damaged Atlantic Cable, when all other means had failed.

65. The Harbour Works of recent date are remarkable rather for magnitude than for novelty of principle. Some reference has already been made to the methods employed for founding and building masonry in deep water. With respect to those jetties, piers, and lighthouses, which stand on posts or piles, allowing the waves to pass unresisted, the most remarkable invention of recent date, is that of screw piles, by Mr. Mitchell of Belfast. The knowledge of the true principles of obtaining and preserving deep water in tidal channels, has for some time been gradually advancing; and an excellent example of its application is afforded by the Clyde Navigation. Amongst recent harbour works of magnitude, may be mentioned those of Cherbourg, Plymouth, Dover, Tynemouth, and Sunderland.

66. Amongst Land Vehicles, Railway Carriages may be specified. The tendency of the present time is to increase their size, so as to augment their accommodation for passengers, as compared with their cost. On lines with sharp curves, some advantages are possessed by carriages constructed in the American style, of great length, supported at the ends by rollers and pivots, upon a pair of small four-wheeled trucks.

67. In Ship-building, the extension of the use of iron instead of wood is well known; but, on account of the difficulty of keeping the bottoms of iron ships free from barnacles, there has been of late a certain disposition to return to the use of wood for sailing vessels. The progress of improvement in iron ship-building is much retarded by the manner in which the builders are restrained from exercising the skill resulting from their experience and ingenuity,—being fettered in some things by government regulations, and in others by conditions as to the forms and proportions of ships, laid down by the purchasers of them and by underwriters. Another cause which has for a time retarded improvement in iron ship-building has been the practice of imitating the structure of a wooden ship, with keel, ribs, and planking; a construction which is the most suitable for timber, but quite unsuitable for iron, as was well pointed out by Mr. Scott Russell at the meeting of the British Association in Dublin. The Great Eastern is an admirable example of the use in ship-building of the true principles of construction in iron; and it is to be hoped that other examples of the same kind may be multiplied, and that all iron ships may be constructed so as to give the greatest strength and capacity with the least weight, and so to realize the great principle of economy.

68. Besides strength and capacity, a ship requires stability and speed. The principles of the stability of ships were long ago investigated by Bossut, and other French mathematicians, and successfully applied to

practice in the French navy, the ships of which became examples in this respect to the rest of the world. The building of ships of the forms most suitable for speed, was at first cultivated chiefly by the Americans, who attained great perfection in it by practical experience. Of late years it has also been cultivated by ourselves with good success, and in a great measure by practical trial alone. The *Wave-line System* of Mr. Scott Russell was deduced by him from experiments on the resistance of boats and transmission of waves, and has been put in practice with success, both by Mr. Russell himself, and by other builders. It must be admitted that the main principles of that system,—viz., that the figure of the water-lines of a ship should be that of a wave, and that the lengths of her bow and stern, best suited to a given speed, are respectively the half-lengths of waves of certain kinds which travel naturally with that speed,—are founded to some extent on analogy, and not on strict demonstration. But even supposing that Mr. Russell's system is not absolutely the best, it is certain that it must be a good approximation towards the best system.

69. Considerable progress has of late been made both in the theoretical determination and in the practical use of the law which connects the FIGURE, SIZE, AND SPEED OF A SHIP, with the POWER required for her PROPULSION. Experiments on models have thrown but little light on this problem, which can be solved only by accurate recording of the results of experience on the large scale.

70. The consideration of ships, which are machines as well as structures, has led us to the subject of MACHINES in general. Machines may be considered in three lights :—First, with respect to the prime mover which drives them; secondly, with respect to the transmission of power and motion from the prime mover to the working parts; thirdly, with respect to the nature of the useful work performed.

71. The EFFICIENCY of a machine is its economy of power or energy; that is, the ratio of the useful work performed to the energy exerted. *Work* is measured or expressed by the product of a resistance into the distance through which it is overcome; for example, by the product of so many pounds into so many feet, called so many *foot-pounds*. *Energy*, or the capacity for performing work, is expressed in the same way. In all machines,—indeed, in all systems of bodies acting on each other in any way, and in the universe itself, the *Energy exerted is equal to the work performed:* but in machines, constructed by human art for human purposes, part of the work always consists in overcoming resistances foreign to the purposes of the machine, and is said to be *lost* or *wasted*. The remainder is the *Useful Work*, which, together with the lost work, makes a total of work equal to the energy expended. The great end of

improvement in machines is to diminish the lost work, so as to make the efficiency approximate to *unity*. The introduction into the theory of machines of correct ideas respecting those general principles, has been of great practical utility. It is due chiefly to Carnôt, Coriolis, and Poncelet, in France, and to Smeaton, Mr. Moseley, and other writers, in Britain.

72. Delusive machines, from which their projectors expect to realize an efficiency greater than unity, form the class commonly called PERPETUAL MOTIONS. It is satisfactory to observe that the patent lists show a slight diminution in the proportionate number of such projects.

73. The ordinary sources of the power of PRIME MOVERS are, Animal strength, the weight and motion of water, the motion of wind, and heat; to which may be added electricity and magnetism, as sources of power, sometimes, though rarely, employed. Dr. William Thomson has proved (what, indeed, George Stephenson is said to have maintained before him), that the original source of the energy obtained by all these means, is the sunshine; and from Dr. Thomson's researches also, founded on an idea first put forth by Mr. Waterston, there is reason to believe that the light of the sun is produced by the friction of showers of matter falling towards him under the force of gravitation.

74. Little has been done of late towards the improvement of the modes of using animal strength. It is worth noting, however, that Dr. Scoresby and Dr. Joule, a few years ago, pointed out, that animals are the most efficient of all prime movers. They are not the most economical, because of their food being more costly than the materials consumed by inanimate engines.

75. The WEIGHT AND MOTION OF WATER act in prime movers, which may be classed as *Water-pressure Engines*, *Overshot* and *Breast-Wheels*, *Undershot-Wheels*, and *Turbines*.

76. WATER-PRESSURE ENGINES, in which the water drives a piston, have been brought to high perfection by various inventors, especially Mr. Armstrong, so as to work with great efficiency. They are applied to hoists and cranes, to pumping, and to the driving of mechanism in general.

77. The greatest improvement in OVERSHOT and BREAST-WHEELS, is that invented by Mr. Fairbairn, which consists in the simple expedient of providing an outlet at the back of each bucket, to permit the escape of air while the water enters in front, and thus to prevent that loss of power from the agitation and waste of water, which was formerly an obstacle to the use of overshot-wheels at all except very low speeds, and which even at low speeds increased their cost, by making it necessary to use a wheel considerably broader than the stream of water

The efficiency of overshot and breast-wheels is now from seven to eight-tenths.

78. UNDERSHOT-WHEELS have had their efficiency doubled—(it having been increased from three-tenths to six-tenths),—by Poncelet's invention of curved float-boards, which throw the water backwards relatively to the wheel, and cause it to drop into the tail-race without horizontal motion, so as to make it communicate the greatest possible proportion of its energy to the wheel.

79. TURBINES, or horizontal wheels, acted upon by a vortex or whirlpool of water, have long been used in a rude and imperfect form; but the bringing of them into an efficient state has been the work of recent inventors, who have made them realize an efficiency equal, or nearly equal, to that of overshot-wheels. Whitelaw and Stirrats' Turbine is a modification of Barker's mill or Reaction-wheel. In Fourneyrou's Turbine, a vortex moving spirally outwards, drives a vane-wheel surrounding the case from which the water is supplied. In Cadiat's Turbine, the vortex moves vertically, and the vane-wheel is below the casing. In Professor James Thomson's Turbine, or Vortex-Wheel, the vortex moves spirally inwards, and drives a vane-wheel, surrounded by the casing that supplies it with water. This wheel possesses over the others the advantage of being easily regulated, and of requiring a less speed for the production of its maximum efficiency. Its invention was the result of an investigation, by Mr. Thomson, of the theory of the motion of fluids in whirlpools.

80. WINDMILLS have undergone no alteration in principle since Smeaton investigated their best forms and proportions. The details of their construction have been improved, along with those of other machinery.

81. The energy of HEAT may be made to drive a prime mover, by its effects on the volume and pressure of any elastic substance; but the only elastic substances which have been used in practice for that purpose are water, air, alcohol, and ether; and of these the last three have been used to so limited an extent, that water, operating in the STEAM ENGINE, may be said to be the only vehicle which is extensively used in practice for the mechanical action of heat.

82. In a STEAM ENGINE have to be considered—first, the efficiency of the furnace and boiler, being the proportion of the heat made available in the evaporation of water to the whole heat produced by the combustion of the fuel; secondly, the efficiency of the steam, being the proportion of the heat which disappears in performing mechanical work upon the piston to the whole heat expended in producing the steam; and, thirdly, the efficiency of the mechanism, which is the proportion

of the energy exerted by the engine on the machinery which it drives, to the work performed by the steam on the piston.

83. The EFFICIENCY OF THE FURNACE AND BOILER has from time to time been improved by a great number of inventors, sometimes by contrivances for insuring a thorough combustion of the fuel, by means of a regular supply of air, neither too much nor too little, and sometimes by giving a greater extent or a more favourable form to the heat-receiving surface of the boiler. Inventions for improving the combustion of fuel are so numerous, and involve so many controverted points, that we cannot venture to enter upon their details. An important series of experiments on the evaporating powers of the coal of the North of England has just been published by a committee who have for some time been at work. It is very desirable that similar inquiries should be carried out with reference to other coal-fields.

84. The production of heat from mechanical power, or of mechanical power from heat, depends on the LAW OF JOULE, that heat requires for its production, and produces by its disappearance, mechanical energy in the proportion of 772 foot-pounds for so much heat as raises the temperature of one pound of water by one degree of Fahrenheit's scale. Some such law as this was anticipated by all who considered heat to be a *state* and not a *substance*, but its *exact numerical determination,* though approximated to by Seguin and Mayer, was accomplished by Dr. Joule.

85. The EFFICIENCY OF THE ELASTIC VEHICLE in a heat-engine is regulated by a law which is a case of the general law of the transformation of energy, and which is as follows:—That *the proportion of the heat converted into mechanical energy, to the whole heat received by the elastic substance, is that of the difference between the absolute temperatures at which it alternately receives and gives out heat to the absolute temperature at which it receives heat.*

86. The discovery of this law in its general and exact form is of recent date; but in its special application to steam, WATT knew its practical effect sufficiently to be aware, that the efficiency of the steam was promoted by keeping the temperature at which it enters the cylinder as high, and the temperature at which it is condensed as low, as is consistent with the circumstances of the case; and this is the principle of his separate condenser, his clothing for the cylinder, and his expansive working, to lower the temperature of the steam by exerting energy against the piston, and not by mere abstraction of heat by means of additional water of condensation.

87. All engines in which saturated steam is used are in fact Watt's engine, modified and improved in the details. It is chiefly by expansive

working that inventors have sought to increase the efficiency of the steam; and amongst the earliest of those who were successful in doing so, may be mentioned Hornblower, Woolf, and other makers of Cornish engines; but your reporters must observe, that if they were to name all those engineers who have given proofs of skill and ingenuity in the manufacture of steam engines, the list would be as bulky as the whole of this report.

87 (A). The most promising method of increasing the efficiency of the steam beyond that which has hitherto been attained is that called SUPER-HEATING; that is, raising the temperature of the steam beyond the boiling point corresponding to its pressure, and thus enabling it to exert a given force through a greater space than an equal weight of saturated steam would do.

87 (B). To give an idea of the present condition of the steam engine, it may be stated, that in the most economical class, single-acting pumping engines, the duty of one pound of coal is not uncommonly 1,000,000 foot-pounds, and has sometimes been raised as high as 1,200,000; that in locomotive engines, ordinary land engines, and ordinary marine engines, that duty varies from 200,000 to 500,000; that in the most economical class of double-acting land engines, the duty is about 700,000, and that the same result has been attained in marine engines by recent improvements; and that one of your reporters was lately present at an experiment on a marine engine, in which a duty of 1,945,000 was realized.

88. The EFFICIENCY OF THE MECHANISM depends on accurate workmanship and proportions, in the same manner with that of machines in general.

89. A STEAM TURBINE or momentum-wheel, invented by Mr. Gorman of this city, was for some time used at the City Saw Mills. It is much to be desired that some precise experiments should be made on the efficiency of this kind of engine.

90. ELECTROMAGNETIC ENGINES depend, as to their efficiency, upon the law of the transformation of energy in another shape. They can be made to have a considerably greater efficiency than heat-engines; but they are less economical, owing to the much greater cost of the materials consumed by them.

91. In the TRAINS OF MECHANISM by which power and motion are transmitted from prime movers to the points where the useful work is performed, one of the most important objects to be attained is the diminution of the lost work to the least possible amount, through the *reduction of friction* and the *avoidance of shocks;* and that is accomplished by accurate workmanship, by adjustment of the strength of

each piece to the forces applied to it, so that it shall not, by being too large or too heavy, give rise to unnecessary friction; by the balancing of all moving pieces, so that their inertia shall not cause unnecessary strains, and by proper lubrication. As a novelty with respect to lubrication, may be mentioned the use of BITUMINOUS UNGUENTS, or mineral grease and oil, which appears to succeed well.

92. As a recent invention in the mechanism by which power and motion are transmitted, may be mentioned the FRICTIONAL GEARING of Mr. Robertson, in which wheels act upon each other by wedge-formed ridges and grooves, extending round their circumferences, instead of acting by means of teeth. This kind of mechanism has the same advantage which belts have, in occasionally permitting the wheels to slide on each other, so as to prevent sudden shocks.

93. There remains a third point of view from which machines may be considered—that which regards their PURPOSES, or the kinds of work which they perform. But although we have touched as briefly as possible upon all the preceding divisions of our subject, our Report has already extended .to as great a length as is consistent with the proper limits of a paper to be read before this Society; and, besides, the full consideration of machines, as regards their *purposes*, would embrace the whole range of Arts and Manufactures,—a subject not for one, but for many reports, and not for one committee of Engineers, but for several committees, each composed of persons conversant with a particular branch of Arts and Manufactures. Here, therefore, we beg leave to conclude for the present.

For the Committee,

W. J. MACQUORN RANKINE, *Convener.*

A few additions and alterations have been made in this Report, having reference chiefly to discoveries and improvements which were made in the interval between the time at which it was read (April, 1858), and that at which it was printed (November, 1858).

April 21, 1858.—*The* PRESIDENT *in the Chair.*

Mr. Hastie stated that the Council, at a meeting held yesterday, agreed to concur in a memorial to the Board of Trade from the Meteorological Society of Scotland, in favour of a grant of money to that Institution.

The President announced, that at an extra meeting of the Society to be held on Wednesday, the 28th instant, Mr. Thomas Rose, on the invitation of the Council, would exhibit and explain an apparatus invented by him, for illustrating the persistence of images on the retina.

Dr. Walter G. Blackie read a paper "On the Recent Acquisitions made by Russia at the expense of the Chinese territory of Manchooria, with some account of the river Amoor in its physical aspects and as a pathway of commerce."

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*Recent Acquisitions made by Russia at the expense of the Chinese territory of Manchooria, with some account of the river Amoor in its physical aspects and as a pathway for commerce.** By W. G. Blackie, Ph. D., F.R.G.S. With a Map.

The river Amoor claims our attention in consequence of the command of its navigation having passed into the hands of Russia, by whom it has been opened to commerce, and by whom it was employed as a means of transporting provisions, munitions of war, and supplies of troops to her forts on the Pacific at a period when we little suspected her to be in possession of so splendid a highway to the ocean.

The Amoor is one of the largest rivers in Asia, being only exceeded in length of course by the Yang-tse in China, and the Yenessei and Lena in Siberia, and in the area of the basin which it drains by the last two named rivers and the Obi, likewise in Siberia. From having direct communication with the north Pacific Ocean, it is superior as a commercial highway for conducting intercourse with foreign countries, to the other rivers of northern Asia, all of which fall into the almost inaccessible parts of the Arctic Sea. It is formed by the junction of

* *Authorities.*—Bericht über die Beendigung der Expedition von Udskoy-Ostrog durch das Oestliche Gränzgebirge, und das Amur-Gebiet bis nach Irkutsk, in 1845. Von Hr. von Middendorff. Beiträge zur Kenntniss des Russischen Reiches. St. Petersburg, 1855.

Die neusten Russischen Erwerbungen im Amurlande. Zeitschrift für allgemeine Erdkunde, 1855.

Die ostsibirische Expedition des Kais. Russischen Geographischen Gesellchaft. Zeitschrift für all. Erdkunde, 1857.

Über Nikolajewsk und das Gebiet am Amur. Zeit. für all. Erdkunde, January, 1858.

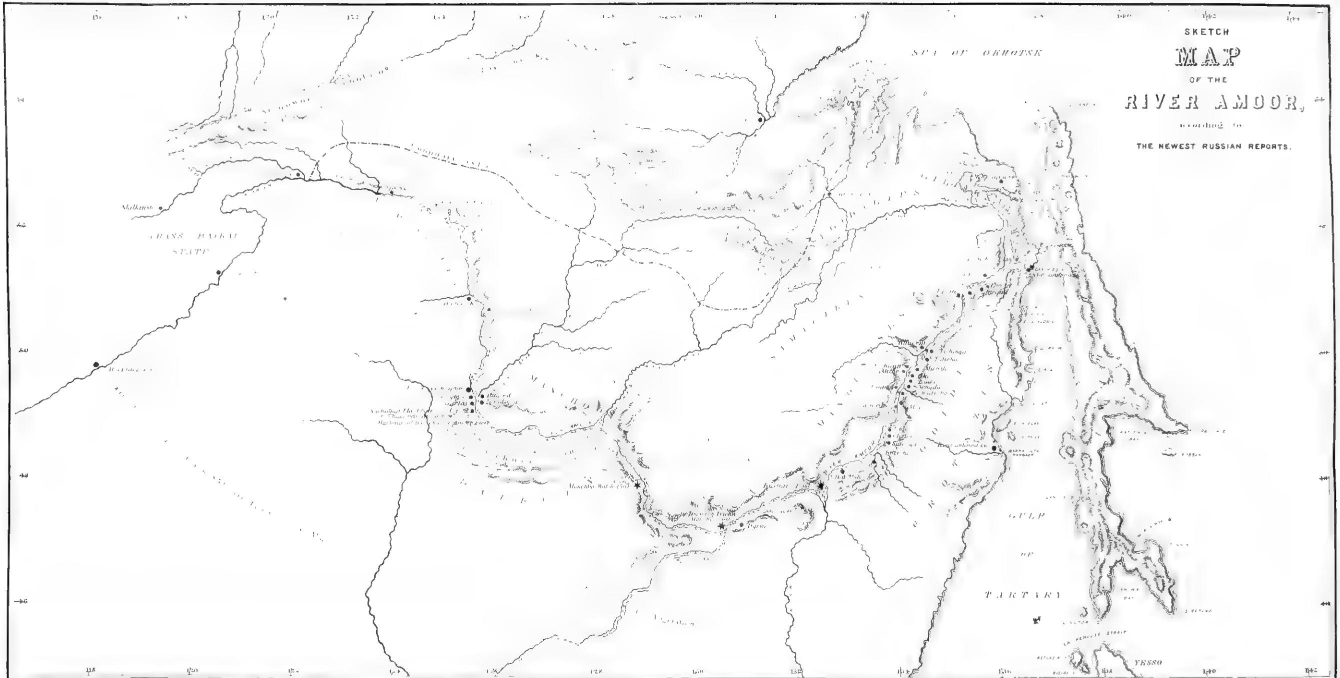
L. Schrenks, Erforschung des untern Amurlandes und der Insel Sachalin. Petermanns Mittheilungen, 1856.

Beschreibung des Amur-Stromes, mit besonderer Rücksicht auf Hydrographie und Ethnographie von Peschtschuroff. Beschreibung des Amur-Stromes, mit besonderer Rücksicht auf Geologie, Thier-und Pflanzenleben von Permikin. Die Amur-Mündung, von Schenurin. Die Vegetation des Amur-Landes, von C. Maximowitsch und Ruprecht. Schrenk's letzte Forschungen im Amur-Lande. Petermanns Mittheilungen, 1857, &c., &c.

the rivers Shilka and Argun, which unite their waters in lat. 53° 19′ 27″ N., lon. 121° 50′ 7″ E., in the north-west of the Chinese territory of Manchooria; thence it flows first in a south-east, and then in a north-east direction, and falls into the northern part of the gulf of Tartary, opposite the island of Saghalien, after a course, reckoned from the head waters of the streams of which it is composed, of 2,380 geographical miles, or about 2,731 statute miles; and, after draining a basin, whose area is estimated at 582,880 geographical square miles, or more than the united area of France, Austria, Great Britain, and Ireland. It is navigable throughout its whole course, from the junction of the Shilka and Argun to the sea, or probably not less than 1,500 statute miles.

Early in the seventeenth century, the Russians carried their arms into eastern Siberia, and, about 1636-1639, obtained information through some Cossacks of the existence of a large river in Manchooria, called by the Chinese He-long-kiang, but which they named the Amoor. This is the first notice of this river received by Europeans. In 1643, the Cossack officer, Vasilei Pojarkoff, accompanied by a band of adventurers, entered Manchooria, in the hope of discovering silver ore. Taking his departure from the newly founded town of Yakutsk, he proceeded up some of the affluents of the Adan river, till he reached the Yablonoi, or Stanovoi mountains, which separated the then territory of Yakutsk from Manchooria, and occupied two weeks in crossing this mountain range and reaching the banks of the river Seja, or Dschi. Along this stream Pojarkoff sailed to its junction with the Amoor, and he then navigated the latter river till he reached the ocean. Pojarkoff found no silver ore, but he returned laden with such a quantity of costly furs that other adventurers soon followed his steps. In 1650, the Cossack leader, Jerofei Chabaroff, animated by like views, entered the Amoorland, planted a line of fortified posts along the Amoor river, and the upper part of its principal affluents, and subdued the greater part of Manchooria to the Russian crown. Chabaroff did not reach the embouchure of the river, but this was accomplished by one of his officers, the Cossack Nagiba, in the year 1651.

For a time after Chabaroff's conquest, the Manchoos were too much occupied in consolidating their power in China, which had recently been brought under their sway, to give proper attention to the proceedings of the Russians, who were forming settlements in the Amoorland. Still the fortress of Albasin, founded by the Russians in 1658, was destroyed by the Chinese in 1664 and 1665—rebuilt by the Russians, and a second time taken and razed by the rightful owners of the soil. At length, in 1689, the Chinese emperor Kang-hi sent to the Amoor a strong military force, which the Russians could not withstand. All


SKETCH
MAP
OF THE
RIVER AMOOR,
according to
THE NEWEST RUSSIAN REPORTS.
SEA OF OKHOTSK
GULF
OF
TARTARY
YESSO

their settlements and posts were destroyed, and the whole Amoorland was once more brought under the dominion of the Manchoo rulers in China. On the 7th of September, in the same year, a treaty of peace was concluded at Nertschinsk between the belligerents, by which all the Russian possessions in Manchooria, and along the Amoor, were given up, after having been kept about forty years from the time of their subjugation by Chabaroff.

According to this treaty, and a subsequent one concluded at St. Petersburg in 1728, the boundary between the territories of China and Russia was to be formed by the Yablonoi or Stanovoi mountains, which proceed east from the source of the river Gorbiza, an affluent of the Shilka from the north. All the waters flowing to the Amoor were to belong to China,—those flowing in the opposite direction, to belong to Russia. Ignorance of local geography prevented any distinct boundary line from being fixed between the point where the mountain range turns northward and the sea. The Russians, however, taking the waters that flow to the north, the boundary line has been understood to pass south of the head waters of the rivers Ud and Maja. There being no provision in the treaty for securing to Russia the right of navigating the Amoor, the Chinese took advantage of the omission, and immediately closed the river, in which state it remained until a few years ago. Until which time, likewise, our knowledge of this great and important stream, and of the country which it drains, made no material advance. Even the Russian accounts of it were based merely upon the desultory information obtained during their occupation of the country in the seventeenth century, and the meagre notices found in Chinese geographical works.

In 1845, the Siberian traveller, Middendorff, undertook a journey in the Amoorland. He started from Udskoi, followed a zig-zag course from the river Tuggur, which flows into the sea of Okhotsk, to Uststrelotschnaja at the junction of the Argun and Shilka, and discovered on his route a number of Chinese boundary marks, placed not upon the crest of the Yablonoi hills, but far down the affluents of the Amoor. The Chinese had apparently placed the marks at the termination of the boat-navigation of these affluents, beyond which lies a hill country inhabited by tribes who depend upon the rein-deer for their livelihood, while the lowlands are inhabited by tribes who subsist mainly upon fish. The former being nomades one day on the north and another on the south of the Yablonoi mountains, esteem themselves Russian subjects, and pay their tribute of skins to the officer in Yakutsk—the latter call themselves Chinese subjects, and pay tribute to the Manchoos. It would thus appear that for a period of above 150 years, an extent of country, having an area of 33,000 square miles (50,000 versts), had been unwittingly handed over by Russia to China, and yet not taken possession of by the latter country. The boundary of 1845 indicates the new line of frontier thus found out. Whether arising from communications respecting this unexpected discovery or not, we do not know, but we are informed that in 1847 China granted to Russia the right to navigate the river Amoor. Along with this privilege, that of forming settlements and of erecting forts, would seem likewise to have been conceded. If not conceded, it was certainly soon taken for the settlement of Alexandrovsk, in the Bay of Castries, at which a fort was built, it appears to have been begun in 1850; and the fort of Nikolajewsk, at the mouth of the Amoor, was in all probability erected not later than 1852.

In 1854, when war broke out between Russia and the Western European powers, and it became necessary to strengthen the Russian positions on the Pacific Ocean, the privilege of navigating the Amoor was found to be of the greatest advantage. In the month of May in that year, a large armed flotilla, carrying above 1,000 men, soldiers, carpenters, &c., was organized at the town of Shilkinsk, which lies on the Shilka, 200 miles above its junction with the Argun. It sailed on May 13th, and reached the mouth of the Amoor on the 27th of June. It is doubtless to a subsequent and similar expedition that Peschtschuroff (who writes one of the most recent descriptions of the Amoor) refers, as having reached the mouth of the river in the middle of July, and as having supplied to Petropavlovsk the armament which enabled it to give the fleet of the allies such a warm reception. Many such flotillas probably descended this river in the course of 1854 and the following year, for we are informed that in the spring of 1855 long trains of fortress artillery, cannon balls, iron gun carriages, anchors, and steam-engines, passed through Irkutsk and over lake Baikal, all on their way to the Amoorland, so that the forts at the mouth of the river were soon alleged to be strongly fortified, and garrisoned by 8,000 to 10,000 men. Some of the steam engines were probably destined for Nikolajewsk, where there are now extensive government workshops for repairing ships and steamers. By having command of the Amoor, a saving of land carriage for these munitions of war was effected, of probably not less than 3,000 miles; the road from Irkutsk to Shilkinsk, from which the flotillas sailed, being about 1,000 miles, while that to Okhotsk, the former port of shipment for Petropavlovsk, is stated to be nearly 4,000 miles, and in many places through a very difficult country.

Where the Russian boundary is fixed at present, it is difficult to say. Probability is in favour of the left bank of the Amoor, with possibly a small portion of the right bank near the mouth of the river; in all likelihood from the fort of Alexandrovsk, in the Bay of Castries, northward. On the other hand, the latest* accounts received, seem to show that the Manchoo officials still exercise authority over the inhabitants of the left bank of the river, along a large portion of its course. They have posts at various points on both sides of the stream. Again, in Russian maps, the boundary is represented in 1852 by a line drawn from the river Argun, in about lat. 49° 25′ N. to the coast, in about lat. 44° 20′ N. Showing evidently, whatever may be the extent of the region over which the Russian sway actually extends at present, that the boundary is intended some time or other to reach the line thus indicated. If, however, we take the left bank of the Amoor to be the virtual boundary, then the Russians have obtained an accession of territory in the Amoor-land from the Chinese beyond what they possessed by the treaty of Nertschinsk, equal to more than twice the extent of the island of Great Britain—(110,000 Ger. sq. m. = 176,000 geo. sq. m.)†

The river Amoor, as has been already observed, is formed by the Argun and the Shilka, two streams which unite their waters in latitude 59° 19′ 27″ N., lon. 121° 50′ 7″ E. The former, under the name of the Kerlon, rises in the Kentei hills, part of the Altai range, to the S.E. of lake Baikal; flows first S.E., and then N.E., and during part of its course forms the boundary between the dominions of Russia and China. It is navigable, at least as far up as Argunsk, ten miles below which Schrenk was stopped by the ice, on October 9th, 1856. The Shilka is formed by the union of the Anon and Ingoda, which takes place about forty miles above Nertschinsk (the former rising hard by the source of the Argun in the Kentei hills), and is navigable, at all events, as we have seen, from Shilkinsk, whence the flotillas of stores, troops, and settlers appear to have been despatched on their way to the mouth of the Amoor. For the last 130 miles of its course, or thereby, the banks of the Shilka are rocky, barren, and uninhabited. As far as the lesser Gorbiza, a distance of about forty-six miles, both banks are composed chiefly of gray limestone, with seams of white marble of considerable thickness. Farther on, the limestone is replaced by granite-syenite and syenite-porphyry, in the former of which are inclosed large crystals of feldspath. In some places the syenite changes to diabas, and both these minerals continue to be seen for a space of nearly fifty miles, after

* Schrenk, dated Irkutsk, November, 1856.

† By intelligence dated St. Petersburg, August 21st, we are authoritatively informed that the Chinese have conceded the Amoor as the mutual boundary between their own territories and those of Russia. By the same treaty, Russia gains possession of both banks of the Amoor from lake Kisi northward.

which they are succeeded by granite, mica-slate, chlorite-slate, serpentine, talc, and then clay-slate, the last forming large rocks, overhanging the rivers on the right side, traversed by veins of quartz of various colours. The strata on the left side of the river, and likewise on the margins of the smaller streams pouring into it, give evidence of the existence of the nobler metals. Silver is wrought near Shilkinsk, where there are furnaces for smelting the ores. For the last 130 miles of its course, the banks of the Shilka are wild, inhospitable, and uninhabited, a character which the Amoor itself maintains as far as the junction of the greater Gorbiza, or Amasar, a distance of about forty miles below Ust-strelotschnaja. "Here," says Permikin, "the Amoor flows smoothly in a deep arm, in which large vessels and steamers could sail." Very little change is to be observed in the banks of the river till we reach Albasin, a further distance of about 120 miles. Between Ust-strelotschnaja and Albasin, the river passes through the Yablonoi mountains in a very winding and irregular course. Mica and clay-slate form the chief strata to be observed, and the vegetation is limited to a few species. On the hills, pines and larches prevail, and on the margin of the stream the sand-willow abounds, the former—for what reason does not appear—are said to be ruthlessly destroyed by the nomadic Tunguses frequenting this region. The masses of stones on the banks are protected from the cold of winter, and from the short continued but strong heat of summer, by a thin coating of moss. Here and there open out meadows and valleys, each of which is traversed by a stream frequently plentifully supplied with fish. In the rainy season, these valleys pour out such quantities of water that in two or three days the level of the Amoor is often raised more than fourteen feet. Islands standing singly and in groups, are numerous, generally in the bends, and only separated from the land during floods. They are frequently submerged, and their soil being thus fructified, they produce the service berry, which forms one of the chief articles of food on which the nomades of the district depend for subsistence.

After leaving Albasin, the islands increase in number, and as they occupy often the middle of the stream, assume the appearance of an Archipelago, forming a very picturesque and characteristic feature, but one not very favourable to navigation. The hills are not now so close upon the stream as they are higher up, but leave open banks, and assume a more rounded form. At times they approach again close in upon the river, and rise from its bosom in steep cliffs, and again becoming more distant, lower gradually down till they change into a range of steep isolated heights. This change in the direction and position of the mountain spurs is specially to be remarked from the rock Malaja Nadeschda (Little hope, lon. 125° 45′), to the mouth of the river Kamara. Close by the rock just named there is a bar in the river, in which there are three feet of depth when the water is low. The chief strata observed between Albasin and the mouth of the Kamara are sandstone, syenite, and amygdaloid ; the sandstone in many localities being carboniferous. One of the most noticeable geological features on this part of the river is the sandstone hill (lat. 52° 25′ N.), Zagajan, extending along one of the bends for about a mile, showing a steep white coloured cliff, about 250 feet high, towards the stream. At the foot of this hill are strata of conglomerate, in the debris of which agates were found. About half way up the cliff, and running in a slanting direction over the top of the hill, is a dark black streak, in some places of which funnels have been found from which ascends a black smoke, but whether this smoke arose from the coal having taken fire underground, or from some other cause, none of the reporters had an opportunity of ascertaining. At Albasin, the vegetation changes considerably. Pine trees no longer exclusively cover the heights, nor do they grow so thickly. The larch is replaced by the oak and the black birch on the southern slopes of the hills, at the foot of which grow the hazel and the elm, with a border of willow, ash, and wild rose. The nomades here still bear an unexplained enmity to the pine trees, dozens of which were seen lying cut every mile. On approaching the river Kamara, which joins the Amoor on the right, the scenery changes considerably. Larch and pine trees become seldomer, oak and birch more frequent, with poplar, ash, pear (*Pyrus spectabilis*), sand-willow, and sweet brier. The wide spread meadows are covered with magnificent grass which could depasture numerous flocks and herds, but all animated existence as yet is here in a state of nature.

The Kamara is a very important affluent. At its mouth is the most northern Chinese post for the surveillance of the tribes subject to their power, and here the nomades assemble during winter. According to native accounts, it maintains a depth of seven feet for about 160 miles upward from its mouth, to which distance it is navigable by boats. The valley of the Kamara forms a fine hunting ground, elks, sables, wild goats, rabbits, &c., being plentiful.

From the Kamara to the Seja the islands continue much as in the upper river. Granite is seen on the left bank, and both sides of the stream are hilly. The vegetation continues in like manner much the same, only pine trees are more plentiful. About latitude 50° 26′, on some flooded shallows and islands on the right bank, pieces of coal were found. This point is about 130 miles, direct distance from the smoking hill Zagajan, near which carboniferous sandstone was seen. On the left bank of the river, a few miles below the mouth of the Kamara, is another Chinese post, and just before reaching the river Seja on the right bank there is a third. At this last, named Amba-sachaljan, the houses, scattered and bad, are built of wood, reeds, and mud, and the windows are filled with oiled paper instead of glass. Round each is a clump of birch, elm, poplar, plane, and acacia trees, and each is provided with a carefully tended garden, in which millet and maize are sown, and small beets, radishes, leeks, onions, Spanish pepper, beans, and other vegetables are grown. There are few cattle, but pigs of various kinds, and barn door fowls are numerous.

The river Seja, or Dschi, along which it will be remembered, Pojarhoff sailed in his exploratory journey, here falls in on the left bank. It flows through a magnificent valley, and brings down such a large quantity of water that the Amoor gains greatly in width and depth by the accession. About twenty miles below the mouth of the Seja, and on the right bank of the river, lies the Chinese town and fortress of Sachaljan-ula-Chotun or Aigunt. Between these two points the banks are thickly covered with villages and isolated houses, and farther down, for some miles, numerous villages are met with. Sachaljan-ula-Chotun is the chief seat of the Chinese power on the banks of the Amoor. It has a considerable garrison, armed as Chinese usually are, and above the town in the harbour were seen thirty-five large river boats of about 100 tons burden each. No admission to this place is permitted.

The river Seja forms the boundary of a hill country. Beyond it, to the Burija, a distance of about 170 miles, the banks of the Amoor stretch out in wide prairie lands, fitted either for agriculture or cattle rearing. The vegetation becomes almost European. Here grow the lime tree, poplar, bryony, hazel, oak, black birch, &c. The plains are thickly peopled and extensively cultivated, and the inhabitants—Daurians, Manchoos, and Chinese—occupy themselves likewise with cattle rearing.

From the river Burija, which joins the Amoor on the left, near the middle of its course, in lat. 49° 23′ N., long. 130° 5′ 23″ E. to Cape Sberbiejeff, the banks are not wooded. On all sides, at a greater or less distance, hills are visible. Sometimes they approach close to the stream, and form sandy cliffs. At Cape Sberbiejeff, which is a high dark hill, the river turns suddenly south, and in a course of 180 miles, cuts through a ridge of lofty thickly grouped hills. On the right side, there still continue some small valleys, as far as the Manchoo post, at the mouth of the river Oou, which there falls in on the right bank; but beyond that point until the mountains, a branch of the *Chin-gan*, are crossed, the river is literally hemmed in between stone walls, which gradually close in upon it. The current here attains a speed of five knots per hour, which, with the steep hilly banks, render this locality uninhabited. Nevertheless, the soil shows good capabilities, and every accessible height is adorned with white and black birch, oak and elm, nor are larch and pine awanting. Notwithstanding of the great current, not a slip has been carried from either bank, excepting two islands which lie near the end of the rapid,—the one on the left, the other on the right side of the stream, which here has an equal depth all the way across of twenty-eight feet, with a stony bottom. The one island, about two-thirds of a mile long, narrow, and only a few yards high, is covered with trees, under whose shadow grow lofty grasses, some of which attain the height of man, intertwined often with the creeping shoots of the wild-vine,—the grapes upon which attracted the eye of the travellers. The right bank of the river is here low, and covered with rich vegetation; the left bank is steep, high, dark, and wild. A few miles farther on, the one side loses its wood, and becomes a fertile but monotonous flat; and the rocks of the left rapidly depart from the river, and leave it flat like the other. After this quick change, the river for a time maintains its southerly course—then turns suddenly east. Here begins an island sea, with long projecting reefs at the side, which continues to the mouth of the Soongari, and, even with little interval, to the island St. Kirile (lat. 49° 50′). These islands present little interruption to navigation, as far as the mouth of the Soongari; for they lie sometimes on the one, sometimes on the other side of the stream, and there is always plenty of room to pass them. The principal strata observed on this stretch of the river were mica and chlorite slate. Many indications render it probable that the more valuable metals may be found here.

The Soongari joins the Amoor on the right bank, in lat. 47° 42′, lon. 133° E., and is the largest of its affluents. According to some accounts, indeed, it should be regarded as the main stream, the Amoor being the affluent. The Soongari joins in a N.E. direction, and in consequence of forming a semi-circle near the end of its course, and the mouth being covered by a number of islands, the junction is not very remarkable. One phenomenon which is observed here may be noticed. The waters of the Soongari brought down from a broad fertile valley, with low banks and loose sandy soil, are very much discoloured, while those of the Amoor, flowing along a bed, as we have seen, chiefly composed of granite, syenite, clay, and mica-slate, are of a clear black colour. For a short way below the junction, a struggle is maintained between the waters of the two streams, and a sharply defined line marks the mutual boundary between them. As in the case, however, of the muddy Arve and the clear blue Rhone, the Soongari soon gains the victory, and thence to the sea the Amoor becomes a turbid stream. The Soongari forms one of the routes by which the Chinese traders pass to the Amoor. It is navigable at least as high up as Girin Chotun (667 miles), where vessels for the navigation of the river are built.

At the mouth of the Soongari, the Amoor has reached its farthest south point, being $5\frac{1}{2}°$ to the south of Ust-strelotschnaja. From this point, its course begins to be N.E., a direction which it maintains till it reaches the sea. As far as the mouth of the river Ussuri, another important affluent on the right, the banks, as a whole, are flat and uninteresting, backed by heights at some distance, and crossed by numerous streams,—at the mouth of one of which, named the Chorolog or Chorolak, which falls in where the stream is encumbered by a labyrinth of islands—large numbers of Manchoos gather in the middle of summer for the purpose of fishing. Still, the fishing in this locality does not, after all, appear to have great attractions for the Manchoos, of whom, with the exception of a few miserable huts, no settlements were seen between the mouths of the Soongari and the Ussuri, and these were not placed near the thicket of islands, but on projecting points of the river's banks. The chief strata observed on this portion of the river were grauwacke and greenstone schist.

The Ussuri, for a considerable way above its junction with the Amoor, continues to be of considerable breadth and depth. Its banks are thinly inhabited, yet in some localities Chinese settlers carry on horticulture, and raise various sorts of vegetables, such as cabbage, potatoes, cucumbers, beans, melons, water-melons, gourds, and also maize and red pepper; but tobacco, the most important article of exchange, both here and in the Amoor, is the chief object of attention. The valley of the Ussuri presents a large region, fitted for both agriculture and cattle rearing. Of the latter, none is carried on by the inhabitants, probably on account of the number of beasts of prey with which the valley is infested. Shortly before Schrenk visited it, a few horses kept in Purmi, at the mouth of the river, had been carried off by the tigers, and a like fate often befalls the domestic dogs. The inhabitants of this valley are composed of Golde and Orotsches, with a few Chinese engaged in trade and horticulture, with the Ussuri, closes the uninhabited region. At its mouth, when visited by Peschtschuroff, there was a Manchoo post on the left bank of the Amoor; Schrenk, who was there in 1856 on his journey up the river, says, here he met with the first Russian post *on the left bank.* The Golde, who are numerous in this locality, know all the creeks and islands in the river. They furnished Peschtschuroff with pilots, who conducted him to the village of Sawaga, sailing during the night as well as during the day, through a labyrinth of channels, sometimes not more than 260 to 130 yards wide, and sometimes even narrower. The Ussuri forms the boundary between the extensive plains which lie higher up the Amoor, and a hill country which thence accompanies that river to the sea,—allowing space, indeed, for its arms and islands, but sometimes likewise sending high spurs to its very brink. Here we meet with numerous settlements of Golde,—first two and three houses together, and then in dozens. A few miles north of the village of Sawaga, the Amoor separates into two broad arms, which unite again into one stream at the island of St. Kirile; but lower down, at Cape Ommoi, a high round hill, the river is again divided up in a most remarkable manner, exhibiting a wide stretch of water, with here and there some islands interspersed through it, and bordered at the horizon with blue mountain peaks. From this point the river flows more in one broad channel. However, after receiving the Goryn, Numur and other shallow streams, it divides again into arms, two of which connect it with lake Kisi and the post on its banks named Kisi or Mariinsk. Fourteen miles before reaching Nikolajewsk, all the arms unite again to form one stream $1\frac{1}{2}$ to two miles broad, and twenty to thirty fathoms deep. Notwithstanding the great mass of water which thus flows on, with a speed of three knots an hour, to the Tartarian gulf, the current is not sufficient to clear a proper channel into the sea. Behind the promontories Pronge and Tebach, near its mouth, shallows begin, so that at low water the depth on the north shore is only ten feet, and on the south thirteen feet,—a statement, however, that scarcely tallies with the fact that frigates are known to have sailed for protection right in under the guns of fort Nikolajewsk. From the Ussuri downwards, the chief strata observed were mica and siliceous slate and sandstone; as far as island St. Kirile, siliceous slate and greenstone schist; thence to lake Kisi, near which iron ore was seen; and clay-slate and greenstone schist, with several varieties of iron ore, on to Nikolajewsk. South of the mouth of the river is amygdaloid, and north and south of the mouth on the seaboard, there is limestone. On the left bank of the stream, below the island of St. Kirile, the hills rise in four parallel ridges, one above the other, of which the last is destitute of wood. The vegetation, as we descend the stream, gradually changes, and assumes a more northern aspect, till about half way between the Goryn and lake Kisi the foliage trees cease, and only pines and larches cover the hills. The valley of the Goryn, which contains several villages, is wooded both with pines and foliage trees, and is a favourite hunting ground of the natives, who here take sables, foxes, otters, and elks. The mouth of this river forms the northern boundary of the tiger and of the Siberian stag, neither of these animals being met with farther north than this point. From the mouth of the Amoor there is access to the ocean, both north to the sea of Okhotsk, and south through the narrow strait at Cape Lasarew to the gulf of Tartary and the sea of Japan. Lake Kisi, which has already been named, is about 28 miles long, and nowhere above 450 yards wide. It is connected with the Amoor by two broad arms, and is separated from the Bay of Castries, in the Gulf of Tartary, by a mountain ridge ten miles broad, over which there is easy access. On its north bank, near the Amoor, lies the Russian post of Kisi or Mariinsk.

The population on the banks of the Amoor, as we have already seen, is very unequally distributed. It is composed of about ten tribes—settled, half-settled, and nomadic. To the first class belong the Manchoos, Nekans, and Daurians, the first named being the most important, and the governing race which garrisons the forts and levies the tribute. All three are much alike in external appearance, having round hard visages, flat eyebrows, a dark bronze colour, medium stature, and dark blonde hair, which they twine into a tail. The common people do not shave the head, and their wild native bush resembles a badly built hayrick, round which the tail is twisted in the vain attempt to keep it in order. Their dress consists of a white shirt of Chinese cut, very wide linen trousers, either pushed into the stockings, or bound round at the knee with a band, Chinese shoes with turned up toes, or made of hide without any special shape. Besides the shirt, they wear a short upper garment, composed of wild animal or fish skin, bound round the body with a leathern girdle, in which is stuck a small knife, a copper tobacco pipe, apparatus for obtaining fire, and a tobacco pouch. The chief seat of the Manchoos is on the rich plains near the middle of the Amoor, stretching about 100 miles below the confluence of the river Seja. They cultivate the fields, and appear to be in comfortable circumstances. Besides agriculture, they are engaged in cutting wood, for which they have to go to near the Kamara, and in fishing among the islands near the mouth of the Chorolog.

The Golde, Manguntses, Samagires, and Giljaks, as they are hardly at all acquainted with agriculture, and generally shift their dwellings in winter, may be reckoned half-settled. They dwell all along the Amoor downwards from the mouth of the Ussuri. The Giljaks have spread out on the seaboard, and even into the island of Saghalin. Of these tribes the Golde is the most numerous, and all support themselves by fishing. The winter dwellings consist of a large quadrangular building, with benches along the walls and round the fire-place, which is in the centre. In one of these houses is to be found a whole family, from grandfather to grandchild, often amounting to thirty or forty individuals, male and female. Round the houses, and near the banks of the stream, are places for drying nets and fish; and at a little distance from the river are to be seen cages containing bears. Among all the tribes, especially among the Giljaks, the bear is an object of the most tender solicitude to the whole village; and in their religious ceremonies he plays the first part, and also the last, as far as he is concerned, for he is ultimately slain and roasted. Their fishing-boats are formed of three boards, fastened with wooden nails; and vary in size from two to sixteen oars. For short distances, when speed is the object, they use small boats made of birch bark. In winter they travel on light sledges drawn by dogs.

The purely nomadic tribes are the Orotshes, a branch of the Tunguses, the Manegres, Gantses, and Kapliares. The Manegres are the most numerous. They frequent the basin of the Kamara and its vicinity, occupy themselves with hunting and fishing. All these nomade tribes are so poor that they often subsist for weeks on service-berries, and, notwithstanding the severity of the climate, go nearly half naked.

Respecting the climate, along the Amoor, the accounts before us give little information, except such as is to be derived from the nature of the vegetation that grows upon its banks. From the fact, that among trees, only pines and larches will thrive near the mouth of the stream, and yet, at its southern bend, five and a-half degrees farther south, the grape vine grows wild, and excellent tobacco is cultivated, we at once obtain a general impression of the varied nature of the climate in the extensive regions traversed by this mighty stream. One authority, speaking of the lower Amoor, says, the summers are short, but pleasant—snow melts the beginning of May. There is ice in the gulf to the middle of June, though the river at Nikolajewsk is clear at an earlier period. In September the mornings are cold, and in October snow falls. Schrenk was stopped by ice in the Argun on October 9th, in nearly the same latitude as Nikolajewsk. We shall therefore probably not greatly err, if we take the mouth of the Amoor to be closed somewhere from the beginning to the middle of October. Admiral Newelskoi, as the result of three years' observations, informs us that the ice in the firth of the Amoor clears away from the 1st to the 13th of June. The season, during which it is open for navigation from the ocean, may therefore be taken as beginning about the middle of June, and ending at the commencement of October. At Kisi, the Amoor is free of ice for six months, and the Bay of Castries is open for eight months. To insure a longer season for navigation than is attainable at Nikolajewsk, it is said to be in contemplation to unite Kisi with the Bay of Castries by means of a railway.

Apart from the accession of territory rich in furs, probably rich in metals, and possessing large tracts with a genial climate excellently suited for colonization, the opening of the Amoor is an important event for the government of Russia. By means of this great water way free access is obtained to the ocean for several months in the year, enabling supplies to be forwarded from the corn growing country round lake Baikal to the ports and settlements on the Pacific more speedily, and at a cheaper rate than by the long and difficult land route by way of Yakutsk to Okhotsk. One single fact will illustrate the remarkable advantage thus gained. In Kamtschatka, meal which formerly had been sold for from 10-15 paper roubles the pound (about 8s. 4d. to 12s. 6d.), has, since the opening of the Amoor, fallen to 15 kopecks, silver (about 6d). Not only Kamtschatka, but all the eastern part of Siberia, will feel the impulse given by the facilities thus attained for sending her mineral and other riches to the ocean, and receiving in return articles of foreign product at a price much below what she must have formerly paid. What effect the opening of the Amoor may have upon the great exchange mart of Kiachta and Maimachen, it is not easy to predict. It may, however, be reasonably supposed to be considerable. The Russians receive there annually 4,700,000 lbs. of tea, some authorities say 12,000,000 lbs. Besides the tea, they receive through this mart silks, nankeens, porcelain, sugar-candy, musk, rhubarb, and tobacco. In return, they supply the Chinese with furs, skins, leather, woollen and linen cloth, cattle and reindeer horns, from which last a gelatine is obtained that forms a much esteemed delicacy among the celestials. Perhaps the greatest tea district as yet ascertained is the vicinity of Shanghai, a port which is distant from Maimachen 1,600 miles, measured in a bee-line over mountain and dale. If we call the road distance 3,000 miles, we shall probably not over state the length of the path along which the tea must be carried before it reaches the hands of the Russians. Very probably part of the quantity now annually sent to Siberia may find its way by sea to the mouth of the Amoor, and thence by water to the interior of the country; and it is not at all unlikely that some portions of the other kinds of goods, now sent to Maimachen, may follow the tea to Nikolajewsk or to the Bay of Castries. Chinese traders even now descend the Soongari and the Ussuri to the Amoor to barter with the natives, and go as far as the village of Pulj, which lies to the north of lake Kisi. The traffic by these routes may be extended, and Russia may yet form in the Amoorland a market more extensive and more profitable than that of Kiachta.

Our cousins across the Atlantic have for some years been directing their attention to Siberia as a profitable market, and now that the navigation of the Amoor has been opened, they have been among the first to take advantage of it. An American barque named the Oscar, from San Francisco, belonging to a German named Otto Esche, on the 14th of July, 1857, reached the Bay of Castries, where pilots were obtained to guide the vessel to the mouth of the Amoor. While the Oscar remained at Nikolajewsk other six vessels arrived, two from Boston, one from Hong-kong, and three Russian. It would appear that, besides such furs as may be obtained, the chief articles of trade for a return cargo are confined meantime to Siberian hemp, said to compare favourably with that of Russia, tobacco, which has already been referred to, and hard wood, such as oak, beech, plane, &c. The Russian government has fourteen steamers on the river, and there are other fifteen belonging to private parties. Some of these vessels are employed in towing flat boats with cargo from Transbaikalia, and the more southern parts of the Amoor to Nikolajewsk. These flat boats, many of which are 60 feet long 20 feet broad and 8 to 9 feet high, are built at the junction of the Schilka and Argun, and at the mouth of the Seja. They fetch salt meat, ham, pease, hemp, rye-meal, leather, iron ware, wooden casks, household ware, &c. Dried fish may likewise become an important article of trade, the Amoor being frequented by incredible quantities of fish, including salmon, salmon trout, sturgeon, pike, &c., and a fish named Iluam-iu, weighing 1,000 to 2,000 pounds, with very white delicate cartilaginous flesh, and so highly esteemed by the Chinese officials that it is taken for the emperor's table.

Peschtschuroff tells us, that besides coin, namely, small silver money, the best articles for trading with the natives, are a kind of blue woollen cloth, of an inferior sort, called Daba, Russian tobacco, which on account of its intoxicating quality is preferred to the Chinese, and even to the American, powder, lead, small ornamental articles of copper, plated or gilt, common glass beads, &c.

Foreign merchants, according to the report of the owner of the Oscar, are very well received by the Russian officials. There are several mercantile houses already in Nikolajeswk, of which two are American, several Russian, and one German. The Californian butter and wine, brought by the Oscar, met with a ready sale, but foreign goods generally are not yet in great demand, excepting by the Russian settlers and soldiers, who are found in all quarters, and who give in return for what they require valuable products, such as furs.

Besides trade with foreign parts, an active intercourse will be kept up between Nikolajewsk and the other Russian ports in the Pacific, more especially with Ajan, the head-quarters of the American-Russian Fur Company, with Okhotsk, the seaboard termination of the great land route from eastern and central Siberia, by Irkutsk, and Yakutsk,and with

Petropavlovsk, in Kamtschatka, to which last, we are informed, steamers already ply at intervals. Important for the development of the Russian marine on the Pacific, and for the general trade to Nikolajewsk, are the excellent timber to be obtained on the Amoor, and the excellent coal, said to equal the best English, found and already wrought in Jonquiere Bay, in the island of Saghalin, an island on which the Russians have evidently set their heart, and over which they will likely soon extend their sway (as indeed they appear in part to have already done), notwithstanding of the objections that may be urged by the brother of Moon, in Pekin, or the Siogun in Yeddo.

In conclusion, it may be remarked, that if the trade of the Amoor be valuable to the merchants of the United States, it must likewise be so to those of Great Britain, and that the voyage from Glasgow, Liverpool, or London, to Nikolajewsk, is as short as it is from New York, and that the voyage from Singapore, Hong-kong, or Vancouver's Island, is shorter than it is from San Francisco.

A communication was received from Mr. William Gardner—"On a new Method of disposing of Night Soil in large towns."

April 28, 1858.—The concluding meeting of the Society was held this evening, in the Hall of Anderson's University,—*the* President *in the Chair.*

Mr. Rose exhibited his Apparatus "For illustrating the Persistence of Images on the Retina," and received the cordial thanks of the Society.

BELL AND BAIN, PRINTERS, GLASGOW.

PROCEEDINGS

OF THE

PHILOSOPHICAL SOCIETY OF GLASGOW.

FIFTY-EIGHTH SESSION.

Anderson's University Buildings, November 2, 1859.

THE Fifty-eighth Session of the Philosophical Society was opened this evening,—Dr. Thomas Anderson, Professor of Chemistry in the University of Glasgow, President of the Society, in the Chair.

The PRESIDENT, in opening the Session, remarked, that the Society had now reached the fifty-eighth year of its existence, and that during the whole of that period, it had gradually advanced, both in the number of its members and the importance of its proceedings; and that it now possessed a library of considerable extent, well stocked with scientific periodicals, and calculated to be of much value to its members. He pointed out the great importance of such a Society in a city like Glasgow, at a time when the arts and the sciences on which they are founded are every day coming more closely into contact. It is only necessary to watch the progress of the useful arts to feel convinced on this point; for we find that in all those which are most closely related to science a watchful care is exercised to discover and apply every discovery that is likely to prove useful. On the other hand, instances are constantly offering themselves in which, from the neglect of science, particular arts have fallen far behind our knowledge of the theoretical principles on which they depend; and in others, it has required the active interference of scientific men to bring about the practical application of many principles which they have determined.

It was left for Wollaston to discover a proper means of obtaining platinum from its ores in a malleable state, and platinum manufacturers have gone on using the same process from that day to this; and it was left for another scientific chemist, Deville, to contrive a new process which bids fair to revolutionize that want of manufacturers. To the same chemist also we owe the development of the manufacture of sodium and aluminium, the methods of effecting which have been patent to the manufacturers for many years, if they had chosen to make use of them.

The manufacture of a candle has also been revolutionized by the results of chemical investigations of an abstract character; and it is remarkable, that because manufacturers chose to look upon them as abstract, they were not applied to practical use for a considerable time after they were made public; and an interregnum of about twenty years lies between Chevreul's discovery of the true constitution of the fats and oils, and its practical application—a period which was thus lost to that art. While it would have been easy to illustrate this point at much greater length, he trusted that these observations would not be considered misplaced when referring to the rise of a Society whose sphere he trusted would be yet more enlarged.

Mr. Edmund Hunt exhibited and explained the "Cinephantic Colour Top," with which he reproduced some of Mr. Rose's effects, and showed a number of new colour experiments. Mr. Hunt was requested by the Society to continue his experiments at next meeting.

November 16, 1859.—*The* President *in the Chair.*

The following gentlemen were elected members of the Society, viz.:—Dr. Mathie Hamilton, 22 Warwick Street; Mr. James Armstrong, 10 Salisbury Street; Mr. Robert Garroway, Manufacturing Chemist, Rosemount; Mr. Thomas Rose, 11 Florence Place; Mr. James Cruikshank Roger, Merchant, 27 Union Street; Mr. Peter C. Orr, Calico Printer, 14 West Prince's Street; Mr. Peter Hamilton, jun., St. Rollox Bar-Iron Works, 126 North Montrose Street.

Mr. Cockey, the Treasurer, gave in an abstract of his Account:—

Dr.						
1858.—Nov. 1.						
Cash in Union Bank,	£98	12	10			
Less due the Treasurer,	0	9	8			
				£98	3	2
To Entry Fees from 25 New Members, at 21s.,	26	5	0			
,, Annual Dues from 272 Members, at 15s.,	204	0	0			
,, Do. from 5 Members in arrear one year, at 30s.,	7	10	0			
,, Do. from 6 Old Members, at 5s.,	1	10	0			
				239	5	0
,, Sale of *Transactions*,				1	2	2
,, Interest on Bank Account,				3	1	0
				£341	11	4

Cr.

1859.—Nov. 1.

By New Books purchased,		£82 10 1	
,, Binding,		8 13 0	
			£91 8 1
,, Stationery,			1 19 0
,, Printing Circulars,			10 16 3
,, Salary to Assistant Librarian,		52 11 3	
,, Fee to Officer of Andersonian University,		4 0 0	
,, Do. for Engrossing Minutes,		2 2 0	
,, Delivering Circulars,		7 16 4	
			66 9 7
,, Rent of Hall,	£45 0 0		
,, Less Rent received for use of do.,	41 0 0		
		4 0 0	
,, Fire Insurance,		6 7 6	
,, Gas,		2 3 0	
			12 10 6
,, Petty Charges,			2 3 2
,, Printing and Illustrating Society's *Transactions*,			47 11 0
Balance in Union Bank,		106 1 0	
Do. in Treasurer's hands,		2 12 9	
			108 13 9
			£341 11 4

Glasgow, 28*th October*, 1859.—We have examined the foregoing Account, and compared the same with the Vouchers, and find that there is in the Union Bank the sum of £106 1s., and in the Treasurer's hands £2 12s. 9d.,—together, £108 13s. 9d. to the credit of the Society at this date.

The Treasurer has also exhibited to us a Voucher which he holds for money lent to the Corporation of Glasgow, from the proceeds of the Society's Exhibition in 1846, amounting, with interest, to £772 8s. 5d.

JAMES BRYCE.
WILLIAM RAMSAY.

Dr. Bryce, the Librarian, reported that the Library now consisted of 2,930 volumes, exclusive of the English, French, and German Periodicals.

The Society appointed the following gentlemen to be its Office-bearers for Session 1859-60:—

President.

Professor Thomas Anderson, M.D.

Vice-Presidents.

Professor W. J. Macquorn Rankine, LL.D.
Mr. Alexander Harvey.

Librarian.

James Bryce, LL.D.

Treasurer.

MR. WILLIAM COCKEY.

Joint-Secretaries.

MR. ALEXANDER HASTIE. | MR. WILLIAM KEDDIE.

Council.

MR. J. P. FRASER.	MR. ROBERT BLACKIE.
MR. GEORGE ANDERSON.	MR. GEORGE SMITH.
MR. JOHN CONDIE.	DR. FRANCIS H. THOMSON.
MR. JAMES COUPER.	MR. EDMUND HUNT.
PROFESSOR WM. THOMSON.	MR. JAMES R. NAPIER.
MR. WALTER CRUM.	PROFESSOR ROGERS.

Professor William Thomson submitted to the Society a proposal which had this evening been deliberately considered and recommended by the Council, that the *Proceedings* of the Society should be printed and issued fortnightly, instead of annually, or at longer intervals, as heretofore; the members to be supplied with a copy of the publication, containing the *Proceedings* of the previous meeting, along with the billet intimating the next meeting; that extra copies be printed and preserved for the members, to be delivered in a complete form at the close of the session; that the number of honorary members of the Society be increased by the election of men distinguished in the different departments of science; and that copies of the fortnightly publication be regularly sent to the honorary members. The Society approved of the proposal, and remitted to a committee, of which Professor William Thomson was appointed convener, to mature a plan for carrying it into effect.

On the Cinephantic Colour Top. By MR. EDMUND HUNT.*

Mr. Hunt again exhibited the Cinephantic* Colour Top. The following is the substance of Mr. Hunt's explanation and description of the experiments:—The writer was led to make his experiments by hearing an imperfect account of some exhibited in London, and which afterwards proved to have been made with Mr. Gorham's Kaleidoscopic Colour Top, described in Vol. VII. of the *Microscopical Journal.* At the time, however, all he could make out clearly was, that a colour top similar to Professor Maxwell's was used, a black disc, perforated with various patterns, being carried loosely by the spindle a short distance above the coloured disc. The motion of this loose disc was retarded

* The term *Cinephantic* is used to distinguish Mr. H.'s modification from Mr. Gorham's *Kaleidoscopic* Top, and from other colour tops; and signifies "producing apparent motions," or "producing optical phenomena by motion."

by a string drag, and thus different from that of the coloured disc. The writer at once perceived the possibility of obtaining an endless variety of beautiful effects with these differential motions, and having a small colour top, he had a perforated loose disc made; but without proposing to do more than realize, for his own amusement, what he understood to have been already exhibited. The first experiment failed to produce any effect worth looking at, but induced a more searching consideration of the conditions necessary to success. The writer next thought the London top had probably been made to reproduce some of the effects shown to the Glasgow Philosophical Society by Mr. Rose, in April, 1858, but with the addition of colours; at any rate, he in a little time succeeded in reproducing these effects. He also produced other beautiful and to him quite new effects; and ultimately found that he had carried out his experiments in a direction differing considerably from that taken by Mr. Gorham. This was not much to be wondered at; for the elements of the experiments, simple as they are, are so prolific, in number and variety, of optical effects, that it would have been more surprising had two persons, working independently, happened to have pursued the same track.

In Mr. Gorham's experiments, the first effect to be noticed was the multiplication of the colours on the top, as seen through the perforated disc. A simple example of these colours comprised three sectors, respectively tinted violet, green, and scarlet. When the top was spun, and before the loose disc was added, the three colours were merged into a single compound tint; but when seen through the loose disc, the colours appeared separated and repeated in five groups, every group comprising the three colours in the reverse order to that of their actual arrangement on the top. The next effect to be noticed was the multiplication of the perforated devices. The repetition of the colours arose very simply, and depended on the ratio of the velocities; it was, however, difficult to explain without a diagram. As to the multiplication of the perforated devices, the writer gives what he believes is the true explanation, observing, however, that it is not that of the inventor, Mr. Gorham, which last will be found in the work already referred to. The central aperture of the loose disc is made slightly larger than the diameter of the top spindle, and the latter acts like a pinion, gearing into an internally-toothed wheel—the wheel being represented by the edge of the disc aperture. If the disc is prevented from turning, but held free, every point will describe a circle of minute radius. If the disc is now allowed to turn round, but not as fast as the top, the circles will be converted into cycloidal curves. To demonstrate this, a number of white points were put upon one of Mr. Gorham's discs, and a black disc was placed below, to prevent the interference of the colours that would otherwise be seen through the perforations. On repeating Mr. Gorham's experiment with these alterations, a variety of cycloidal curves were delicately traced by the white points, and with such rapidity as to appear continuous round the disc. Near the centre the curves were looped; further out, cusped; and at the outside, undulated. The best effect was yielded where the points moved in the cusped cycloidal path; and on considering the motion of each point in the curve generated in the manner described, we find it varies, being most rapid at the middle of each hollow, and gradually becoming slower, until at the cusp it is momentarily at rest. Afterwards the motion as gradually increases again, and so on. Now, whilst the motion of any part of the device is rapid, the impression on the eye is comparatively faint and indistinct, particularly if contrasted with that received when the motion is for a moment neutralized. The eye, in fact, only appreciates the impressions made at intervals corresponding to the cusps of the curve, and these impressions are extremely well defined, and, with well selected devices, form very pleasing combinations. The images, as it were, experience a species of pulsation during their motion, and each impression is charged with the colour which happens to be beneath the perforation at the instant; whilst the number of impressions depends on the number of curve cusps in the circle.

The first of Mr. Rose's effects produced by the writer was that of apparent rest whilst the discs were in rapid motion. The loose disc had six apertures, with equal openings and intervals. Various series of coloured sectors were placed on the top, and when the proper ratio of velocities was obtained, five apparently stationary repetitions of the series were seen. This experiment was first tried on a small scale, and various peculiarities were observed, which led to further experiments.

The next effect sought for was that of the rotatory or other motion of details, in a series of apparently stationary circles, arranged in a ring round the top. This presented considerable difficulty; but was finally obtained by means of strongly contrasted colours, and by confining the brightest to a comparatively small sector. The loose disc was perforated with twelve circles, a small circle or ball being left in each. In one circle, the ball was at the point furthest from the centre of the disc; in the next, a twelfth round; in the third, two-twelfths round, and so on. Mr. Rose showed a similar device in black on white, and he produced the effect by illuminating the entire disc at (rapid) intervals, between which the circles, owing to the disc's motion, took each other's places in succession; so that if the eye was fixed upon the apparently highest circle, the actual successive change of the several circles into that position produced a series of impressions, in each of which the ball was in a different position, the whole combining to suggest the rotation of the ball. In the top, however, the bright colour—yellow, for example—in rotating very much faster than the perforated disc, produces an impression through each circle in succession. The disc is, however, moving round slowly, and by the time the yellow sector has made a circuit, the disc has shifted to such an extent, as that the next series of impressions is made in the positions of the first, through different circles. The circles appear stationary, as the impressions are repeated in the same positions; but the balls appear to rotate, as in each successive impression of any apparently stationary circle they occupy a different position.

The top with which the experiments were shown was a brass disc, about five inches in diameter, with a brass spindle projecting downwards about an inch, and upwards about two and a-half inches. A nut was screwed upon the spindle, to fix the coloured papers upon the top, the top of this nut serving as a collar to support loose discs. It is, however, better to provide a light frame, nicely fitted to the spindle, to receive the loose discs. The retardation may be effected by means of vanes attached to this loose frame, and made capable of adjustment. A simpler plan is to apply the finger as a friction brake to the rim of the loose frame during the experiment. Mr. White, Optician, 1 Renfield Street, Glasgow, made the top shown, and can supply copies of it. The top being spun by means of a string, the loose frame, with its disc, is dropt on, and gradually acquires motion from the top. The ratio of the velocities gradually changes through the experiment, and the effects change also; but in general one effect in each case comes out more brilliant and satisfactory than any of the others; when this is got, it may be retained by a proper adjustment of the retardation. A very pleasing experiment is made with a loose disc, with say four rings of apertures, the outmost one having nine, the next eight, the next seven, and the inmost one six apertures. The rings appear to rotate with different velocities, and to be stationary in succession. An endless variety of apparent motions may be obtained in this way—radial, circular, serpentine, reciprocating, contrary, differential, &c., as will be easily understood by those who have seen Mr. Rose's experiments.

In some of the first experiments the colours appeared softened, or partially shaded into each other at their edges. The questions occurred, whether this shading could be extended and improved, and if it could be obtained without the multiplication of the colours. As with six apertures five sets of the colours were shown, it was concluded that with a smaller number of apertures, fewer sets would be got, but owing to a mistake as to the way in which the shading arose, it was apprehended that if two apertures were used the shading would become less, or disappear altogether. Five, four, and three apertures were consequently first successively tried, and gave four, three, and two sets of colours respectively—the openings and blackened intervals being equal in all cases. Contrary to expectation, the shading and general brilliancy were improved at each experiment. At first three sectors of blue, yellow, and crimson were fixed upon the top, but it was afterwards found that green, scarlet, and violet gave much better results. Thus, with these colours on the top, and a loose disc having two apertures, a most beautiful spectrum was obtained, constituting an imitation rainbow in a circular form. The green was delicately graduated through yellow and orange into scarlet, and scarlet through crimson and purple into violet, and the violet through indigo and blue into green. Each radius was of a uniform tint from centre to circumference, but the gradation from radius to radius circularly was insensible. By tapering to points the black sectors of the loose disc the colours were gradually shaded off radially into the neutral tint seen without the loose disc. In this way, if certain natural colours were fixed upon as standards, almost all the possible combinations of colours could be exhibited by this mechanical method of mixing or shading them by insensible gradation, and names referring to their relative positions on the spectrum obtained could be satisfactorily given to each.

The spectrum showing one set of colours was afterwards obtained with two, three, or more sets of colours on the top, by using loose discs having as many apertures, plus one, as there were sets of colours; and it was found that the brilliancy increased with the number of sets of colours, as far as was tried. There would, of course, be a limit to this increase of brilliancy. In these experiments the entire disc appeared occupied with colour, the black portions being quite lost to the eye, and in addition the colours appeared more vivid than colours lying on the table, and duplicates of those actually fixed on the top. This is the more remarkable when it is remembered that in the experiments there was at no time more than *half* the coloured surface exposed. It is probably attributable to the alternate flashing of the coloured and black sectors on the eye. The pupil is well known to accommodate itself to the amount of light reaching the eye, so as to reduce the variation of the amount actually entering it. It has suggested itself to the writer that many complex phenomena of vision would be accounted for by a second accommodating power residing in the retina (or other surface at which the visual image acts on the nerves), each point of the surface possessing this power independently. The supposition of fatigue of the nerves does not appear to the writer to account sufficiently for the phenomena. A fact in favour of the secondary accommodating power is the gradual enlargement of the pupil after contraction, on emerging from a dark into a light space. The duration of a vivid image on the nerves gradually causes a less intense sensation to be transmitted, in consequence of this accommodating power. In the experiments the rapid alternation of coloured and black or non-acting images prevents the accommodating power from acting to the extent it otherwise would, a reaction taking place during the black or non-acting impression. The nerves thus transmit the intermittent sensations as more intense than a continuous sensation from the same coloured surface at rest. It must not be forgotten, however, that the mental impression produced by the intermittent flashes of colour in the experiments is continuous, the black or dark intervals being unappreciated. This latter effect is an example of what is termed "persistence of vision;" but if the increased brilliancy in the writer's experiments is due to some such action at the retina as he has supposed, it is obvious that the "persistence" cannot take place at the same part, but must arise at some more advanced point in the track of the visual sensation towards the sensorium, if not in the latter. The supposition explaining the superior brilliancy of the colours in the experiments over those at rest, also easily explains the still greater vividness when the greater number of sets of colours are used.

The beautiful gradation of the colours arises very simply, and will be most easily understood by taking a coloured and a perforated disc, and placing them in the various successive relative positions which they assume in the experiment. Assuming there are two sets of three colours on the top, the loose disc must have three apertures, and the ratio of the velocities must be as three to two. It will be found that during the entire period of rotation three apparently stationary radii are exclusively coloured, each with one of the original colours, whilst the intermediate radii are severally tinted with two of the colours, the alternations of which vary in their relative proportions with the positions of the radii.

If with the same colour disc a two-aperture loose disc is used, the entire series of graduated colours is not seen at once, but a uniform tint occupies the entire disc at every instant, this tint gradually changing through all the various tints of the spectrum previously described. If we next take a two-aperture disc, with the sides of the apertures shaped to volute curves instead of being radial, we have the colours thrown into concentric circles, and flowing out from or in towards the centre, according to the directions of the volute curves, the shading or gradation between the colours being still shown. These last two experiments are extremely pleasing, and the effects are perhaps enhanced if, instead of three colours being fixed on the top, there are only two, and these nearly complementary to each other, such as green and crimson, blue and orange, or violet and yellow. Further, if gray is substituted for one of the colours, the other being moderately brilliant, the gray becomes apparently charged with the colour complementary to the other colour. The complementary colours are brought out very strongly in this way.

The writer having now described the more remarkable of his experiments, would observe that he thinks they furnish valuable materials for testing theories relating to colour-vision. He has not, however, as yet been able to make much use of them in this way beyond rendering himself dissatisfied with all such theories with which he is acquainted.

November, 30.—Mr. Alex. Harvey, *Vice-President, in the Chair.*

George Blair, M.A., was elected a member of the Society.

Professor William Thomson reported that the Committee appointed at last meeting to prepare a plan for the fortnightly publication of the *Proceedings* had agreed to the following regulations:—

Regulations adopted, November 30, 1859, with reference to the publication of *Proceedings* and the election of honorary members:—

1. A printed account of each meeting, except the last of the session, shall be circulated among all members of the Society, along with the billet summoning the next ensuing meeting.

2. Authors and speakers who wish accounts of their communications to be printed, shall furnish abstracts to the Secretary, with sketches of illustrative diagrams, when such are required, not later than the end of the week in which the meeting was held.

3. Full discretion to deal with matter thus supplied, and to complete the account of the meeting in the time for circulation within the period specified, shall be allowed to an Editorial Committee, consisting of the Secretary, President, and one other member of Council.

4. Papers too long to be published in the ordinary fortnightly Report, can only appear in the *Proceedings* by an express order of the Council; and, when so ordered, shall be published in a supplementary number, to be circulated along with the account of the last meeting of the session, within a fortnight of the date of that meeting.

5. Duplicate copies of the Reports of all the meetings, except the last of the session, shall be printed and sewed up along with the Report of the last meeting, in the supplementary number, so as to form a complete Report for the session, which shall be circulated among all

members of the Society, within the period specified in the preceding rules.

6. The original practice of appointing eminent members of the Society to be honorary members, on going to reside in another locality, shall be maintained as hitherto ; but in addition, distinguished men of science belonging to any part of the world, may be elected as honorary members.

7. The number of honorary members, not formerly members of the Society, shall not at any time exceed twenty.

8. The election of an honorary member can only be made on the motion of the Council, and shall be openly discussed and decided upon in the same manner as other public business of the Society.

9. The printed Reports shall be sent regularly by post to honorary members resident in the United Kingdom, and by whatever means can be found convenient, to honorary members residing abroad.

William Thomson, *Convener.*

The Society unanimously approved of these regulations, and authorized the Committee to proceed with the fortnightly publication of the *Proceedings.*

The Society agreed to take charge of the Reports of the Commissioners of Patent Inventions, and to make them accessible to the public, on condition of the entire expense being borne by the Town Council.

Mr. David Mackinlay read an account of a visit to Iceland.

Notes of a Visit to Iceland in the Summer of 1859, *by* Mr. David Mackinlay.

In this paper the writer gave an account of a fortnight's journey he had made from Reykiavik, the capital, to the south coast of Iceland, interspersed with many interesting observations on the condition of the country and the habits of the people. On his way Mr. Mackinlay visited Thingvalla and the Geysers; and on his return, the hot springs of Reykum and the sulphur mines of Krisuirk. We subjoin the principal part of the description of the Geysers :—

These springs are situated near the base of a low trap hill, which slopes away to the south and west. The Great Geyser and Strokkr are the two principal.

The *Great Geyser* pipe is about ten feet in diameter and sixty feet deep, and opens above into a somewhat oval saucer-shaped basin, about sixty feet across and four feet deep. Usually the basin is full to overflowing ; but after an eruption the water sinks, the degree of sinking being in some measure proportioned to the violence of the eruption.

Many little eruptions occur in the course of the day. Whether small or great, they are accompanied by more or less tremor of the ground near the basin, and by a series of subterranean noises, as if Vulcan was wielding his sledge hammer on some refractory metal. Where my tent stood—seventy yards from the basin—these noises were loud enough, during a small eruption, to awake an ordinary sleeper; but, during a grand eruption, they would disturb the repose of Rip Van Winkle himself. A sensible welling up of the water attends even the slightest noises; but when these are violent the water rises in a bell-shape to the height of one to five or more feet. In such cases the eruption resembles the effect produced by a large charge of gunpowder in deep water. During my three nights' stay, there were several fine eruptions; but the finest which I saw occurred on the afternoon of Thursday, 24th June. On this occasion the tremor and noises were but trifling, but soon became violent and frequent. Heavy bells of water rose in succession to the height of three or four feet, and then sunk into the basin. The earth-shocks became stronger, and the noises louder and louder. The mass of upraised water now burst, and sprang up, at first six or eight feet—then twelve or fifteen feet—twenty feet—twenty-five feet—and so on, till it reached the height of seventy to eighty feet. It was a most magnificent spectacle. And now the eruption seemed dying away; but before the column had lost a third of its height, it shot up again as high as before, and then all was still. The duration of the eruption was four minutes. The column of water was partly hidden below by dense volumes of steam, which rolled grandly across; but it seemed to expand as it ascended, for probably two-thirds of its height; the upper part had an arborescent form, tapering towards the top. The water did not form a solid column, but, as Lord Dufferin happily expresses it, "a sheaf of columns," the height of which varied according to the violence of the earth-shocks. In less than a minute after the last great jet, I descended into the basin, which was now quite empty. The water stood ten feet, or more, below the top of the pipe, but was gradually rising; in an hour it filled the pipe, and every now and then boiled furiously. Three hours after, when the basin was about two-thirds full, a second eruption took place, the height of which did not exceed twenty feet. Most observers agree in stating that the Geyser eruptions do not rise higher than 100 feet; but it is probable that on rare occasions they attain a much greater height. The Governor of Iceland, who has visited the Geysers four or five times, and has seen several fine eruptions, told me, on my return to Reykiavik, that the last eruption he witnessed was nearly 200 feet high, and that, at the close, the pipe was emptied to a much greater depth than he had ever seen before.

Strokkr has no basin, and a shorter and narrower pipe than the Geyser. It erupts naturally, at rare intervals; but an eruption may be excited at any time by throwing in a few spadefuls of turf. The water usually stands about twelve feet below the top of the pipe, and boils violently, with an uneasy churning motion. When six or eight spadefuls of turf are thrown in the churning motion ceases, and the water becomes still. In two minutes, or so, a sound is heard as of a man breathing heavily, and this continues till the water begins to boil. The boiling is slight at first, but shortly becomes violent. During this time, the water is gradually rising in the pipe; then it heaves upwards, by successive throes, till it approaches or overflows the lip. Now is the time for the onlooker to withdraw; for when things reach this state, the eruption begins. There are neither subterraneous noises nor earth-shocks, and the column of water has much less body than that of the Great Geyser, though of greater height. The eruption is not a continuous stream of water, varying somewhat in height, but a succession of jets, such as might be produced by the intermittent action of a huge syringe. In an ordinary eruption, the jets are thrown up as high as fifty or sixty feet; but a double supply of turf will cause them to rise to the height of 150 feet, or more. Immediately after an eruption, the water in the pipe is found to stand about fifteen or sixteen feet below the lip. At this depth the pipe gets much narrower, and seems to change its direction. There may be some truth, therefore, in the opinion of Henderson, that the artificial eruption is due to the partial confinement of the steam, and the consequent increase in the temperature of the water. The turf thrown in is not wholly expelled during the first eruption. When this ceases, a period of repose, five to ten minutes long, ensues; the heavy breathing sound before mentioned is again heard; the boiling and paroxysmal heavings of the water follow; and in fifteen to twenty minutes, or more, after the primary eruption, a second one occurs on a smaller scale. The jets of the secondary eruption are not so grand as those of the primary one; but they are more beautiful, in consequence of the greater purity of the water. The duration of the eruption varies; but it is seldom less than two minutes, or more than four.

The non-erupting springs are about fifty in number, but most of them are small. The largest and finest of these is the one called *Blesi*, from its fancied resemblance to the white marks often found on a horse's head. It lies west of the Great Geyser, and a little higher up the hill. It is an irregular oval pool of bluish water, of great depth, and divided in the middle by a narrow silicious bridge, about fifteen inches thick. It overflows, but does not boil, the temperature not exceeding 198°. The play of light on the walls of the pool at all hours of the day and night is most exquisite. It is hardly right, however, to speak of night at a season of the year when the glow of the rising sun is merely a continuation of the setting. The water shelves for three or four feet under the silicious covering of the south side of the pool, and then dips down into an abyss which makes one almost shudder to look into. Last century Blesi was an erupting spring, but an earthquake silenced it.

The most of the springs are at some distance from Blesi, at the very bottom of the hill. Here they lie so close together that one cannot help feeling at first as if the whole ground were cavernous. All the overflowing springs are clear as crystal; but a few which boil without overflowing are tinged of a grayish white. Near one of the smaller openings there is a hidden pool whose violent boiling imparts a constant vibratory motion to the earth above it. Indeed, in walking about among those springs, one treads almost instinctively with cautious steps; for here and there the water underlies a crust of earth so thin, that one fears being precipitated into the gulf below. All the springs which I tested, save one, had an alkaline reaction, and gave out more or less sulphuretted hydrogen. (The paper was illustrated by specimens of the mineral products of the country, and by articles of dress worn by the people.)

PROCEEDINGS

OF THE

PHILOSOPHICAL SOCIETY OF GLASGOW.

DECEMBER 14, 1859.

ALEX. HARVEY, ESQ., *Vice-President, in the Chair.*

Mr. George Thomson, designer, Partick, and Mr. John Goodall, 116 St. Vincent Street, were elected members.

Mr. Walter Crum read an account of the Process of Ageing in Calico Printing. (An abstract of this paper is deferred till it can be accompanied by an illustrative woodcut.)

Recent Investigations of M. LE VERRIER *on the Motion of Mercury.* By PROFESSOR WM. THOMSON.

Professor W. Thomson stated that he had had his attention called, a few days since, to recent investigations of M. Le Verrier on the motion of Mercury, which, he believed, would interest the Society, not only as constituting a new step of high importance in the theory of the planetary motions, but as now affording that kind of evidence of the existence of matter circulating round the Sun within the earth's orbit, which, more than five years ago, in publishing his theory of meteoric vortices* to account for the Sun's heat and light, he had called for, from perturbations to be observed in the motions of the known planets. M. Le Verrier, in a letter to M. Faye, published in the *Compte Rendu* for September 12, 1859, which contains his account of the investigations referred to, writes as follows:—

"You have not perhaps forgotten how, in my studies regarding the motions of our planetary system, I have encountered difficulties in the

* "On the Mechanical Energies of the Solar System," by Professor W. Thomson —*Transactions of the Royal Society, Edinburgh*, and *Philosophical Magazine*, 1851.

way of establishing a complete agreement between theory and observation. This agreement, said Bessel, thirty years ago, is always affirmed, yet has never been hitherto verified in a sufficiently serious manner.

"The study of the difficulties offered by the Sun has been long and complicated. It has been necessary, in the first place, to revise the catalogue of the fundamental stars, so as to leave no systematic error there. I have next taken up the whole theory of the inequalities in the Earth's motion; in connection with which I have been led to discuss as many as 9,000 observations of the Sun, made in different observatories. This work has shown that the meridian observations may not always have had the precision which has been attributed to them, and that thus the discrepancies at first indicated as belonging to the theory must be rejected, because of uncertainty as to the observations.

"The theory of the Sun's apparent motion once put beyond question, it became possible to resume, with advantage, the study of the motion of Mercury. It is this work on which I wish now to engage your attention.

"While for the Sun we possess only meridian observations liable to great objections, we have, for the planet Mercury, a certain number of observations of an extremely accurate character, made in the course of a century and a-half. I mean the internal contacts of the disc of Mercury with the disc of the Sun, at the end of a transit of that planet. Provided that the place of observation is well known, and provided that the observer has had a passable telescope, and a clock showing time within a few seconds of perfect accuracy, his observation of the instant of the internal contact ought to afford an estimate of the distance between the centres of the two bodies, with no error exceeding a second of arc. From 1697 to 1848, we have twenty-one observations of this kind, which ought to be perfectly satisfied if the perturbations in the motions of the Earth and Mercury have been well calculated, and if correct values have been attributed to the disturbing masses.

"The results of my first studies on Mercury, published in 1842, did not represent with great accuracy the transit observations. Among other discrepancies was to be remarked a progressive error in the transits of the month of May, reaching as much as nine seconds of arc in the year 1753. Deviations such as this could not be attributed to errors of observation; but not having revised the theory of the Sun, I believe that I ought to abstain from drawing any conclusion from them.

"The use of the corrected tables of the Sun has not, however, in my new work, made these discrepancies disappear;—systematic discrepancies for which the observations cannot be blamed, unless we suppose that such astronomers as Lalande, Cassini, Bouguer, &c., could have committed errors amounting to several minutes of time, and even varying progressively from one epoch to another!

"Now, what is remarkable is, that it suffices to augment by 38″ the centenary movement of the perihelion of Mercury's orbit to represent all the transit observations to within a second, and most of them even to less than half a second. This result, so precise and simple, which gives at once to all the comparisons an accuracy superior to that which has been hitherto attained in astronomical theories, shows clearly that the increase in the motion of the perihelion is necessary, and that when made to fulfil this condition, the tables of Mercury and the Sun possess all desirable accuracy."

M. Le Verrier proceeds in his letter to examine the different suppositions by which it may be attempted to explain the perturbation in Mercury's motion, which he has thus discovered. An increase of $\frac{1}{10}$th on the supposed mass of Venus would account for it; but the periodical disturbances in the Earth's motion, and the secular variation of the inclination of the Earth's axis to the plane of the ecliptic produced by Venus, do not allow any such change in our estimate of her mass. On the other hand, a planet revolving round the Sun inside Mercury's orbit, might produce precisely the variation in the perihelion to be explained, without sensibly disturbing the motions of Venus, the Earth, or any of the superior planets. M. Le Verrier shows, for instance, that a planet equal in mass to Mercury, and revolving in a circular orbit in the same plane, at a little less than half the distance from the Sun, would fulfil these conditions; and, therefore, that a less mass in a larger orbit, or a greater mass in a smaller orbit, would do the same. But, considering that so large a mass could scarcely have escaped observation, either in its transits across the Sun's disc, or by its own brilliant illumination, which would render it visible to us during total eclipses of the Sun, even if, on account of its nearness to the Sun, not ordinarily seen as a morning and evening star alternately, M. Le Verrier thinks it most probable that the disturbing mass consists in reality of a series of corpuscules circulating between the Sun and Mercury.

Here, then, by a profound appreciation of purely astronomical data, the great French physical astronomer, leaving those remote regions where, independently of our own countryman, Adams, he tracked the unseen planet by its disturbing influence on the remotest body of the then known list, has been led to conclude that the innermost of the recognized planets is also disturbed by planetary matter, not previously reckoned among the influencing masses of our system.

Is this new planetary matter, like the other till discovered by its influence, unseen? Surely, on the contrary, it is it that we see as the Zodiacal Light, long before conjectured to consist of a cloud of corpuscules circulating round the Sun, and, in the dynamical theory of the Sun's radiation, supposed to contain the reserve of force from which this Earth, as long as it continues a fit habitation for man as at present constituted, is to have its fresh supplies of heat and light.

On Photographed Images of Electric Sparks.

By Professor Wm. Thomson.

Professor W. Thomson exhibited photographed images of electric sparks reflected from a revolving mirror, which a few days since he had received from Mr. Feddersen of Leipsic, and which afforded a remarkable illustration of the "oscillatory discharge" indicated by dynamical theory as occurring when a Leyden phial of not too great electrostatic capacity is discharged, by a sufficiently easy conducting train, through a channel presenting sufficient "induction on itself" or "electro-dynamic capacity." The occurrence of an oscillatory discharge, under certain conditions, had been first anticipated by Helmholz, in his *Erhaltung der Kraft* (Berlin, 1847.) The law of discharge, when the discharging train possesses no sensible electrostatic capacity, had been fully investigated, and the conditions under which it takes place with oscillations, discriminated from those under which it takes place with continuous subsidence, had been determined, in a mathematical paper communicated to this Society about seven years ago "On Transient Electric Currents"—*Proceedings of Glasgow Philosophical Society*, January, 1853, and *Philosophical Magazine*, June of same year.

At that time the numerical relation between electrostatic and electrodynamic units had not been determined, and therefore a certain co-efficient in the mathematical formula was left for experimental investigation. The want has been since supplied by W. Weber, who has continued the system of absolute measurement inaugurated by himself and Gauss for terrestrial magnetism, and has extended it with the greatest advantage into every department of electric and magnetic science. The consequence is that the mathematical formula for an electric discharge can now be fully reduced to numbers, the criterion as to whether it is oscillatory or continuous applied, and, when it is oscillatory, the time of an oscillation determined for any stated dimensions and form of apparatus. Professor Thomson further stated that he had calculated dimensions, &c., and found that arrangements could readily be made to give rise to oscillations in periods not less than $\frac{1}{10000}$ of a second, which could therefore be easily shown by Wheatstone's method of the revolving mirror, as he had anticipated might be possible when he first communicated his mathematical investigation to this Society. The barred appearance of each of the photographic images now before the Society would, if the rate of rotation of the mirror, and the distance from it of the plate receiving the impression, were known, be enough to determine the period of the electric oscillation by which they had been produced. He hoped soon to have particular information as to these and other details from Mr. Feddersen, and so be able to make a thorough numerical verification of the theory, which he would not delay to lay before the Society.

Note on the Bursting of the Reservoirs of Crinan Canal, showing the Power of Running Water. By MR. WILLIAM KEDDIE.

THE paper commenced by citing some of the few recorded examples in Scotland of the effects of floods in producing permanent changes on the surface of the country. In last session of the Society, a desire was expressed for some facts connected with the bursting of the reservoirs of Crinan Canal, in Argyleshire, on the 2d of February, 1859; and although the place should have been visited immediately after the accident, in order to witness the full extent of the devastation, its effects were still sufficiently manifest in the month of September, to show the enormous force exerted by the torrent in its descent upon the valley of the canal. By the obliging assistance of Mr. H. D. Graham, an intelligent observer resident in the neighbourhood, the following particulars of the catastrophe were obtained, for the illustration of which the same gentleman had made a copy of the original chart of the canal and reservoirs, prepared by Mr. Rennie in 1792, and now in possession of Mr. Fyfe, the present engineer. The highest elevation of the canal is at its centre, about four miles from either extremity, surmounted by a series of locks within a space of less than two miles. Among the hills, overlooking this part of the valley traversed by the canal, there is a chain of natural lochs, serving as reservoirs for supplying the canal. These lochs occupy an elevation of 600 feet (the official report on the disaster says 800 feet) above the summit level of the canal. The superficial extent of Camloch is 28 acres, with an average depth of 10 feet; of Duloch, a continuation of Camloch, 5 acres; of Loch Clachaig, 31 acres, with an average depth of 15 to 20 feet. The surplus waters of these lochs flow into Glen Clachaig, where there is an embankment regulating the supply for the canal, and forming an artificial reservoir with an area of 40 acres, and an average depth of 20 or 25 feet. The measurements, however, vary to a considerable extent, and the entire superficial area of the reservoirs may be stated at 80 acres. After heavy and continuous rains at the end of January and the beginning of February, the waters of Camloch burst their embankment, and rushing into the two adjoining lochs, caused their irruption into Glen Clachaig; the yielding of whose barriers let loose the accumulated mass into the valley below. Descending the hillside with the force of an avalanche, the stream tore up the rocks into a deep and broad channel, carrying great masses of earth and stone along its course; and, precipitating the *debris* into the valley, effaced in a brief space every vestige of the canal for the distance of a quarter of a mile. The glen down which the waters rushed is about a mile and a half in length from the reservoirs to the canal.

Where the glen opens upon the valley, a broad delta was formed by the detrital matter, across which massive blocks of stone were hurled into the centre of the canal. On the side of the ravine, the overflowing water uncovered a large surface of the mica-slate of the district, revealing in its grooves and striations the traces of ancient glacial action, produced in the direction of the axis of the valley, and at right angles to the course of the torrent. The blocks of stone becoming piled together in a compact pyramidal mass, in the line of the canal, had the effect of dividing the current of water into two streams—one flowing towards the east, and the other towards the west; a fortunate circumstance for the village of Lochgilphead, which would inevitably have been submerged, had the unbroken force of the flood descended upon the low grounds in that direction. The divided currents, running in opposite courses along the line of the canal, carried all before them; locks, tow-path, and road were laid in ruins, and the bed of the canal was filled with mud, till at Cairnban on the one side, and at Dunardry on the other, the flood, breaching tremendous chasms in the banks resembling the cutting of a railway, escaped by one opening into the fields near the bay of Loch Gilp, and by the other into the level of the great Crinan Moss, covering the country for miles in both directions with sand and mud. On the road on the Lochgilphead side, the water after descending from the canal rose as high as a horse's breast. At Lochgilphead, just as the flood had reached the sea, after flowing over five miles of dead level, it encountered a rustic bridge of solid masonry, and swept away the entire structure, rolling the materials fifty yards along the level grassy banks, in broken masses such as eight men would fail to move. The force of the current in the canal was spent in little more than half an hour. It was not, however, till midnight that the flood subsided in the lower levels.

In the month of September, after considerable progress had been made in repairing the effects of the *debacle*, the line of the canal still continued strewed with the blocks of stone carried down by the torrent. Many of the larger masses had previously been removed by blasting. The following are the measurements of a few of those that remained, to which Dr. Bryce, who is accustomed to such calculations, has added an approximate estimate of their weight:—1. A block of granite, grooved and water-worn, measuring 5 feet in length, 4 feet in breadth, and 2 feet in depth, weighing probably about 3¼ tons. 2. A boulder of porphyritic trap, 8 feet 4 inches in length, 5 feet in breadth, 2½ feet in depth, weighing from 8 to 10 tons. 3. Another mass of trap, with smooth surface, measuring 3 yards 6 inches in length, 2 yards 7 inches in breadth, and 1 yard in depth; weight from 18 to 22 tons. 4. An angular mass of mica-schist, torn out of the rock, and brought down by a divergent stream, measured 8 feet 6 inches in length, upwards of a yard in breadth, and 4 feet 7 inches in depth; weight from 8½ to 10 tons. These may be regarded as of the average bulk of the larger blocks, which lay scattered about in hundreds, several months after a numerous body of workmen had been employed in blasting and removing the original pile; while masses of smaller, interspersed with not a few of larger dimensions, lay in thousands along the course of the canal, at that time still to a large extent unexcavated. The valley for several miles resembled a region which had been shaken by some great convulsion of nature, instead of exhibiting only the consequences of an engineering accident. Mr. Graham writes—"The attention of the passing tourist is mainly attracted to the effects of the fall of water evinced in its powers of destruction; but you would have found it more interesting, leaving the canal and its ruins, to have ascended along the course that the water took in its descent, commencing at the *debouchure* of the short-lived though trace-leaving river, and following up the chasms and rock-encumbered gullies to the sources of the cataract, in the dried basins of the broken reservoirs. It is difficult to believe that all these cuttings, and rocks tossed about like chuckie-stones, mark the work of minutes, instead of years."

The Crinan Canal originally cost £127,360. In 1805 the canal burst its banks, and was repaired at an expenditure of £25,000. In

1811 the reservoirs gave way, and their repair cost £8,000. One of the latest grants of money voted in the last session of Parliament was £12,000 to repair the effects of the disaster of February; but this sum conveys an inadequate idea of the destructive effects of the flood upon the canal, or of the injury done to property in the neighbourhood. It is remarkable that no lives were lost.

PROCEEDINGS

OF THE

PHILOSOPHICAL SOCIETY OF GLASGOW.

JANUARY 4, 1860.

ALEX. HARVEY, ESQ., *Vice-President, in the Chair.*

Mr. Archibald Duncan, junior, Mr. John Robertson, Teacher, Mr. Mark Fryar, and Mr. William Moore, Mining-Engineer, were elected members.

On the motion of Professor William Thomson, the Society unanimously elected the following as Honorary Members:—

FOREIGN.

CHEVREUL,	PARIS.
DUMAS,	PARIS.
PROFESSOR H. HELMHOLZ,	HEIDELBERG.
PROFESSOR ALBERT KOLLIKER,	WURZBURG.
BARON LIEBIG,	BAVARIA.
M. LE VERRIER,	PARIS.
PROFESSOR W. WEBER,	LEIPZIG.

AMERICAN.

PROF. JAMES D. DANA,	YALE COLLEGE, CONNECTICUT, U.S.
PROF. JAS. HENRY, SECY.,	SMITHSONIAN INSTITUTION, WASHINGTON.
PROFESSOR LOOMIS,	NEW YORK.

BRITISH.

PROFESSOR FARADAY,	ROYAL INSTITUTION, LONDON.
PRINCIPAL JAMES D. FORBES,	ST. ANDREWS.
W. HOPKINS, M.A.,	ST. PETER'S COLLEGE, CAMBRIDGE.
DR. J. P. JOULE,	MANCHESTER.
MR. JOHN MERCER,	OAKENSHAW, LANCASHIRE.
GENERAL SABINE, R.A.,	LONDON.

On the Variation of the Periodic Times of the Earth and inferior Planets, produced by Matter Falling into the Sun. By PROFESSOR WM. THOMSON.

IT may be remarked, in the first place, that the absolute effect on the periodic time of Mercury, producible by such a distribution of planetary matter as M. Le Verrier concludes must circulate between Mercury and the Sun, is not discoverable. The true mean distance of Mercury from the Sun is not, in fact, known with sufficient accuracy to allow us to judge whether or not the central force corresponding to its periodic time, when compared with the forces experienced by the other planets, deviates from the law of inverse squares of distances from the Sun's centre to such an extent as must be the case if M. Le Verrier's disturbing planetary matter is altogether inside Mercury's orbit. But it does not follow that the periodic time of Mercury, or even that of Venus, and the Earth may not be sensibly influenced by the falling in of portions of that matter to the Sun. To discover the general character of this influence, and to estimate its amount, we may first consider the resultant force experienced by a planet under the joint influence of the Sun and a concentric circular ring in the plane of its orbit. It is easily seen that the Sun's force must be diminished by the attraction of the ring, if this lies outside the planet, but, on the contrary, increased, if inside. If the radius of the ring be very small in comparison with the distance of the planet, it is clear that to a first approximation the attraction of the ring may be calculated, by supposing its mass collected at its centre. The full expression for the resultant attraction of the ring being the following convergent series:—

$$\frac{m}{a^2}\left\{1+3\left(\frac{1}{2}\right)^2\left(\frac{r}{a}\right)^2+5\left(\frac{1\cdot3}{2\cdot4}\right)^2\left(\frac{r}{a}\right)^4+7\left(\frac{1\cdot3\cdot5}{2\cdot4\cdot6}\right)^2\left(\frac{r}{a}\right)^6+\&c.\right\}$$

where m denotes the mass of the ring, r its radius, and a the distance of the planet from its centre, shows that the resultant force is in reality somewhat greater than it would be if the mass were collected at the centre. The planet's orbit being nearly circular, the attraction of such a ring as we have supposed will be represented to a second approximation by supposing a mass greater than its own in the ratio of 1 to $1+\frac{3}{4}\left(\frac{r}{a}\right)^2$, collected at its centre, or which would produce the same effect, distributed uniformly over the Sun's surface. Hence the gradual falling in of such a ring to the Sun will diminish the force experienced by the planet as much as would be done by a simple subtraction of $\frac{3}{4}\left(\frac{r}{a}\right)^2 m$, from the Sun's mass. The amount I have estimated as falling in annually to produce the solar heat and light is $\frac{1}{16200000}$ of the Sun's mass. The effect of this, if coming from a ring at distance r, would be to diminish the central force on a planet at distance a, in the ratio of

$$1 \text{ to } 1 + \frac{3}{4}\left(\frac{r}{a}\right)^2 \frac{1}{16{,}200{,}000}$$

According to the investigation contained in addition No. I. to my paper "On the Mechanical Energies of the Solar System," the effect of such a change in the Sun's mass would be to alter the angular motion of the planet in the inverse ratio of the square of the mass. The integral effect of this will, therefore, be a diminution of the planet's helio-centric longitude amounting to

$$\frac{3}{4}\left(\frac{r}{a}\right)^2 \frac{n^2}{16{,}200{,}000} \times 360^\circ$$

in n revolutions. Merely for the sake of example, let us consider the effect on the Earth's motion, produced by matter falling in at the supposed rate during a period of two thousand years from a ring of double the Sun's diameter. In this case

$$\frac{r}{a} = \frac{1}{107{\cdot}5} \text{ and } n = 2{,}000$$

Hence the disturbance in the Earth's longitude would be a diminution amounting to $\frac{360^\circ}{62400} = 20''{\cdot}8$ an amount of loss altogether undiscoverable over such a period of time.

To estimate the effect of the same transference of matter upon the motion of Mercury, we must take $\frac{r}{a} = \frac{1}{41{\cdot}7}$ The period during which we have the most accurate knowledge of Mercury's motion is, as Le Verrier has remarked, from the year 1697 to 1848. This being about 624 of Mercury's revolutions round the Sun we may take $n = 624$; and we find by the preceding expression $13''\frac{1}{2}$ as the effect on the helio-centric longitude of the planet. This will amount to nearly $8''\frac{1}{2}$ of geo-centric arc—an error which could not possibly have escaped detection in the very thorough investigation which M. Le Verrier has applied to the motion of Mercury. It may be concluded that if matter has been really falling in at the rate supposed by my dynamical theory of the solar radiation, the place from which it has been falling, must be either nearer the Sun or more diffused from the plane of Mercury's orbit than we have supposed in the preceding example. With a view to determining whether this theory is tenable or not, it will be necessary to consider whether the appearances presented by the zodiacal light, and the photo-sphere seen round the Sun in total eclipses, allow us to find a place for a sufficient future dynamic supply without supposing a denser distribution of meteors or meteoric vapours than is consistent with what we know of the motion of comets before and after passing very close to the Sun.

On Instruments and Methods for observing Atmospheric Electricity. By Professor Wm. Thomson.

After briefly explaining the modes of observation followed by Beccaria, Volta, and Delmann, the author proceeded to describe a new method for reducing a conductor to the same electric potential as that of the atmosphere at any point, which had recently occurred to him, and which he had already to a slight extent put in practice, with a good prospect of satisfactory results. The apparatus used for it was shown in action before the Society, as was also a portable electrometer adapted to write with a burning match as collector. The following extracts from a short article written for the forthcoming edition of Nichol's Cyclopædia contains an account of these methods and instruments, as described and exhibited to the Society. The woodcuts representing the instruments are introduced here by the kind permission of the publishers, Messrs. Griffin & Co.

"A very simple apparatus (Fig. 1), by which I can observe atmospheric electricity in an easy way, consists of an insulated can of water set on a table or window-sill *inside*, and discharging by a small pipe through a fine nozzle two or three feet from the wall. With only about ten inches head of water, and a discharge so slow as to give no trouble in replenishing the can with water, the atmospheric effect is collected so quickly, that any difference of potentials between the insulated conductor and the air, at the place where the stream from the nozzle breaks into drops, is done away with at the rate of five per cent. per half second, or even faster. Hence a very moderate degree of insulation is sensibly as good as perfect, so far as observing the atmospheric effect is concerned. It is easy, by my plan of drying the atmosphere round the insulating stems, by means of pumice stone moistened with sulphuric acid, to insure a degree of insulation in all weathers, by which there need not be more than five per cent. per hour lost by it from the atmospheric apparatus at any time. A little attention to keep the outer part of the conductor clear of spider lines is necessary. The apparatus I employed at Invercloy stood on a table beside a window on the second floor, which was kept open about an inch to let the discharging tube project out, without coming in contact with the frame. The nozzle was only about two feet and a-half from the wall, and nearly on a level with the window-sill. The divided ring electrometer stood on the table beside it, and acted in a very satisfactory way (as I had supplied it with a Leyden phial, consisting of a common thin white glass shade, which insulated remarkably well, instead of the German glass jar—the second of the kind which I had tried, and which would not hold its charge for half a day).—I found from $13\frac{1}{4}°$ to $14°$ of torsion required to bring the index to zero, when urged aside by the electro-motive force of ten zinc-copper water cells. The Leyden phial held so well that the sensibility of the electrometer, measured in that way, did not fall more than $13\frac{1}{2}°$ to $13\frac{1}{4}°$ in three days. The atmospheric effect ranged from 30° to above 420° during the four days which I had to test it; that is to say, the electro-motive force per foot of air, measured horizontally from the side of the house, was from 9 to above 126 zinc-copper water cells. The weather was almost perfectly settled, either calm, or with slight east wind, and in general an easterly haze in the air. The electrometer twice within half an hour went above 420°, there being at the time a fresh temporary breeze from the east. What I had previously observed regarding the effect of east wind was amply confirmed. Invariably the electrometer showed very high positive in fine weather, before and during east wind. It generally rose very much shortly before a slight puff of wind from that quarter, and continued high till the breeze would begin to abate. I never once observed the electrometer going up unusually high during fair weather without east wind following immediately. One evening in August I did not perceive the east wind at all, when warned by the electrometer to expect it; but I took the precaution of bringing my boat up to a safe part of the beach, and immediately found by waves coming in that the wind must be blowing a short distance out at sea, although it did not get so far as the shore.

The electrometers referred to in the preceding statement were on two different plans. The first, or "divided ring electrometer," consists of—(1.) A ring of metal divided into sectors, of which some—one or more—are insulated and connected with the conductor to be electrically tested, and the remainder connected with the earth. (2.) An index of metal supported by a glass fibre, or a wire, stretched in the line of the axis of the ring, and capable of having its fixed end turned through angles measured by a circle and pointer. (3.) A Leyden phial, with its insulated coating electrically connected with the index. (4.) A case to protect the index from currents of air, and to keep an artificially dried atmosphere round the insulating supports—glazed to allow the index to be seen from without, but with the inner surface of the glass screened (electrically) by wire cloth, perforated metal, or tinfoil, to do away with irregular reflections on the index. In the instrument represented in the drawing (Fig. 2), the ring is divided into only two parts, which are equal, and separated by a space of air about one-twentieth of an inch. Each of these half rings is supported on two glass pillars; and by means of screws acting on a foot which bears these pillars, it is adjusted and fixed in its proper position. The index is of thin sheet aluminium, and projects in only one direction from the glass fibre bearing it. A stiff vertical wire, rigidly connected with it, nearly in the prolongation of the fibre, bears a counterpoise considerably below the level of the index, and heavy enough to keep the index horizontal. A thin platinum wire, hooked to the lower end of this vertical wire, dips in sulphuric acid in the bottom of the Leyden phial. The Leyden phial is charged either positively or negatively; and is found to retain its charge for months, losing, however, gradually, at some slow rate, less generally than one per cent. per day of its amount. The index is thus, when the instrument is in use, kept in a state of charge corresponding to the potential of the inside coating of the phial. When one of the half rings is connected with the earth, and a charge of electricity communicated to the other, the index moves from or towards the latter, according as the charge communicated to it is of the same or the opposite kind to that of the index. This instrument, as an electroscope, possesses extreme sensibility—much greater than that of any other hitherto constructed; and by the aid of the torsion arrangement, it may be made to give accurate metrical results. There are some difficulties in the use of it, especially as regards the comparison of the indications obtained with different degrees of electrification of the index, and the reduction of the results to absolute measure, hitherto obviated only by a daily application of Delmann's method of reference to a zinc-copper water battery, which Delmann himself applies once for all, to one of his electrometers (unless his glass fibre breaks, when he must make a fresh determination of the sensibility of the instrument with its new fibre). The high sensibility of the divided ring electrometer renders this test really very easy, as not more than from ten to twenty cells are required; and a comparison with a few good cells of Daniell's may be made by its aid, to ascertain the absolute value and the constancy of the water cells. The difficulty thus met is altogether done

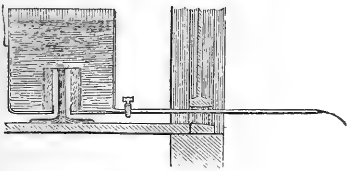


Fig. 1.—Water Apparatus.

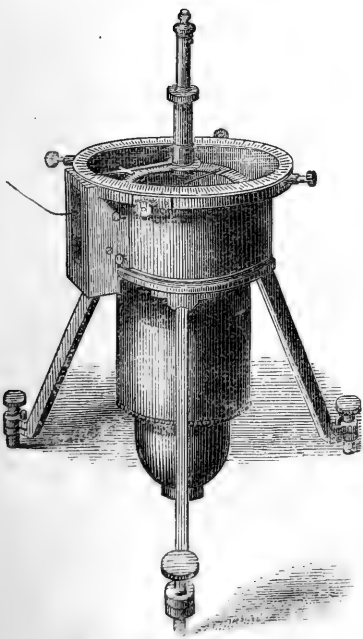


Fig. 2.—Divided Ring Electrometer.

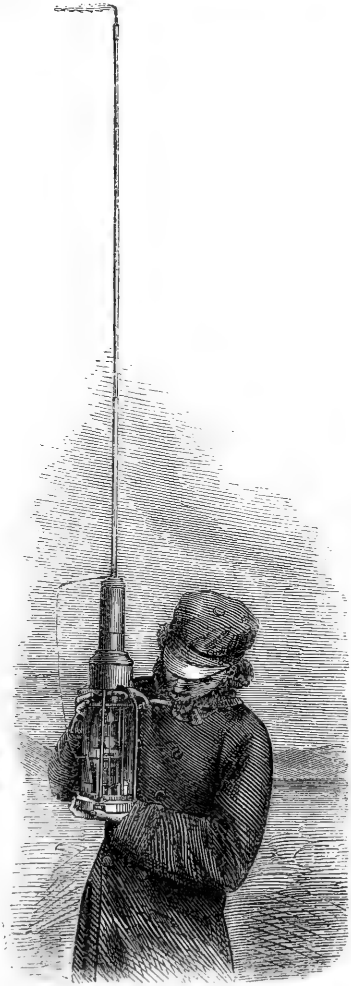


Fig. 3.—Portable Atmospheric Electrometer.

away with in another kind of electrometer, also "heterostatic," of which only one has yet been constructed—the electrometer of the portable apparatus shown in the third drawing. In it the index is attached at right angles to the middle of a fine platinum wire, firmly stretched between the inside coatings of two Leyden phials, and consists simply of a very light bar of aluminium, extending equally on the two sides of the supporting wire. It is repelled by two short bars of metal, fixed on the two sides of the top of a metal tube, which is supported by the inside coating of the lower phial, and has the fine wire in its axis. A conductor of suitable shape (Fig. 3), bearing an electrode, to connect with the body to be tested, insulated inside the case of the instrument, in the neighbourhood of the index, and when electrified in the same way, or the contrary way, to the inside coatings of the Leyden phials, causes, by its influence, the repulsion between the index and the fixed bars to be diminished or increased. The upper Leyden phial is moveable about a fixed axis, through angles measured by a pointer and circle, and thus the amount of torsion, in one-half of the bearing wire, required to bring the index to a constant position in any case is measured. The square root of the number of degrees of torsion measures the difference of potentials between the conductor tested and the inner coating of the Leyden phial. In using the instrument, the conductor tested is first put in connection with the earth, and the torsion required to bring the index to its fixed position is read off. This is called the zero, or earth reading. The tested conductor is then electrified, and the torsion reading taken. In the atmospheric application, this is called the air reading. The excess—positive or negative—of its square root, above that of the zero reading, measures the electro-motive force between the earth and the point of air tested. This result, when positive shows vitreous, when negative resinous potential in the air, if the index is resinous. By the aid of Barlow's table of square roots, the indications of the instrument may thus be reduced to definite measure of potential, almost as quickly as they can be written down. Once for all, the sensibility of the instrument can be determined by comparison with an absolute electrometer, or a galvanic battery. In the portable apparatus a burning match is used—instead of the water-dropping system, which the writer finds more convenient than any other for a fixed apparatus—to reduce the insulated conductor to the same potential as the air at its end. It is in reality the electrification of the earth's surface which has either directly or virtually been the subject of measurement in all observations on atmospheric electricity hitherto made. The methods which have been followed may be divided into two classes—(1.) Those in which means are taken to reduce the potential of an insulated conductor to the same as that of the air, at some point a few feet or yards distant from the earth. (2.) Those in which a portion of the earth (that is to say, a conductor connected with the earth for a time) is insulated, removed from its position, and tested by an electrometer, in a different position, or under cover. The first method was very imperfectly carried out by Beccaria with his long "exploring wire," stretched between insulating supports, on elevated portions of buildings, tree tops, or other prominent positions of the earth (see above, § 1); also, very imperfectly by means of "Volta's lantern"—an enclosed flame, supported on the top of an insulated conductor. On the other hand, it is put in practice very perfectly, by means of a match, or flame burning in the open air, on the top of a well-insulated conductor—a plan adopted, after Volta's suggestion by many observers; also, even more decidedly, by means of the water-dropping system—described in the preceding extract—which has recently occurred to the writer, and has been found by him both to be very satisfactory in its action and extremely easy and convenient in practice. The principle of each of these methods of the first class may be explained best by first considering the methods of the second class, as follows:—If a large sheet of metal were laid on the earth in a perfectly level district, and if a circular area of the same metal were laid upon it, and, after the manner of Coulomb's proof plane, were lifted by an insulated handle, and removed to an electrometer within doors, a measure of the earth's electrification at the time would be obtained; or if a ball, placed on the top of a conducting rod in the open air, were lifted from that position by an insulating support, and carried to an electrometer within doors, we should also have, on precisely the same principle, a measure of the earth's electrification at the time. If the height of the ball in this second plan were equal to one-sixteenth of the circumference of the disc used in the first plan, the electrometric indications would be the same, provided the diameter of the ball is small, in comparison with the height to which it is raised in the air, and the electrostatic capacity of the electrometer is small enough not to take any considerable proportion of the electricity from the ball in its application. The idea of experimenting by means of a disc laid flat on the earth, is merely suggested for the sake of illustration, and would obviously be most inconvenient in practice. On the other hand, the method by a carrier ball, instead of a proof plane, is precisely the method by which, on a small scale, Faraday investigated the distribution of electricity induced on the earth's surface (see above, § 1), by a piece of rubbed shellac; and the same method, applied on a suitable scale, for testing the natural electrification of the earth in the open air, has given, in the hands of Delmann of Creuznach, the most accurate results hitherto published in the way of electro-meteorological observation.* If, now, we conceive an elevated conductor, first belonging to the earth (§ 1), to become insulated, and to be made to throw off, and to continue throwing off, portions from an exposed position of its own surface, this part of its surface will quickly be reduced to a state of no electrification, and the whole conductor will be brought to such a potential as will allow it to remain in electrical equilibrium in the air, with that portion of its surface neutral. In other words, the potential throughout the insulated conductor is brought to be the same as that of the particular equi-potential surface of the air, which passes through the point of it from which matter breaks away. A flame, or the heated gas passing from a burning match, does precisely this: the flame itself, or the highly heated gas close to the match, being a conductor which is constantly extending out, and gradually becoming a non-conductor. The drops into which the jet issuing from the insulated conductor, on the plan introduced by the writer, produce the same effects, with more pointed decision, and with more of dynamical energy to remove the rejected matter, with the electricity which it carries, from the neighbourhood of the fixed conductor."

* Through some misapprehension, Mr. Delmann himself has not perceived that his own method of observation really consists in removing a portion of the earth, and bringing it insulated, with the electricity which it possessed *in situ*, to be tested within doors, otherwise, he could not have objected, as he has, to Peltier's view.

PROCEEDINGS

OF THE

PHILOSOPHICAL SOCIETY OF GLASGOW.

JANUARY 18, 1860.

Professor Anderson, *the President, in the Chair.*

Mr. A. S. H. Peterson, merchant, was elected a member.

On Incrustations of Boilers using Sea-Water. By Mr. J. R. Napier.

In Volume IV. of the *Proceedings* of this Society is a paper by Mr. James Napier, Chemist, on the Incrustations of Steam-boilers. Feeling much interested in his suggestions, his method was tried on board the *Islesman*, on a voyage to the north of Scotland in 1858, in order, if possible, to see the effect. At 9h. 30m. half a pound of dissolved soda ash was forced into the boiler along with the feed-water; at 11h. 30m. another half pound was forced in; at 3h. 30m. one pound was forced in; and at other times, more was put in. The only effect observed by these operations was making the water in the gauge glass of a milky appearance, within a few minutes after the soda was introduced, and it continued so for probably an hour after each injection, a small pipe near the surface of the water allowing a continuous discharge from the boiler. These experiments showed, that if the system proved economical, a simple plan could easily be arranged for carrying it out. But as Mr. Napier, in his paper, states "that this sort of crust (sulphate of lime) cannot be avoided by care or mechanical means, except by keeping the salt in the water under its crystallizing quantity, which would necessitate such an amount of blowing off and supply as would render it expensive," the expense of both methods has been calculated,—the chemical one of neutralizing the sulphate of lime with soda, and the mechanical one of an abundant discharge and supply, so as to keep the sulphate of lime under its crystallizing quantity.

It is necessary for this purpose to know the relative proportions of feed-water, and water required to be discharged, in order to prevent scale or crust. Many writers treat this crust as if it were common salt, and instruct how to make and graduate instruments for ascertaining its quantity, the graduations being effected by observing the depths to which the instrument sinks in water in which certain proportions of common salt has been dissolved. They say, "Sea water contains 3 per cent. of salt, and when the boiler contains less than 12 per cent. there will be little or no crust," therefore, it is necessary to blow off $\frac{3}{12}$ths or $\frac{1}{4}$th of the feed-water, in order to prevent the formation of crust. This reasoning, however, is unsatisfactory, as it is evident to any one who has the sense of taste, that the crust is not common salt; and chemical analysis shows that sea-water from the English Channel, although it contains nearly 3 per cent. of common salt, contains only about 0.8 per cent. of the materials forming the crust, and only 0.14 per cent. of the material of which, according to Mr. Napier, upwards of 90 per cent. of the crust is composed. It is also shown by analysis that a saturated solution of this material, sulphate of lime, in cold distilled water, is as 1 to 380, and as 1 to 388 in boiling water, or 25·7 parts of lime to 10,000 of solution. Mr. Napier, however, found 203 grains of sulphate of lime per gallon, in water taken from a boiler off Ailsa Craig. Its density is not stated; but I have assumed it to contain twice its natural quantity of saline matter, or its density to be 1·0548, sea-water being 1·0274; this gives the ratio 203 to 73,836 or 1 of sulphate of lime to 364 of solution, or 27·47 of sulphate of lime to 10,000 of solution. This proportion, it is inferred, is either a saturated solution, or such as the engineer of the vessel found little or no crust formed in. For want of better data, 28 of sulphate of lime to 10,000 of solution is assumed as the limit of saturation in boilers using sea-water, working at pressures not exceeding twenty lbs. above the atmosphere. This is equivalent to discharging $\frac{14}{28}$, or one-half of the feed-water. This assumption is confirmed by the practice of the British and North American Mail Company; by Mr. Napier's Ailsa Craig engineer, who was evidently blowing off nearly this amount; and by an experiment of Mr. Thomas Rowan, one of Dr. Penny's pupils, made for the purpose of ascertaining when the sulphate of lime and when the common salt deposited. He found, when he

evaporated $\frac{2}{10}$ths of the water, a trace of sulphate of lime deposited.

" $\frac{4}{10}$ths do. do. do.

" $\frac{5}{10}$ths, the sulphate of lime began to deposit in larger quantities.

" $\frac{6}{10}$ths, do. do. decided quantities.

" $\frac{8}{10}$ths, { sulphate of lime deposited in very large quantities; also magnesia and salt began to form.

Mr. Rowan's experiment, although indefinite as to the quantities, shows that the sulphate of lime begins to deposit before even one-half of the water is evaporated. It is probable, therefore, that this quantity, or more, would require to be discharged in order to prevent the formation of crust in boilers.

A saturated solution of common salt, in distilled water, is given as 27 of salt to 100 of solution, and a saturated solution in sea-water is said to be 36 of salt to 100 of solution. The former ratio has been chosen for this comparison, so that $\frac{27}{270}$, or only $\frac{1}{10}$th of the feed-water would require to be discharged in order to prevent the formation of common salt, and $\frac{8}{10}$ths to be neutralized by soda, to prevent the deposit of sulphate of lime, the $\frac{1}{10}$th discharged being a saturated solution of sulphate of lime and common salt. It is thus shown that by the chemical method, it is necessary to discharge $\frac{1}{10}$th of the feed-water, and neutralize the sulphate of lime in $\frac{8}{10}$ths of it with soda, according to Mr. Napier's method, to prevent crust; and by the mechanical method, it is necessary to discharge $\frac{5}{10}$ths.

The quantity of soda ash (supposed to contain 50 per cent. soda) is found by the formula $\frac{62}{68}$ of $\frac{14}{10,000}$ of $\frac{8}{10}$ of feed-water.

For the purpose of illustrating the expense of both methods of preventing crust, and also the loss by the blowing-off method, the case of a vessel has been taken working at a temperature of 270°, and evaporating at that temperature 7½lbs. of water from 100° per lb. of coal.

		Chemical Method.
Sea-water supplied to boiler, tem. 100°	15 lbs.	8·33 lbs.
Water discharged, 270°	7½	0·83 lbs.
Water evaporated,	7½	7½ lbs.
Total heat evaporating from 100° at 270° $h_{1\cdot2}=1092+\frac{3}{10}(T_1-32)-(T_2-32)$ 1095·4	8215°·5	8215°·5
Heat discharged,	1275°	142°
Fuel consumed in evaporation,	1· lbs. coal	1· lbs. coal
Fuel consumed in preventing crust,	0·155 lbs coal	0·0172 lbs. coal + 0·0085 lbs. soda ash
Total fuel,	1·155 lbs coal	1·017 lbs. coal + ·0085 soda ash

Thus it is seen that it requires only 172 lbs. coal + 85 lbs. soda ash, containing 50 per cent. soda, to be as efficient in preventing crust, as 1,550 lbs. of coal alone, which evaporates 7½ lbs. water from 100° at 270°. And these methods are equally expensive when the soda ash is 16·2 times dearer than the coal. This ratio varies with the efficiency of the fuel and the temperature of evaporation.

Although when coals are 10s., and soda ash £10, Mr. Napier's method is more expensive than the ordinary one of discharging the saturated water, there are many cases where it is probable the owners of vessels would profit by its adoption. In long voyages, for example, a vessel requiring, by the ordinary mode, 1,155 tons of coal, would, by Mr. Napier's method, require 1,017 tons coal, and 8½ tons soda ash, or 1,025½ tons weight. There would be a saving in money, therefore, of 138 tons coal at *x*/ + 129 tons freight *y*/ — 8½ tons soda ash at *z*/, or if coals are 10/ per ton, freight £3, and soda ash £11 per ton, the saving would be £362. That boilers, however, can be worked till the water in them is nearly saturated with common salt, or that the soda ash can be so accurately proportioned as *exactly* to neutralize the sulphate of lime, are problems which are believed to be new, and have not yet been attempted. The considerable saving which may be effected shows that the method is worthy of a trial.

From the foregoing example of a vessel worked at a temperature of 270°, it is also seen that a quantity of fuel, equal to 15½ per cent. of that which produces evaporation, is consumed by the ordinary blowing-off method, in order to prevent crust, and this amount increases with the temperature. Brine chests have been frequently used for the recovery of this notable loss; but apparently from a misapprehension of the quantity of water necessary to be discharged, and a want of knowledge of the amount of surface required to absorb the discharged heat, of a capacity greatly too small for their purpose. If Peclet's formula for calculating this surface is to be trusted, those chests on board the West India Mail Steamship *La Plata*, and some of the British and North American Company's packets are $\frac{1}{15}$th to $\frac{1}{20}$th of the size that would be efficient. When these brine chests, regenerators, or heat economizers, therefore, are made with a *sufficient* amount of surface, so that abundance of water can be supplied to and discharged from the boilers, with little loss of heat, then there will be no incrustation of boilers, and a probable saving of from 12 to 13 per cent. of their fuel. Peclet's formula, or Professor Rankine's reduction of it, which gives the probable amount of surface required for a difference of temperature of 140° between the feed and the discharged water, at $\frac{1}{10}$th square foot per lb. of brine discharged per hour, becomes under the same circumstances, and when the quantity of brine discharged is equal to the quantity of water evaporated, $\frac{1}{10}$th square foot of surface per lb. of water *evaporated* per hour. The introduction of Dr. Joule's spiral wires to the system will probably render less surface efficient. This amount of discharge and surface, it is expected, will prevent incrustation, and save nine-tenths of the heat at present lost.

On the Density of Steam. By Prof. W. J. Macquorn Rankine.

It has been known for some time that the Density of Steam deviates from the laws of the perfectly gaseous condition; and deviates more and more as the pressure increases.

A formula for deducing the density of a vapour from its pressure, temperature, and latent heat, was first deduced from the Mechanical Theory of Heat, by Professor Clausius, in 1849.

Professor Rankine, in the absence of precise experimental data, made use of a formula substantially identical with that of Clausius, to compute tables of the volume and density of steam for practical use, which have been published in his work *On Prime Movers.*

Experiments have for some time been in progress by Mr. Fairbairn and Mr. Tate, on the density of saturated steam at various boiling-points, part of which were communicated to the British Association in September, 1859. In the following table, the results of these experiments are compared with those of the theory, computed by the aid of the tables of volume and density before mentioned.

"Specific Volumes" of Steam, as computed from the Mechanical Theory of Heat, and as determined by the experiments of Messrs. Fairbairn and Tate:—

Temperature Fahrenheit.	Ratio of Volume of Steam to that of Water at 60 degrees. By Theory.	By Experiment.	Difference.
136°·88	8276	8262	+14
160°·016	4790	4911	−129
171°·55	3722	3710	+12
175°·15	3433	3426	+7
182°·32	2960	3045	−85
188°·09	2630	2621	+9
197°·48	2180	2147	+33
244	936	896	+40
245	920	890	+30
257	756	751	+5
262	698	684	+14
268	635	633	+2
270	616	604	+12
283	506	490	+16

PROCEEDINGS

OF THE

PHILOSOPHICAL SOCIETY OF GLASGOW.

FEBRUARY 1, 1860.

PROFESSOR ANDERSON, *the President, in the Chair.*

Professor Grant, University of Glasgow; Mr. William Simons, Whiteinch, Partick; Mr. Andrew M'Onie, engineer, Tradeston; and the Rev. Henry William Crosskey, were elected members of the Society.

Observations on Sensations experienced while climbing the more elevated Mountains of the Andes in Peru and Bolivia. By MATHIE HAMILTON, M.D., formerly Medical Officer to the London, Potosi and Peruvian Mining Company, Physician to Military Hospitals in Peru, &c.

SOME persons, who never climbed on their feet in elevated regions, have denied that travellers in such localities have been affected by painful and difficult respiration. The doubts and assertions on this subject, have originated, we may suppose, from what has been experienced in balloon ascents, during which people have gone up to great elevations, without being much affected in their respiratory organs. From such partial and insufficient data, some persons have contradicted the statements made by travellers, who, when climbing the Andes and other lofty regions, have suffered severely from painful and difficult respiration, vertigo, and sickness at stomach—in some cases with vomiting and purging, head-ache, and general lassitude,—in fine, all the symptoms of aggravated sea-sickness.

Without here attempting to investigate the causes of phenomena which, in some cases, are the result of climbing on foot steep mountains of great elevation, I will narrate that which I felt, and that which came under my own observation—also a few facts as stated to me by the late Rear-Admiral Charles Hope. In the year 1835 the British Frigate "Tyne" was in the South Pacific Ocean at Arica, and the Commander, Captain Charles Hope,* with his Surgeon, Dr. Cunningham, R.N.,† came up to Tacna, where I then resided. Along with an Indian guide, they went up to a canal which was being made, to fertilize the desert between the Andes and the ocean. The highest point to which they ascended is about 15,000 feet, English measure, above the ocean and on his return to Tacna, Captain Hope informed me that he had nearly perished when near the crest of the mountain; and that he ascribed his escape from death to the timely aid that was given to him by Dr. Cunningham. The Captain stated that he was affected with difficult and painful respiration when attempting to climb on foot, suffering extreme nausea and vomiting, with vertigo and severe headache,—in fine, with the symptoms of aggravated sea-sickness. ‡ [Dr. Hamilton next quoted the testimony of Captain Wilkes, in his *Narrative of the United States Exploring Expedition in the years* 1838–42, as to similar effects being produced on some of his party in ascending a mountain near Lima, 15,000 feet high.]

I will now briefly notice my own experience, when climbing mountains, while traversing both the western and the eastern or more internal Andes of Southern Peru and Bolivia, in 1827.

Don Joachin de Achavel, a merchant of great celebrity, being on his return from the west coast to the interior of the Continent, I accepted his urgent invitation to visit along with him the cities of Oruro, Potosi, Chuquisaca, &c., with the return journey to the Pacific, through the great Desert of Caranjas, *via* Andamarca and the Mountain of Sahama, which Mr. Pentland states rises more than 22,000 feet above the ocean.

We moved from Tacna on 24th August. Our party consisted of eight men (I being the only Englishman), with two horses and twenty-four mules, and arrived at Palca in the evening of the same day. It is about

* The late Rear-Admiral Charles Hope was brother to the late Lord Justice Clerk.

† The much lamented Cunningham, who, when on a solitary botanizing ramble in the southern hemisphere, was attacked by savages, murdered, and eaten by them; his bones and other relics having been found by a party of his shipmates, who went from the frigate in quest of him.

‡ In the year 1735 the Kings of France and Spain sent commissioners to the equatorial regions of America; and in a work written by one of them, and printed in Madrid in 1792, it is stated that the "*Mareo*," which he notices as affecting travellers in Peru, was not experienced by the Academicians while at the Equator. It may be noted that neither these savans nor the Baron Humboldt ever visited South Peru, where there are cities at a much greater altitude than any in Mexico or Central America.

9,000 feet above the sea, and thirty-six miles from Tacna. This gorge or pass across the Cordillera begins at a spot called San Francisco, which is 2,000 feet above the ocean. Within an hour after our arrival at Palca, and without having had food or drink since morning, I climbed the mountain path a short distance, when I was attacked by a fit of the soroche, of which I had been warned before leaving the coast. The attack was dangerously severe, there being acute headache and violent throbbing of the temporal arteries, also vomiting excessively severe,—in fine, all the symptoms of aggravated sea-sickness.

Men, horses, and mules occasionally perish under soroche while on the Andes; and yet some persons who never were 3,000 feet above the level of the ocean, or if so, have only been sitting in a balloon in a state of muscular quiescence, have ridiculed statements of facts, such as those here noted.

Travellers in such lofty regions are not all affected with equal severity, and some scarcely in any degree—also, there is more predisposition to be affected by soroche in some horses and mules than in others; but many mules perish in those mountainous regions from the ignorance or cruelty of the drivers, when mules are not allowed sufficient time to draw breath, while climbing certain steep localities. Horses are rarely used on the higher pinnacles of the Andes in Bolivia or Peru. Judging from our own observation, the best preventive against fatal effects, when suffering under difficult respiration, is to let the animal rest, and remain motionless a few minutes; though it is an opinion among Peruvian muleteers that holding a bit of garlic to the nostril of a horse or mule, while the animal is halting, removes the malady; but as I have seen in numerous cases, it is the state of quiescence in the man, and in the mule, which prevents or removes an attack, by restoring in some degree the balance of circulation in the organs of respiration.

Next day, when we were on the crest of the Cordillera, at the height of more than 15,000 feet above the ocean, I became so drowsy as to fall asleep on the mule while riding; but there was not vomiting: the circulation of the blood was more rapid than natural, and the temporal arteries throbbed strongly. Native muleteers and others hold the opinion, that at those localities where the soroche is most frequently seen in operation, there are unseen metallic veins, or influences, which affect both mules and men; but it may be noted that such places are very steep, and the ascent exceedingly difficult. I will here notice only two localities out of many which might be mentioned, where I experienced the phenomenon of difficult and very painful respiration while climbing them on foot. The one is the mountain in the eastern or internal Andes, called "Tolopalka" by the Indian mountaineers; but better known to many in Bolivia, as "*the Cordillera of the Friars,*" from a sad catastrophe which occurred there more than two centuries ago,—when a numerous party of friars from Europe were lost in a snow-storm.

The crest of this mountain is 14,000 feet above the sea-level; and on the day when we crossed the pass it presented a mass of ice and snow; but the atmosphere was clear, and the sun shone on us with brilliancy. Our animals halted to breathe every few paces, and those of us who dismounted and climbed on foot were glad to do what our mules did, in order to obtain temporary relief from painful respiration. Again, when in the city of Potosi, I was taken to see the Mint. The outer wall of the Mint is built on a plateau, which was cut on the face of the hill, with much labour and expense, when the present Mint was erected in 1750.

The narrow passage by which I returned from the Mint to the square is by far the steepest paved locality I ever saw in any country. When slowly walking up that inclined surface, I suffered severely from acute lancinating pain in the thoracic region, and was compelled to stop and remain quiescent during some time after every few steps, to get breath and relief from pain.

These sensations must have been caused by the pedal upward locomotion, and not merely a result of the altitude of the place; for though the height is more than 13,000 feet above the level of the ocean, during the journey from the coast, and on our return to it, we were at various points several thousand feet higher, without feeling much uneasiness while riding.

I observed that both mules and men with the thorax narrow are more subject to soroche than those who exhibit a chest and breathing organs more expanded. The Peruvian mountaineer generally presents a large thorax and well-formed lower limbs, the muscles being fully developed.

When in Potosi, I made an attempt to climb to the summit of the "cerro" or cone, in which the mines are situated, where, during three centuries, men have been digging in quest of silver. The top of the mountain, evidently of volcanic formation, is above 16,000 feet in altitude from the level of the ocean. And under the guidance of an Indian, hired for the purpose, I gained an elevation far above the highest pinnacle of the city, but was compelled to give up the attempt, both in consequence of difficult breathing and the looseness of the footing on the mountain, which gave way at almost every step. Though we were much higher than the Mint buildings, respiration was not so painful, nor so much impeded as it was in the passage from the Mint to the Plaza, because the "cerro" or cone being very steep, it was necessary for us to climb it circuitously, so that at no part of our ascent was the acclivity so steep as in the vicinity of the Mint.

In those elevated regions the sense of hearing is very different from what is experienced nearer the sea-level, where the atmosphere is so much more dense. In Potosi the human voice, the ringing of bells, the sound of a trumpet, or musical instruments of any sort, or the discharge of fire-arms, act on the tympanum with much less force than in the lower regions. It has been noted that in Potosi church bells are more apt to crack than on the coast, unless their sides are made thicker than usual.

No acoustic phenomenon on the higher places of the Cordillera struck me more forcibly than the native music of the Peruvian mountaineers, as it sounded there, compared with similar notes when reverberated 13,000 or 14,000 feet lower down. The instruments of those people are chiefly a sort of clarionets, and are played on a flat key, and when a number of them are blown together, and well played, the sounds emitted excite, on a delicate ear, a sensation peculiarly sad. Perspiration is very rarely seen on people on the Andes of Southern Peru, when at the altitude of 13,000 or 14,000 feet above the level of the ocean. I saw it in two cases only while in Potosi. One case was that of Indians working in the mines there, who, when they appeared at the mouth of a mine, with burdens which they had carried from below, were perspiring in the face; and the other case was that of a party of people who were carrying through the streets of Potosi a colossal image of the Virgin Mary, which was on a heavy platform, in a grand procession on the day of All Saints.

Evaporation of water proceeds with much rapidity there, the air being generally exceedingly dry, and acting with extreme severity on the cuticle of white people when it is exposed without any precaution. The face may in some degree be protected by its being covered when travelling with a white cloth, leaving only one eye exposed to the solar rays; but, in spite of all precautions, blood burst repeatedly from my lips.

The hands become rough and scaly, and the fingers, more especially at the articulations, are both swollen and scaly, exhibiting what the Indians there call "*chuno*," which is a word in the *Quichua* language signifying anything wrinkled or shrivelled and tanned with cold.

Temporary blindness is in some cases a result of exposure to the sun's rays, when they are reflected from a mass of ice or snow, in that tenuous atmosphere. The Indians call such loss of vision "umpe;" and occasionally it causes permanent blindness, the retina or optic nerve seeming to be paralyzed.

A very great difference of temperature is experienced during day, when the solar beams are operating on people while out of doors, and when the same persons go under cover; for though, when in the open air, they have been overpowered by the solar heat, yet immediately after, if out of its influence, they may be seen shivering with cold, as if suffering under ague.

Though I did not cross the Andes to practise medicine, I was occasionally consulted in the places visited, and noted that cases of pulmonary consumption did not come under my observation. On this subject I some time ago wrote to a friend residing in London. His answer is as follows:—

"London, 10th Nov., 1856.

"During more than *ten* years' practice in La Paz,* I did not meet with a *single case* of *phthisis pulmonalis*. The theory that, at a certain height above the sea, the disease is never met with, has for many years been a favourite idea of mine, amounting almost to a *conviction*."

Mr. Robert Hart made the following communication to the Society, on Spots on the Sun:—

The paper on the 4th January by Professor William Thomson, called the attention of the Society to matter falling into the Sun. I beg to follow up his observations, by laying before the members a drawing of the appearance of the Sun on the 31st January, 1860; and also magnified views of the spots on its surface. And to show the general aspect of these spots, and illustrate the quick changes they undergo, I have also given the appearance of some of the spots, of which I made drawings every day they were to be seen. They show the change in form, increase, and diminution, at the dates marked on each.

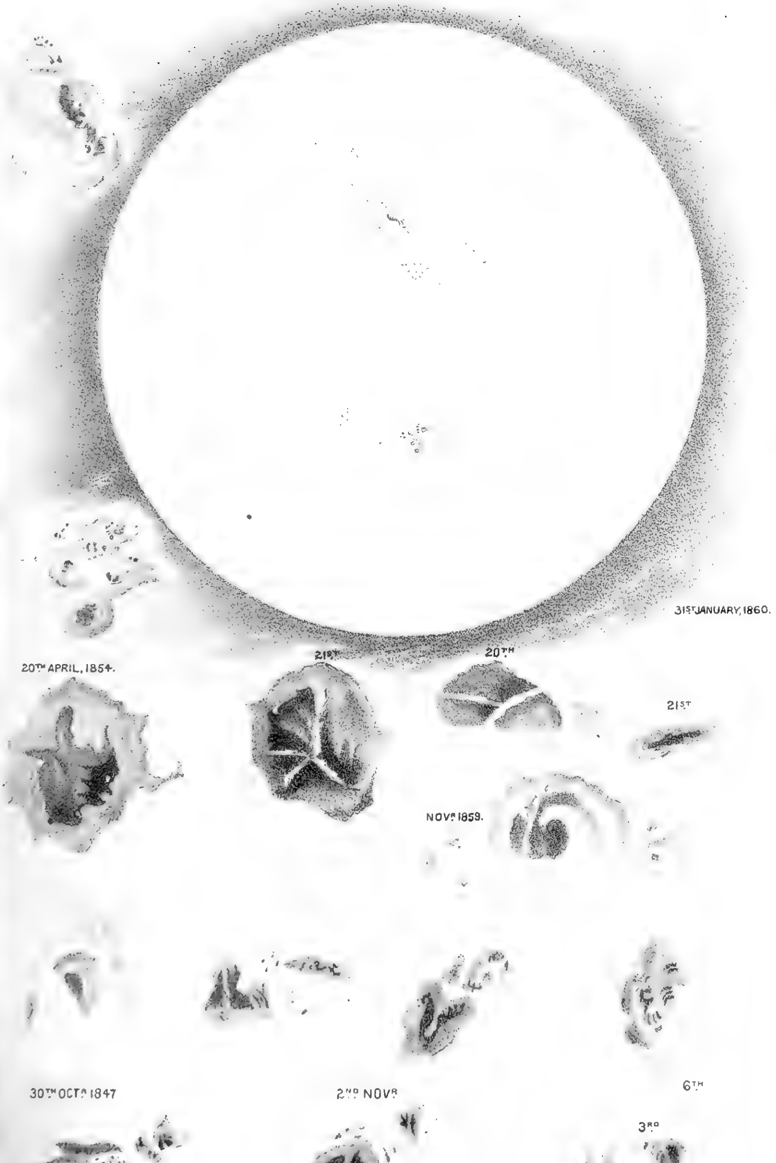
Can these disturbances on the Sun's surface be caused by the falling of matter into it?

The whole of the Sun's surface has a granulated appearance. This uniform surface is disturbed at times by parts of it being driven into ridges, like long waves, or snow-wreathes; and at these parts, the openings often take place.

Observations on the Supply of Coal and Ironstone, from the Mineral Fields of the West of Scotland. By William Moore, Civil and Mining Engineer, Glasgow.

The two mineral substances, Coal and Ironstone—the supply of which from the Lanarkshire district forms the subject of this paper—

* La Paz is a city with forty thousand inhabitants, and is 12,500 feet above the ocean.



SPOTS ON THE SUN

are indispensably necessary to all manufacturing and commercial prosperity, and the available abundance of these has been the foundation of the great wealth and power which have placed and maintained Great Britain at the head of all other nations. In whatever district a good coal field is found, there also are to be seen wealthy and industrious communities. Thus, the Staffordshire field produced Birmingham, Wolverhampton, and numerous other hives of industry principally engaged in the manufacture of iron. The Lancashire field has maintained the wonderful manufacturing power of Manchester, and all the towns surrounding it. The great Northumberland and Durham field furnishes more than one-fourth of the whole produce of all the coal fields of Great Britain, and not only supports a busy manufacturing population over its own surface, but supplies fuel for most of the southern counties of England, and sends also large quantities to continental Europe. The Welsh field yields about a third of all the iron produced in Great Britain, and throughout its hills and valleys the unceasing blaze of the blast furnaces and ring of the forge hammer give proof to the eye and the ear of a population busy in the production of wealth. The Derbyshire, Nottinghamshire, and Yorkshire fields, and others of less extent, are also seats of England's great manufacturing industry; and when we come home to the fields of Lanarkshire and Ayrshire, we recognize the source of Scotland's proud and prosperous position.

The city of Glasgow, where we are now met, had a certain measure of prosperity in her commerce with America and the colonies even before the wealth of the mineral field lying around her was fully known and developed. But it is during the present century that, with the development of her coal field, and the abundant supply of fuel drawn therefrom, Glasgow has increased in manufacturing power, wealth, and population, to its present gigantic dimensions and influence. A continuance of the present abundant supply of cheap fuel is therefore a matter of the utmost importance for the maintenance of her prosperity, and for her future progress. Within the last sixty years, the produce of iron from the mineral fields of this district has increased so enormously, that it is now the most important trade of this city and neighbourhood, and has constituted Lanarkshire one of the greatest seats of the iron trade in Great Britain.

In 1800 the annual quantity of pig iron produced in Scotland was about 8,000 tons; in 1825 it had increased to about 30,000 tons; in 1845 it had reached 476,000 tons; and the make for the last year (1859) was nearly 1,000,000 tons, or about one-third of the whole quantity produced in Great Britain.

The works producing this enormous quantity of iron are situated in Lanarkshire and Ayrshire—the greater part in the Middle Ward of Lanarkshire, in the neighbourhood of Coatbridge.

The whole fields supplying the iron-works in both of these districts are too extensive to be discussed in one paper. I shall therefore reserve the Ayrshire field for another occasion, and at present give you only the result of my examination of the fields lying eastwards of this city as far as Bathgate; north-east as far as Denny; south-east as far as Carluke; and westward of the city as far as Maryhill on the north, and Govan on the south; all as delineated on the accompanying map. Keeping in view that the object of this paper is neither geological nor mining instruction, but simply to show the result of my inquiry into the quantity of minerals still available for the future supply of this important district, I shall not enter upon the geological features of the fields or strata in which these minerals lie, nor upon any details as to the mode of working the same, but shall proceed to describe the several workable seams of coal and ironstone, so far as known, and in the order of their position, as shown in the accompanying general section. Of course, I do not mean by this section to represent the actual depth of the seams under the surface at any one place, but simply their relative position in the stratification of the whole field, were it possible at any one place to find them all together.

I will take first the uppermost seam, and, proceeding downwards, will show the estimated quantity of each seam in the section, and within the boundaries or area shown on the map, deducting, of course, the quantities already worked out.

Palace Craig Ironstone.—*At* 42 *Fathoms—Average thickness,* 12 *Inches.*—This seam is the uppermost workable ironstone in the Lanarkshire mineral field, and lies close to the bottom of the new red sandstone, and is worked at Palace Craig, Faskine, and Carnbroe. Its position in the strata extends over a large district of country around Glasgow and Hamilton; but it is usually too poor in iron to be at present profitably worked. At Souterhouse Colliery, near Coatbridge, it contains about 15 per cent of iron. At Drumpeller, west from Coatbridge, it is only a ferruginous shale, quite valueless. In the district around Clyde Iron-works it is known as the *mussel band,* where it is also valueless; but although only partially worked, it is well known in the district, and easily distinguishable in the strata by the remains of ganoid fishes which it contains.

In its most favourable state, its quality is inferior, on account of the large proportion of lime and sand contained in it; and it can only be used in the blast furnaces along with other ironstone of superior quality, and in the proportion of not more than one-fourth of the whole quantity. The workable limit of this seam in the field to the east of Glasgow appears to be near the line of the large slip passing through the Woodhall lands at the mill. On the west the boundary of its existence is not distinctly known; but it has not been found of quality worth working west of Carnbroe. Towards the north it crops off before coming to the south boundary of Cairnhill. The quality of this seam, so far as seen, is not very regular, but varies in different localities. In stating the quantity still to work, I have confined my calculation to what is known of the seam around Faskine, and I estimate the area at 300 acres.

UPPER COAL.—*At* 48 *Fathoms—Average Thickness,* 40 *Inches.*—This is the first or uppermost coal found in the Clyde basin. In thickness, it ranges from 3 to 4½ feet, and its quality has been long famous for household purposes at Eastfield, Stonelaw, and the collieries around Glasgow. It exists in its best condition on the south side of the Clyde, and on the north bank of it as far as Tollcross and Kenmuir. At the latter place, and eastward, it gradually becomes inferior both in thickness and quality.

At no place out of the district described does the seam appear to exist in a valuable condition. At Bredisholm, near Baillieston, and Drumpeller, near Coatbridge, and throughout the Coatbridge district, it is unworkably thin. At Drumbathie, near Airdrie, it is about 2½ feet in thickness, but not considered of workable quality.

This seam has been worked for a very long period for the supply of this city, and what remains of it is confined to patches lying between Eastfield and Dalmarnock on the west, and Kenmuir on the east. Estimated area still to work, 2,500 acres.

ELL COAL.—*At* 63 *Fathoms—Average Thickness,* 96 *Inches.*—The great thickness and excellent quality of this coal make it the most valuable and important seam of coal in the whole district. It is the principal seam worked in the recently opened-up Wishaw district, and there is now a greater supply drawn from it than from any other seam in the whole of the fields under consideration. This seam extends from Glasgow in a south-eastern direction as far as Netherburn, which lies about half-way between Hamilton and Lesmahagow. Its southern boundary is near the large fault, known as the Eddlewood Dyke, which throws up the strata to the south-west about 100 fathoms. The breadth of the seam along the north side of this dyke averages about a mile and a-half, as far as Hamilton on the south, and Holytown on the north; from Holytown the northern boundary turns northwards to its most northern limit at Stanrig, north-east of Airdrie; thence the line of limit goes south-east by Clarkstone, Newarthill, Newmains, and Lawmuir, to Netherburn again. The quality of this coal is first-class. In the Glasgow district it is used chiefly for household and manufacturing purposes. In some of the collieries near Motherwell it is harder in its nature, and used extensively for manufacturing and smelting iron. At Overtown and Pather it is slightly burned, and is rendered valuable for locomotive purposes. Estimated area still to work, 12,400 acres.

Pyotshaw and Main Coal.—*At* 67 *Fathoms—Average Thickness of Pyotshaw*, 48 *Inches—Average Thickness of Main Coal*, 60 *Inches.*—These two seams often lie close together, as in the districts of Drumpeller, near Coatbridge; Whiterigg and Ballochnie, near Airdrie; and at Newarthill, Morningside, and Wishaw, forming one seam of coal, ranging from seven to nine feet in thickness. They are also frequently found separated by an intervening stratum of shale, ranging in thickness from two feet to six or seven fathoms, as at Bredisholm, near Baillieston, and at Coatbridge, where it may be said to exist in its best state.

These seams of coal (with the exception of the Pyotshaw, which does not exist in the Glasgow district) extend over a rather less area than the Ell coal seam last described. The Pyotshaw is the uppermost of the two, and is a strong Splint coal, ranging from three to five feet in thickness, and is much used for iron-smelting and other manufacturing purposes.

The Main coal seam around Glasgow is a fine, clean, soft coal, ranging in thickness from $3\frac{1}{2}$ to 5 feet. Around Coatbridge and Airdrie it is also of fine quality, and well suited for household and manufacturing purposes. At Springbank, near Glasgow, part of this seam changes into a Parrot coal, and is used at the neighbouring gas works as a gas-yielding coal. The Parrot coal is not of first-class quality, and its extent does not exceed thirty acres. Estimated area still to work—Of Pyotshaw coal, 3,942 acres; of Main coal, 5,750 acres.

Humph Coal.—*At* 76 *Fathoms—Average Thickness*, 20 *Inches.*—This seam cannot be calculated upon as contributing, or as being likely to contribute, much to the general supply of coal for the district. It extends over a considerable area as a thin coal (divided in the centre by a parting of shale and fire-clay), but occasionally thickens into a workable seam of an aggregate thickness of about twenty inches. At Dalmarnock, near Glasgow, and at some of the adjoining collieries, it was worked extensively for some time, and used at some of the manufactories situated on the river Clyde, to which it was conveyed in boats. At Airdrie it is generally thin, but has been worked to assist in the calcining of ironstone, and for the use of the engine fires. Estimated area still to work, 1,150 acres.

Splint Coal.—*At* 81 *Fathoms—Average Thickness,* 40 *Inches.*—This coal was for many years known as the "Lady Anne" coal, and is justly celebrated for the purposes of iron-smelting, and has been used almost exclusively for this purpose at the iron-works around Coatbridge. In the Glasgow district its thickness ranges from thirty to thirty-six inches. At Jerviston, near Holytown, and in the locality around Newarthill, its thickness is upwards of 4½ feet. At Bredisholm, and for a small part of the surrounding district, it changes into a Parrot coal, which begins as a thin leaf, gradually thickening to about a foot, when the Splint coal entirely disappears, except a few inches on the top and bottom of the seam. The Parrot coal is of medium quality, and is shipped in considerable quantities for the supply of the Irish gas-works. It does not extend eastwards far beyond Bredisholm, as we find it throughout the lands of Drumpeller, a compact, hard Splint coal, ranging from three to five feet in thickness, without the least appearance of Parrot in it.

This seam extends over nearly the same area as the Main coal last described, but is much worked out in the north part of the field in the parishes of Old and New Monkland, where it was shallow, and lay convenient to the iron-works where it was consumed. At Mount Vernon, Bredisholm, and Drumpeller, there is still some of it to work; but in these localities it is very much troubled. Estimated area still to work, 14,875 acres.

Throughout almost the entire area where we meet the Splint coal we find it accompanied by a Clayband ironstone, lying immediately above it, of about two and a-half inches in thickness, which is generally worked with the coal, and calcined in bings containing from 800 to 1,000 tons of raw ironstone. Estimated area still to work, 12,000 acres.

Sour Milk Coal.—*At* 84 *Fathoms—Average Thickness,* 36 *Inches.*—This seam is known by these three names—the "Sour Milk" coal, the "Wee" coal, and the "Virgin" coal. It is sometimes divided in the centre by a bed of shale ten to eighteen inches thick, and it is only when this intervening shale disappears that the seam becomes of workable value. In the district south-east of Glasgow—at Dalmarnock and Stonelaw—it is thin and not of much value. At Cardowan and Camedie, about four miles east of Glasgow, it is burned, by its nearness to whinstone, rendering it a most valuable coal for steam-producing purposes.

In the Airdrie district it is valueless, at least for the present, and has not been worked. Estimated area still to work, 1,620 acres.

Mushet Blackband Ironstone.—*At* 103 *Fathoms—Average Thickness* 16 *Inches.*—This celebrated seam of ironstone was first discovered about the beginning of this century by the late David Mushet, who was then manager of the Calder Iron-works. The great value of this stone consists not merely in its freedom from deleterious impurities, but in the large quantity of carbonaceous matter which it contains, whereby it is capable of being calcined without the assistance of an additional mixture of coal, as in the case of Clayband ironstone. In its raw state it contains about 25 per cent. of iron, and in its calcined state about 70 per cent. It was but partially worked and used at the Calder Iron-works, and afterwards at the Clyde Iron-works for a number of years after its discovery, as it was considered too rich to be safely used in the blast furnaces, except in a small proportion along with Clay ironstone; but by experience it was found that the furnaces worked well with large proportions of it; and about the year 1825 it was used alone in the furnaces, without any mixture and with complete success, and its superior quality in every respect proved and established. About that time its value attracted the notice of Messrs. Baird and others; hence arose, in a few years, first the Gartsherrie works, then the Dundyvan, Summerlee, Carnbroe, Langloan and other works. These works drew their chief supply from this seam for many years; but, from its gradual exhaustion, other seams have been explored, and resorted to during the last ten or twelve years. This seam was therefore the foundation of the great increase and prosperity of the iron trade in Scotland, especially when taken in connection with the use of hot blast in smelting, which was discovered and introduced by Mr. Neilson about the year 1829. The discovery of hot blast so improved the smelting process, that raw coal could be used in the furnaces instead of coke, and an immense saving was thereby effected. With Blackband ironstone and Monkland Splint coal, and hot blast, iron could be produced in this district cheaper than anywhere else in the world; hence the important position it holds in that trade.

This valuable ironstone is now nearly all worked out, and may be said to have ceased for some time past to contribute much to the supply of the iron-works of the district, of which it was so long the main stay and support. It never was found workable over more than a small area, bounded on the north by a line drawn from Gartsherrie to Drumshangy and Brownrig, near Airdrie,—on the east, by a line drawn from Brownrig and Arden to Monkland and Newarthill,—on the south, by a line drawn through Cleland,—and on the west, by a line drawn through Woodhall, Rosehall, and Coatbridge. What remains to work of it is confined to patches at Holehill and Rawyards, near Airdrie, and Rosehall, near Coatbridge.

At Quarter, near Hamilton, it is again met with, and is worked for the supply of the iron-works there. Estimated area still to work, 700 acres.

SOFT BAND IRONSTONE.—*At* 106 *Fathoms—Average Thickness,* 20 *Inches.*—This is an inferior ironstone, partially worked at Millfield, near Airdrie; also at Darngavel and Arden. At Darngavel it was of fair quality, and yielded a good per centage of iron, and was used extensively in some of the iron-works; but the working of it has now been entirely discontinued, and notwithstanding the increased distance from which ironstone has to be brought to the furnaces, its quality is not such as to warrant its being opened up and worked; so that we cannot calculate on this ironstone as one which will contribute to the supply, so long as a better quality can be got.

ROUGH, OR CURLY BAND IRONSTONE.—*At* 120 *Fathoms—Average Thickness,* 5 *Inches.*—This band of ironstone lies a few feet above the Virtue Well coal. It lies embedded in a matrix of shale, in round and oval shaped balls, containing no carbonaceous matter. It is therefore mixed in the bing with layers of coal to assist its calcination. It is in its best condition at Cleland, and near Newarthill, and does not seem to be of much value out of those districts. It is seen at Shotts, and has been bored through at Wishaw, but found inferior in quality. Estimated area still to work, 500 acres.

VIRTUE WELL COAL.—*At* 122 *Fathoms—Average Thickness,* 30 *Inches.*—This seam is well known in the Monklands, where it has been long worked as a clean and valuable coal. In the northern portion of the field, along the tract of the Monklands railway, it is burned, by its proximity to a sheet of whinstone which passes over this district, but it is thereby rendered more valuable for steam purposes, and it is worked exclusively for these purposes at Rawyards, Airdrie-hill, and Ballochnie. In the more southern district, in the neighbourhood of Cleland, it is hard and splinty, and admirably adapted for iron-smelting. The seam extends over a large area. In the Monklands its northern limit is near Gartsherrie, Drumshangy, and Meadowfield. On the west it extends as far as Drumpeller, and at one time was worked near Hogganfield, although very thin. On the south limit of the field it is worked at Netherburn, and on the east at Shotts. This coal leaves the New Monkland parish at Avonhead, and enters into Stirlingshire, where it takes the name of the Lady Grange coal, and averages about twenty-nine inches in thickness. It covers a pretty large area in the parish of Slamannan, where it is worked at Limerig and Binniehill. Estimated area still to work, 10,000 acres.

BELLSIDE IRONSTONE.—*At 132 Fathoms—Average Thickness, 7 Inches.*—This is a Blackband ironstone of very good quality, ranging in thickness from four to nine inches. It is worked extensively at Bellside and Greenhill, in the parish of Shotts. It was worked at Newmains some years ago, at a thickness of about four inches. It is also seen at Castlehill, but not of very good quality. On the Wishaw Estate it was bored through some years ago, and found valueless. Estimated area still to work, 1,000 acres.

CALDERBRAE IRONSTONE.—*At 134 Fathoms—Average Thickness, 8 Inches.*—This ironstone is sometimes called the Kiltongue Mussel ironstone, and in some places resembles the Palace Craig band in point of quality. There is a considerable quantity of it in the New Monkland parish, and it is worked at Stand, on the Rochsoles Estate, where the section consists of a thin band of ironstone and one of gas coal, the latter of a very fine quality, and resembling slightly the nature of the Torbanehill Parrot. At Braes, in the New Monkland parish, on the north road to Slamannan, it has also been worked. It exists likewise in the lands of Arden, but has not yet been worked. At Whiflat it is twenty inches in thickness, but contains a very small per centage of iron, and consequently not workable. At "Peep o' Day," on the Monkland Estate, near Airdrie, this band of ironstone is in the position of the Kiltongue coal. Estimated area still to work, 4,400 acres.

KILTONGUE COAL.—*At 136 Fathoms—Average Thickness, 60 Inches.*—Like the Virtue Well coal, this seam is not seen in the Glasgow district. We begin to recognize it as we go eastwards, at Bartonshill. At Drumpeller it exists in its best state, where it is about six and a-half feet in thickness. It is usually divided in the middle by a stone or shaly substance, varying in thickness from four to thirty-six inches, as at Hayhill and Kilgarth, near the north limit of the field. In quality it is somewhat irregular,—sometimes it is hard, and well suited for iron-smelting,—and sometimes soft, and better suited for the purposes of the household. On the north of the field this seam is worked at Hayhill, Kilgarth, Cleugh, and Drumgray, from which it passes into the county of Stirling, where it takes the name of the Splint coal, and is worked under that name as far as Redding and Blackbraes on the east, and Arnloss, Drumclair, Limerig, and Binniehill, on the south. In Lanarkshire it extends as far south as Castlehill, where it is called the four feet coal. At Roughrig and Drumclair, on the Slamannan railway, it is converted into a steam coal, from its proximity to a large whinstone dyke passing through these fields. Estimated area still to work, 9,721 acres.

DRUMGRAY COAL.—*At* 148 *Fathoms—Average Thickness,* 24 *Inches.*—This is a thin coal, and not one which can be calculated upon as forming a large part of the future supply.

It has been worked for many years on the lands of Drumgray, near Airdrie, where it varies in thickness from twenty to twenty-eight inches. In extent, it covers the same area, and possesses the same irregularity of thickness and quality as the Kiltongue coal. It is at present being worked at Stand, on the Rochsoles Estate, but not to a very great extent.

It may be said to extend over the greater part of the New Monkland parish, and the west part of the parish of Shotts.

In Stirlingshire, it is known as the Coxrod coal, and extends over the same area as the Splint seam there, and is a thin but workable seam at Gardrum and Roughrig. Estimated area still to work, 5,000 acres.

SLATY BLACKBAND IRONSTONE.—*At* 208 *Fathoms—Average Thickness,* 18 *Inches.*—This is a carbonaceous ironstone, and second only to the Mushet Blackband, both for the quantity and quality of the iron which it yields. The area containing it extends to about 70,000 acres, and may be said to be bounded on the east by Bathgate, on the west by Airdrie, on the north by Garbethill, and on the south by Carluke.

Under this designation there are three bands of ironstone, known as the upper, the mid, and the lower slaty band;—of which the first is only about seven inches in thickness, and in the present state of the market generally unworkable. The mid slaty band is that known properly by the *slaty band ironstone.* The lower band ranges in thickness from two to four feet, but usually contains so much sulphur as to render its use injurious to the quality of pig iron. It is worked, however, at Goodockhill and Peatpots, in the parish of Shotts, where the sulphur exists in less quantity; but its more extended use will depend on the discovery of some cheap means of freeing it from sulphur. The mid slaty band ironstone has been bored too at Arden, Brownieside, and Meadowhead, near Airdrie, and found to be of good thickness and quality. It is at present being worked at Stepends, Bowhousebog, and near Shotts Iron-works.

In Linlithgowshire it is extensively worked near Bathgate, at Torbanehill, Polkemmet and Barbachlaw; and further south, at Crofthead where it has been worked for many years for the supply of the Coltness and Shotts Iron-works. This seam is very irregular in its position, and is only to be found of workable thickness in detached patches, so that we cannot calculate on more than 14,000 acres, which includes what is workable of the upper and lower slaty band seams. Estimated area still to work, 14,000 acres.

Boghead Gas Coal.—*Average Thickness,* 10 *Inches.*—In the position of the ironstone last described, at Bathgate, occurs the famous Boghead gas coal, or Torbanehill mineral. This coal resembles the ordinary varieties of Parrot coal in its physical character, but gives off about 3,000 cubic feet more of gas, per ton of coal, than any other coal known. The upper part of the seam is brown, and the lower part of a black colour. When distilled at a low heat, it gives off from fifty to seventy gallons of paraffin oil, per ton of coal. This oil is extensively manufactured near Bathgate, and in the United States of America, whither this coal is exported in large quantities for this purpose. This valuable seam does not exist over a large area. It extends as far north as Colinshields, as far east as Bathgate, and as far south as Torbanehill, and on the west it has not been discovered beyond Armadale. In thickness it is very irregular, varying from one inch to twenty, and the area containing it is much troubled and intersected by wants. Estimated area still to work, 400 acres.

About seventy-seven fathoms under the Slaty band, and at about 280 fathoms down in the general section, there occurs the Roman cement seen at Glenboig brick-works, situated on the side of the Monkland and Kirkintilloch Railway, about 2½ miles from Coatbridge. It is about twelve inches in thickness and of excellent quality. About three fathoms farther, is the valuable fire clay used at these works, ranging in thickness from eight to ten feet. At 328 fathoms in the general section is the first or Caulm limestone of Garnkirk, Bedlay, Croftfoot, Moodie's burn, and Castlecarry. This seam is about 6½ feet thick, and divided in the centre by about four inches of hard shale. In quality it is very good, containing rather more than forty per cent of lime. It is extensively worked for the supply of the iron-works in the neighbourhood of Coatbridge, to which it is conveyed by the Monkland and Kirkintilloch Railway.

About two fathoms below the limestone there is a soft coal about twenty inches in thickness, which was partially worked some years ago at Garnkirk and Hogganfield, near Glasgow. At 412 fathoms in the general section is the Bishopriggs limestone, seen in the Edinburgh and Glasgow Railway tunnel. It corresponds in position with the limestone of Cowglen and Jordanhill.

At 443 fathoms in the general section we come to the first Possil coal; and at 447 fathoms, to the Upper Possil ironstone, which is the first valuable seam under the Slaty band.

Possil Ironstone.—*At* 447 *Fathoms—Average Thickness,* 12 *Inches.*—In what is generally known as the Possil field there are five seams,—two of coal and three of ironstone.

The coals are very thin, and are only partially worked. Of the three ironstones the first is the most valuable, and is composed of three inches of clay band, and of a black band, ranging from four to twelve inches thick, with a holeing of coal about ten inches thick below.

The second ironstone is not a regular band. It was opened up and worked at Blackhill, but found of inferior quality, and was discontinued.

The third ironstone is also irregular, and not of first-class quality. It is worked at Keppoch, near Glasgow, but does not exist at Possil, where the upper band is so valuable and so extensively worked.

The position of these bands of ironstone extend over a large area, and may be said to be bounded on the north by a line drawn from Renfrew to Denny by Kilsyth,—on the east by a line drawn from Denny to Glenboig by Cumbernauld,—on the south, by a line drawn from Glenboig to Glasgow by Frankfield,—and on the west by a line drawn from Glasgow to Renfrew.

The ironstones worked at Kinniel, near Bo'ness, are in the same stratigraphical position as the Possil ironstones. The distance between the bands is much increased by a bed of interstratified whin nearly forty fathoms thick. The upper ironstone crops out at the Linlithgow and Bo'ness road, and extends westward for a considerable distance beyond Kinniel House.

The position of the Lowband ironstone extends over an area of about 700 acres south of Bo'ness. In quality and continuance it is very irregular—sometimes changing into an inferior black ironstone, and sometimes into a gas coal.

Of the Upper Band there is still a considerable area to exhaust west of the Snab, and under the Firth of Forth northwards. Of the Lower Band ironstone, the quantity still to work cannot be estimated at more than 300 acres.

There are a number of seams of coal in this field; but the most valuable of them have been worked out many years ago, leaving some of inferior quality, which are only useful for calcining ironstone and engine fires.

At Balbairdie, near Bathgate, we again recognize the low band ironstone of this position; but it does not appear to extend over a very extensive area there, although almost identical with that of Kinniel, having the black band and gas coal of nearly the same thickness. Estimated area of this ironstone still to work in these three districts, 11,200 acres.

GAS COAL.—*At* 467 *Fathoms—Average Thickness,* 12 *Inches.*—The principal seam of this quality of coal is found in the above position in the section, and forms the chief supply for the gas works in Glasgow and surrounding neighbourhood.

At Lesmahagow the coal in this position has been long famous, and is second in quality only to the famous Boghead coal. At Govan it is not of such good quality. It covers an extensive area in the parish of Govan, and extends across the river Clyde to Knightswood and Scaterigg, where it has been long worked for gas-producing purposes.

At Cleuch, near Wilsonton, in the parish of Carnwath, this seam of coal is also worked, and is of the same quality as that at Govan and Knightswood. Estimated area still to work in these districts, 1,700 acres.

Govan Band Ironstone.—*At* 502 *Fathoms—Average Thickness*, 12 *Inches.*—This ironstone has only lately been opened up at Govan. It is believed to extend over the same area as the Possil ironstone, although it has not been so extensively proved, and is in the same position as the ironstone worked at Dalry, in Ayrshire, and Banton, in Stirlingshire. It is of very superior quality, and can be generally cheaply worked. Estimated area still to work, 7,800 acres.

Summary.—The workable seams of coal which I have referred to are ten in number, viz. :—The Upper, the Ell, the Pyotshaw, the Main, the Humph, the Splint, the Sour Milk, the Virtue Well, the Kiltongue, and Drumgray—all as seen on the accompanying section. They are all valuable seams, and extensively used for household and manufacturing purposes; and in these seams the total quantity of available coal still to work is about 424,620,700 tons. Taking the present annual output of the district under consideration at 3¼ millions of tons, this quantity of coal will last 130 years.

Besides the coals named, and taken into account, there are numerous other seams, which, from their inferiority either of position, thickness, or quality, will not be worked, or at least only to a limited extent, so long as those I have described yield a sufficient supply. Amongst these we may mention the coals in the Bo'ness field, which (although some of them are of five feet thickness, and notwithstanding that they are situated all within a mile of the Kinniel Iron-works) are so inferior in quality, as to be considered at present unworkable to profit.

In the Bathgate field there are four or five seams which are also of second-rate quality; and although entirely opened up by the Monklands Railways, they cannot be worked as yet to compete in the same market with the other seams worked in the Wishaw and Monkland districts.

The number of ironstone bands described and shown in the section is twelve. Nearly one-half of these being, so far as now known, of doubtful value, I have made no estimate of them, and have taken only seven into the calculation. These are, first, the celebrated Mushet blackband ironstone, the Rough band, the Bellside band, the Calderbrae band, the Slaty band, the Possil band, and the Govan band ironstone.

All of these are blackbands of excellent quality, with the exception of the second, which is a clay ironstone, but good of its kind. The quantity of ironstone in these seams, within the area of the map, so far as known, will amount to about 72,081,400 tons in the calcined state. This quantity will supply all the iron-works in the district, comprising nearly 100 blast furnaces, for about seventy-two years—supposing them to continue in full operation, as heretofore, and to consume, as at present, one million tons of calcined ironstone yearly.

This gives a very satisfactory prospect for the iron trade of the district, especially as many interested therein have been labouring under a notion that, with the exhaustion of the celebrated Mushet band, the supply of ironstone must cease, and consequently the iron-works be in a great degree extinguished.

This prediction has been in circulation for the last ten or fifteen years; but is now happily disproved by the discovery of, first, the Slaty band, then of the Possil band, and lastly, of the Govan band ironstone. Before these are exhausted other discoveries may be made.

These deposits of ironstone lie in localities easily accessible from the iron-works.

The Slaty band, which forms nearly one-half of the whole quantity, lies between Airdrie on the west, Bathgate on the east, Garbet-hill on the north, and Carluke on the south; and the Monklands Railways run over and command almost the whole of its workable area, and will likely bring most of it to the works around Coatbridge.

The locality of the Possil band ironstone, which forms about one-fourth of the whole quantity, extends north as far as Kilsyth, east as far as Denny, south as far as the Garnkirk Railway, between Coatbridge and Glasgow, and west as far as Maryhill.

From these fields there are ample means of transit to Coatbridge and all the iron-works, by the canal, by the Edinburgh and Glasgow Railway, by the Garnkirk Railway, and by the Monkland and Kirkintilloch Railway.

The position of the ironstone seam in the parish of Govan is about thirty-nine fathoms under the lowest ironstone at Possil, as shown in the section, and it is likely to be found throughout the same area described here as containing the Possil band. If so, it will more than double the quantity taken into account for this ironstone; but being as yet only partially proved, I have left it out of the calculation, and taken only the portion of it lying around the parish of Govan, and what is proved of it in the counties of Dumbarton and Stirling, or about one-sixth of the whole quantity. This ironstone can be conveniently brought to the iron-works either by canal or railway.

The Rough band, the Bellside band, the Calderbrae ironstone, and the remnant of the Mushet black band all lie in convenient proximity to the iron-works, so that the transit of this abundant supply to the furnaces is already provided for by canal and railway.

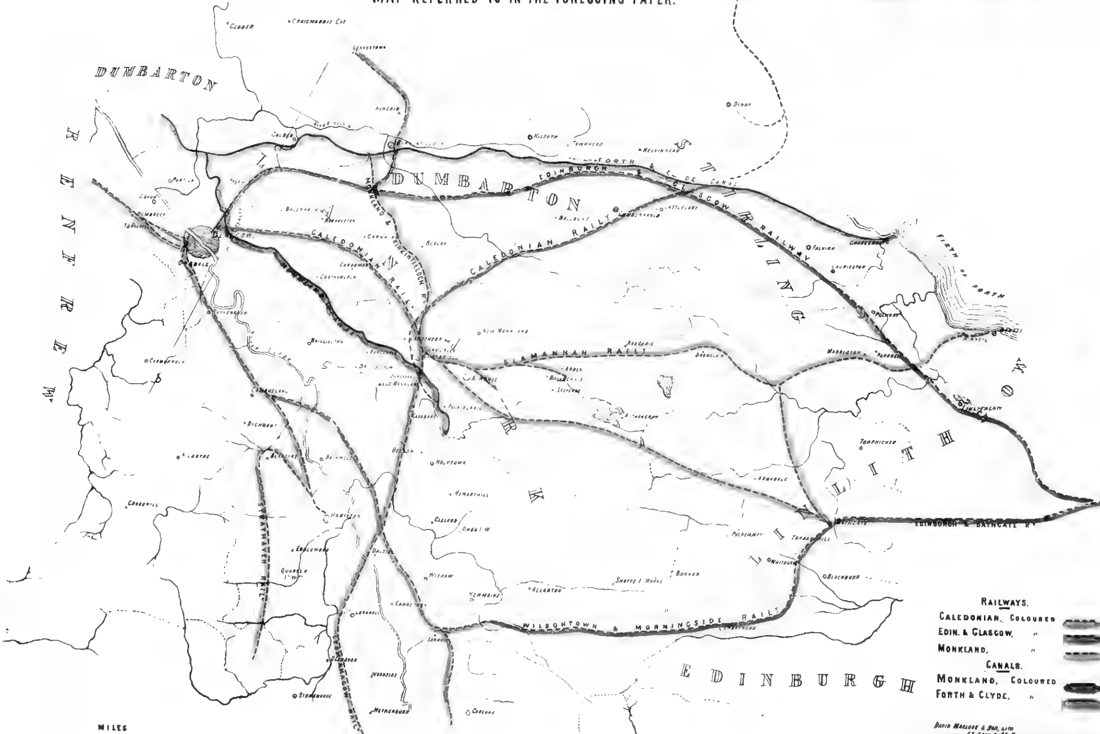
In the process of iron-smelting a large quantity of limestone is used, but as this mineral is so abundant in the country as to place its exhaustion beyond the reach of calculation, I have thought it unnecessary to describe all the various seams of it that lie in and around this district, on all sides. The districts of Campsie on the north, Bathgate on the east, Kilbride on the south, and Hurlet on the west, contain inexhaustible quantities of this mineral. The iron-works consume about 250,000 tons a year.

The supply of coal to these iron-works is a matter of serious importance. The furnaces consume annually about two millions of tons of coal, being about two-thirds of the annual output of the whole district, leaving only about one-third for the manufacturing and household uses of the city of Glasgow and neighbourhood, and for shipment to other places.

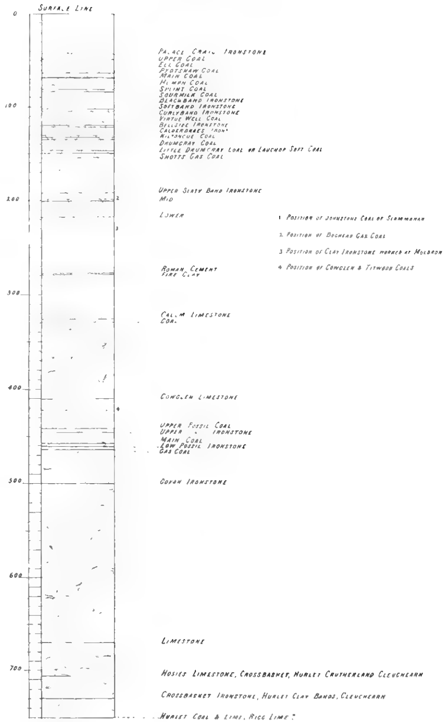
Tabular Abstract.

ENNY
RAILWAY
FALKIRK
GRANGEMOUTH
LAURIESTON
FIRTH OF FORTH
POLMONT
KINNEIL
MADDISTON
LINLITHGOW
TORPHICHEN
ARMADALE
BATHGATE
EDINBURGH & BATHGATE RY.
TORBANEHILL
WHITBURN
BLACKBURN
L I N L I T H G O W
RAILY.
INBURGH
RAILWAYS.
CALEDONIAN, COLOURED
EDIN. & GLASGOW, "
MONKLAND, "
CANALS.
MONKLAND, COLOURED
FORTH & CLYDE, "
DAVID MACLURE & SON, LITH.
62 ARGYLE ST. GLASGOW.

MAP REFERRED TO IN THE FOREGOING PAPER.



GENERAL SECTION



*At Campsie, and at Easterhouse, in the Parish of Carnwath, there is sometimes an Ironstone 12 inches thick worked above this Coal

David MacLure & Son Lith 42 Argyle St Glasgow

TABULAR ABSTRACT.

Depth from surface as at Glasgow.	Name of Seam.	Places where these seams have been found.	Remarks relative to the quality of each seam.	Quantity still to work in each seam of Gas Coal.	Quantity still to work in each seam of Common Coal.	Quantity to work in each seam of Ironstone.
Fthms.				Tons.	Tons.	Tons.
42	Palace Craig Ironstone,	Faskine, Palace Craig, Carnbroe,	Inferior, from the quantity of sand and sulphur it contains.			
48	Upper Coal,	Glasgow, Dalmarnock, Stonelaw, Eastfield,	Superior for household purposes,	......	12,110,400	
63	Ell Coal,	Glasgow, Wishaw, Holytown, Larkhall,	Useful for manufacturing and household purposes,	......	144,107,300	
67	Pyotshaw Coal,	Coatbridge, Airdrie, Baillieston, Wishaw,	Used for Iron-smelting and manufacturing purposes,	......	22,900,000	
68	Main Coal,	Do. do.	Used for household purposes,	24,000	41,782,000	
76	Humph Coal,	Glasgow, Airdrie,	Generally inferior,	......	2,800,000	
81	Splint Coal,	Glasgow, Airdrie, Wishaw, Baillieston, Larkhall, &c.,	Famous for Iron-smelting,	840,100	72,000,000	
84	Sour Milk Coal,	Baillieston, Cardowan, Camedie, Blackfaulds,	Manufacturing and household purposes,	......	7,100,000	
103	Black Band Ironstone,	Airdrie Coatbridge, Quarter, Rosehall,	Of excellent quality,	......	......	1,492,000
106	Soft Band Ironstone,	Airdrie, Airdriehill, Darngavel,	Inferior—not worked,	......	......	
120	Curly Band Ironstone,	Cleland, Newmains, Legbrannock,	Of good quality,	......	......	335,000
122	Virtue Well Coal,	Arden, Coatbridge, Shotts, Greenhill, Slamannan, Benhar,	Used for household and manufacturing purposes,	......	36,518,000	
132	Bellside Ironstone,	Bellside, Greenhill,	Of good quality,	......	......	938,000
134	Calderbraes Ironstone,	Whiflat, Rocholes, Woodhall, Braes,	Of medium quality,	549,000	......	4,721,000
136	Kiltongue Coal,	Drumpeller, Coatbridge, Airdrie, Kilgarth, Wishaw, Shotts, &c.,	Used for household and manufacturing purposes,	......	70,580,000	
148	Drumgray Coal,	Drumgray, Rochsoles, Shotts, Stepends, Redding,	Of medium quality,	......	14,723,000	
			Carry over,	1,413,100	424,620,700	7,486,000

TABULAR ABSTRACT—*continued.*

Depth from surface as at Glasgow.	Name of Seam.	Places where these seams have been found.	Remarks relative to the quality of each seam.	Quantity still to work in each seam of Gas Coal.	Quantity still to work in each seam of Common Coal.	Quantity to work in each seam of Ironstone.
Fthms.				Tons.	Tons.	Tons.
			Brought over,	1,413,100	424,620,700	7,486,000
151	Little Drumgray,	......	Of medium quality.			
193	Upper Slaty Band Ironstone,	Garbethill, Todsbuchts, Cameron Glen, Arden,	Inferior—not much worked.			
203	Mid Slaty Band Ironstone,	Stepends, Crofthead, Armadale, Arden, Shotts,	Of excellent quality,	......	......	33,957,000
217	Lower Slaty Band Ironstone,	Bowhousebog, Goodockhill,	Contains large quantity of sulphur.			
280	Roman Cement,	Glenboig,	Of good quality.			
281	Fire Clay,	Glenboig,	Do.			
328	Caulm Limestone,	Garnkirk, Bedlay, Castlecarry, Moodiesburn,	Do.			
330	Coal,	Garnkirk, Hogganfield,	Of medium quality—very thin.			
412	Cowglen Limestone,	Possil, Bishopbriggs, Jordanhill, Lesmahagow, Kilsyth,	Of good quality.			
443	Upper Possil Coal,	Keppoch,	Of excellent quality,	......	......	18,067,000
447	Upper Possil Iron,	Keppoch, Possil, Titwood, Kenmuir, Blackhill, Kilsyth, Kinniel, Denny,	Do.			
459	Possil Main Coal,	Possil,	Do.			
463	Lower Possil Ironstone,	Possil, Keppoch, Bathgate, Kilsyth, Blackhill, Kinniel, Skaterig, Lesmahagow,	Of very good quality,	300,000		
467	Gas Coal,	Govan, Wilsonton, Lesmahagow, Titwood, Skaterig, Knightswood,	Famous at Lesmahagow — of medium quality elsewhere,	2,481,700		
502	Govan Ironstone,	Govan, Dalry, Kilsyth, Auchinvole, Banton,	Of excellent quality,	......	......	12,571,400
			TOTAL,	4,194,800	424,620,700	72,081,400

ERRATA in some of the copies of MR. JAMES R. NAPIER'S paper on "Incrustations of Boilers using Sea-Water."

Page 282, line 20 from top, *for* 0·008, *read* 0·8.
— 282, line 21 from top, *for* 0·0014, *read* 0·14.
— 284, line 17 from bottom, *for* 129 tons coal, *read* 188 tons coal.
— 284, line 15 from bottom, *for* £348, *read* £362.

PROCEEDINGS

OF THE

PHILOSOPHICAL SOCIETY OF GLASGOW.

FEBRUARY 22, 1860.

ALEXANDER HASTIE, ESQ., *in the Chair.*

Mr. William Gorman and Mr. James Brownlie were elected members of the Society.

Remarks on Glass Painting. By MR. C. HEATH WILSON.

[THIS essay is necessarily abridged, to bring it within the limits allowed by the Society. The essay was copiously illustrated by cartoons, by Mr. Wilson's drawings, made in France and elsewhere, and by numerous cromo-lithographs from important works on glass painting. Various interesting specimens of ancient and modern glass painting were exhibited and explained to the Society.]

Glass painting is a branch of fine art, which, since its first invention in the Middle Ages, advanced *pari passu* with the art of painting itself. Eminent artists designed for, or executed painted windows; and whilst the earliest specimens possess a double value, inasmuch as they illustrate the early history and progress of painting during periods of which, except in illuminated MSS., but few examples remain, its later works vie in excellence of composition and drawing with the most remarkable productions of cotemporary art. The art of glass painting was not in old times a mere system of servile and spiritless imitation, as it now is; on the contrary, it was practised by men who were emphatically artists,—who were also proficients in architectural ornament and in the practical conditions of their art, as well as masters of the effects to be obtained by the most skilful employment of their materials.

I propose to lay before you, as briefly as possible, some remarks on the employment of painting, from an early period till it ceased to be the handmaid of architecture, that I may explain the influence formerly exerted by the painter over subordinate branches of art.

Painting was formerly intimately associated with architecture, and subordinated to it; the principal works of the early masters were decorative of public and private edifices, sacred and secular, thus the position of the painter was in a certain sense that of a decorator, but this implied no degradation; the greatest works of human genius, the noblest efforts of the arts of painting, have been thus produced; and the following are some of the important lessons to be derived from their study:—Symmetrical composition, as otherwise the prevailing idea of symmetry in the general architectural design would be impaired. A solemn, grand and impressive character in the figures, necessary to their harmony with the masses of the architecture, and the stately columns or piers near which they were placed. Distinctness and completeness of parts were conditions of paramount importance, necessitating great power of drawing both of the human form and of drapery, as no convenient melting away of outlines, or tricks of chiaroscuro, concealing incapacity in the rendering of form, were possible; the absolute accuracy and finish in the forms of the architect's work rendered equal perfection necessary in the painter's. Simplicity of effect was another condition; for this reason, as a number of subjects were represented in a series of pictures in the same church or hall, the rigid demands of architectural unity imposed on the painter a similar unity of effect throughout his works; he might not, for instance, make one panel or space light and another dark. It must be obvious that equally strict rules of necessity guided the artist in his balance of colour; each picture, perfect in itself, must also accord with every other; masses of certain colours must re-appear at graduated intervals, or centres of colour be fixed, round which the artist might group his harmonies. The monumental painter thus completed the magnificent design of the architect, covering the walls with histories, enriching every shape with colour, arranged in infinitely varied and beautiful designs. It is to this view of the painter's art, and to the effect of such a view on glass painting that I wish to draw your attention. It must be apparent to you that the laws of composition, colour, and effect, guiding him in its practice, must be different from those regulating him in the production of pictures having no relation to anything beyond their frames.

A consequence of the employment and state of painting which I have endeavoured to describe, was the influence of the master minds of the time over every subordinate branch of art. In their studios, or workshops we may call them, there were pupils of various degrees of skill and mental qualification. Some became great painters, others ornamentists—some painted miniatures in manuscripts—*some painted glass*, others pottery; and we know how admirably they executed all that they undertook, and how precious are the works which they have left us. The influence also of great ideas of art, cultivated and matured by its employment in this manner, is very observable in every work produced by the great masters, however small or unimportant. Thus in easel pictures, even of the smallest dimensions, the subjects were always treated in the grandest manner. So it was in Greece during the flourishing epochs of her schools: the figures on cameos, intaglios, and coins were as nobly designed as the statues of the gods.

It is very different where a low or sensuous taste in art prevails:

the painter does not then occupy the same prominent position, and the public lose many of the benefits derivable from his cultivated taste and directing energy. We may trace in the works of the old masters the gradual change which took place in prevalent ideas of the province of painting. By slow degrees the naturalistic principle gained the ascendancy, till, finally, even selection from beautiful nature ceased, and the greatest and most holy persons were represented under the forms and lineaments of the coarse and too often vicious models of both sexes who were employed by painters. No skill in manipulation, no brilliancy of colour, no power of chiaroscuro can reconcile the cultivated mind to this state of painting. The special branch of art of which I am speaking this evening, decayed after a brief struggle to rival the coarsely designed but brilliant pictures of the seventeenth century; for glass painting followed so closely all the changes which took place in pictures, that when they ceased entirely to be regulated by the conditions which I have dwelt upon, an effort was made to emancipate glass painting from them also, forgetful that it was nothing apart from architecture, but an imperfect, unsatisfactory art, wholly unable to rival pictures.

Before entering upon the archæological portion of my subject, as a means towards understanding the illustrations which I have the pleasure of bringing before you, I propose to offer a brief description of the process of glass painting; but as this might not be interesting to those who are already familiar with the subject, instead of describing the modern method, I shall bring before you an extract from the work of Theophilus, written, it is generally believed, in the tenth or eleventh century. He was, according to his own account, "*humilis presbyter, servus servorum Dei, indignus nomine et professione monachi.*" His account, although written so long ago, will give an excellent idea of the art to those who are not familiar with it; whilst to those who are, it cannot fail to be interesting to compare the earliest with the present practice.

[Mr. Wilson then read the description given by Theophilus of the whole process of glass painting as practised at his time, and explained the present practice of the art where it differed from the old method. He illustrated this portion of his subject by means of cartoons, specimens of ancient and modern glass, and by some of the processes adopted by the glass painter.]

Painted glass, regarded from the archæological point of view, is very interesting. In the first place, we have in this fragile material, numerous examples of the state of the painter's art during epochs of which hardly a picture remains produced by cotemporary artists. It illustrates customs, domestic life, trades, manufactures, arts, and science; and is to our early history what the pictures in the tombs of Egypt are to that of the ancient inhabitants of that land of wonders.

Glass painting of different epochs is distinguished by the style, certain characteristics in manipulation, and peculiarities of manufacture. The distinctive styles have been thus arranged by my friend Mr. Charles Winston, whose profound knowledge of old glass painting is unequalled in our own country:—

The early English, which extends from the date of the earliest specimens extant to the year 1280.

The Decorated, from 1280 to 1380—100 years.

The Perpendicular, from 1380 to 1530—150 years.

The Cinquecento, from 1500 to 1550—50 years.

And the intermediate, comprehending the period which has elapsed from the end of the Cinquecento style down to the present time.

This is the most accurate division possible; but, in his very interesting work on the history of glass painting, M. de Lasteyrie divides the styles by centuries—as, twelfth century glass, thirteenth century glass, and so on, which has the merit of being easily remembered.

Early English, or thirteenth century glass painting, is readily recognized by the general arrangement of the designs, by the details of the ornaments, the drawing and character of the figures, as well as their costumes, the method of painting, quality of the glass, and other peculiarities which it might be tedious to enumerate. The general arrangement is twofold: there are medallion or legendary windows, presenting each a series of figure-subjects, the figures being comparatively on a small scale, and placed in medallions of different geometric forms, united by diapers and scroll-work, and surrounded by rich borders; and there are figure-windows, containing each single figures, sometimes of great size, placed under canopies of very simple and primitive forms, and surrounded by borders of rich foliage,

The figures in these windows are meagre and disproportioned,—the draperies plaited in small folds, like those in archaic Greek art, to which they have a singularly close resemblance, suggesting that primitive art, at epochs remote from each other, sought similar methods of expression. The heads, although rudely drawn, are traditionally of a classic model, the features are marked by strong lines, and the eyes open and staring. The ornament is a descendant from the Byzantine, and very conventional but elegant in its arrangement, and indescribably rich, glowing, and harmonious in colour. The method of execution is vigorous; the shading that which is technically called smear shading; and the effect is aided by strongly marked lines and markings, put in with freedom and decision.

The glass is horny in texture, some of it streaky, and time has coated it with a crust or patina of a silvery-gray tint, which still further diminishes its translucency, so that objects cannot be seen through painted windows of this style, and the rays of the sun pass through them with a tempered fervour, which, as an old writer quaintly remarks, "*est une grande commodité pour ceux que se trouvent en priere claus l'Eglise.*" The leads are numerous and narrow, the iron framework, which takes the form of, and marks out the panels in the medallion or legendary windows, is strong, dividing the design by vigorous black lines, which have an admirable effect, and give, by contrast, brilliancy to the glass

I had the gratification of seeing, besides many other continental specimens, the wonderful series of thirteenth century windows in Chartres Cathedral last summer. By the selection of deep colours and their harmonious arrangement in those of the nave, a quiet twilight reigns in this part of the church, gradually dissipated as we approach the transept. The lower windows here are filled with gigantic figures of prophets, in deep rich tones, above which are the prodigious rose windows, at least thirty-two feet in diameter each, from which a harmonious irridescent light is transmitted downwards, magical in its beauty. In the chapels round the choir a luminous obscurity prevails. There is an alternation of coloured and grisaille windows, producing this solemn effect—an arrangement which I strongly recommended for the lower church, or crypt as it is erroneously called, of our own Cathedral. The sanctuary is surrounded by windows of the most brilliant hues, in which Christ and his apostles appear in a torrent of rainbow light. Such is the great poem which the genius of the thirteenth century has left us in this unequalled series, when one thought, one tradition, directed all who worked in glass; hence that unity, that harmony, which has never since been equalled, and which, in our time, it appears to be a principal object to banish; so little true sentiment and true feeling for art prevails, and so little self-sacrifice, each donor apparently thinking not of the shrine and its dedication, but of himself. I speak of what has been done in our date in every cathedral in the land except our own. In it, thanks to higher feelings, the old principle of unity will be revived.

The painted glass of the next or decorated style is not so rich, and has a less happy harmony and intensity of colour. This is to be attributed to two principal causes: first, the gradual introduction of larger pieces of glass; and, secondly, the much greater use of white and yellow: the yellow stain being invented early in the fourteenth century, was copiously used, particularly in the architectural forms and ornaments, displacing, in a considerable measure, the richly coloured geometric patterns of the older manner; thus white and yellow became prominent in the general effect of colour,—the rubies, sapphires, and other powerful colours were limited to the figures, backgrounds, borders, and to the soffits, panels, and spandrils of the canopies. The white glass of the fourteenth century, although in a somewhat less degree than that of the thirteenth, was of a greenish hue, from the impurity of the materials used in its manufacture; this defect did not injure the beauty of the early windows, but it somewhat impairs that of those of the fourteenth century, which I attribute to a want of harmony between it and the yellow. We must refer the change observable in the windows of the Decorated period to that in the style of architecture, and also to the greater use of books in churches, which made more light necessary. The change, however, was gradual, as it was in every case from one positive and developed style to another; an interval of transition always occurred, when glass painting partook of the character of the old and new modes.

In the style of the fourteenth century we have the first indications of that study of nature which was to lead to a great revolution in art. We are involuntarily reminded of the similar revolution in Greek art, when, prior to the advent of Phidias, the erection of statues to Athletes directed the attention of Greek artists to the study of nature, and led to their emancipation from the trammels of archaic forms.

In the latter half of the century the human figure was treated with more skill; there was more action, and a longing for grace of movement is manifest, not always guided by good taste, yet indicating progressive thought. A notable and unsatisfactory change took place in the substitution of white glass in the faces and hands of the figures for the flesh-coloured glass used in the early English; the hair being stained yellow. In the foliated ornament the progress was marked, and both in painting and sculpture a beautiful style was matured. The canopy-window now received its full development,—the forms were obviously imitative of the architect's creations; but the fancy of the glass painter, soaring beyond constructive necessities, ran riot in shafts, buttresses, pinnacles, and spires of the most delicate and elaborate forms, piled high over the figures which they enclosed and covered, and relieved against the rich diapering with which the remainder of the window was filled.

The Gothic style of architecture culminated in the Decorated: the succeeding Perpendicular was certainly a downward step. But although we must consider this a period of decline in architecture, it was not so in glass painting: the progress made in representing the human figure was decided and remarkable, thus we find in the heads a distinct advance towards good style in form, a sense of beauty, and very delicate modelling in the execution,—this last the result of the introduction of stipple-shading, which was a most important discovery, enabling the artists to execute with a refinement, delicacy, and truth of chiaroscuro, hitherto unthought of. The introduction of thinner and purer glass, and the use generally of lighter colours, would have rendered the glass painting of the fifteenth century weak and unsatisfactory, but for this improvement in the method of painting; for we have now much use of half tints, and the lights are reduced to points, as in nature and in all good art. The thin quality of the glass has been adverted to as a reason for this extended use of the brush, necessary to give the requisite solidity; but it is impossible to doubt that it was also the result of new and advanced ideas of art. Artists were no longer satisfied by a process which was, in fact, little better than rude sketching, they evidently looked at and desired to imitate nature, and to this would I attribute the improved method of this period of glass painting. It is remarkable that whilst making this advance in the representation of the human figure, the same artists should have been satisfied with a very conventional and by no means beautiful style of ornament. The practice of framing the figure-subjects with canopies, or borders of white and yellow glass, is distinctive of the style, as well as that of carrying the picture part of the design across the entire window. Some progress had been made in this system in Decorated continental glass, although not in English examples; but it was freely adopted in England towards the close of the fifteenth century. Perpendicular glass is brilliant, silvery, and sparkling; the execution is soft and delicate; and this, the last phase of Gothic art, is full of interest and beauty, occupying a very important place in the history and practice of fine art.

We have thus traced the history of Glass painting, step by step, and the lesson to be derived is a most striking and important one. We find that no age of real art imitates servilely that of preceding times. Wherever servile imitation is seen, it is a certain proof of incapacity to originate.

The Revival or Cinquecento style reached its perfection between the years 1525 and 1535, which may be termed the golden age of glass painting. I have alluded to the light silvery tones, and pallid colour of Perpendicular glass; in Cinquecento glass, colour resumes its sway, regulated by a consummate knowledge of the laws of harmony; this doubtless we owe to the *perfervidum ingenium Italianum* manifested in the superbly coloured windows existing in Florence and some other Italian cities. In Cinquecento windows the ornamental and figure portions are kept distinct—the ornament forming the frame to the figures, not in the modern sense, however, but after a fashion of which a few examples remain in Italy, the most notable which I recollect being at S. Fior. A picture by Cima da Conegliano in the principal church, is surrounded by a blue and gold carved frame, the columns, pilasters, and ornaments of which repeat similar details represented in the picture. I am satisfied that there is an analogy between this remarkable practice and some of the arrangements which we find in glass painting.

To return to Cinquecento windows, the superb canopies frequently occupy the whole width, and are composed of white and yellow glass, richly shaded with brown, the chiaroscuro being effectively made out; there is also much use of half tint; in this respect differing as essentially in effect as in form from the canopies of older style. The pictures in the finest specimens are remarkable for gorgeous colour and powerful contrasts of light and shade; we usually find a principal mass of some colour, round which others are harmoniously arranged. There is no confusion of parts; that distinctness which was so remarkable a quality of the works of the great masters is invariably maintained. In the execution the stipple-system was continued; but to it the artists added a method of hatching with the brush, which gave greater strength to the shadows, without diminishing their transparency. Smear shading was resorted to in the ornament as most appropriate; and the effect was aided by vigorous lines marking the forms and giving decision whereever required. Many new tints of coloured glass were invented; and the single and double stain of yellow were applied to coloured as well as white glass, whilst a flesh-coloured enamel remedied the unpleasant effect produced by employing white glass for the faces, hands, and other uncovered portions of the body. A process of abraiding coated glass so as to obtain two colours in one piece was introduced, represented in modern art by that of removing the coloured coat by means of fluoric acid.

The Cinquecento had its decline, like others: such is the fate of every style. It degenerated into mannerism and extravagance. A singular phase of the decay of glass painting, to which I have already adverted, is observable in the churches at Antwerp and Brussels, at Liege, and in other places in Belgium. The grand Brabant School of Painting, with Rubens at its head, dazzled the world with its meteor splendour. Glass painting, as has ever been the case with this art, tried to follow in the wake of painting on canvas. We have burgomasters and their wives in black, as in the pictures of Vandyke; and we have paintings on glass, with the pedestals, columns, and rich hangings, which were now so frequently introduced in pictures, and which are still the great resource of the modern portrait painter in need of backgrounds. Every conceivable plan was had recourse to, to produce opacity in parts of these windows; but glass painting was not susceptible of such effects, and the true principles on which it depends being lost sight of, it rapidly fell in estimation as an art. * * * * * * *

PROCEEDINGS

OF THE

PHILOSOPHICAL SOCIETY OF GLASGOW.

MARCH 7, 1860.

Dr. Anderson, *the President, in the Chair.*

Mr. Edward M. Dixon, Teacher, was elected a member of the Society.

On the Incrustation of Marine Boilers. By William Wallace, Ph.D., F.C.S.

Having given some attention to the subject of Mr. James R. Napier's paper on the "Incrustation of Boilers using Sea-water," read at the meeting of the Philosophical Society on the 18th of January last, and which is a chemical as well as a mechanical one, I may be able, perhaps, although I have not had an opportunity of prosecuting practical experiments, to make some suggestions which may be useful.

The first point which presents itself for inquiry is the composition of the water employed. Many analyses have been published, showing the composition of sea-water at different places. From these it appears that the ocean varies much in composition at different points, so that no analysis can be taken as the basis of calculation, to find the amount of any chemical compound required to prevent the formation of crust in steamers plying in various parts of the globe. The following analysis of water, taken off Ailsa Craig, may probably be accepted as giving a tolerably accurate idea of the composition of the water in the Irish Channel and the West Coast generally. A gallon of the water weighed 10·2521 lbs., and contained the following ingredients, represented in grains:—

Sulphate of Lime,	101·71
Sulphate of Magnesia,	126·97
Sulphate of Potash,	48·92
Chloride of Sodium,	1910·36
Chloride of Magnesium,	202·41
Bromide of Magnesium,	3·15
Carbonate of Lime,	3·36
Carbonate of Magnesia,	·95
Alumina and Phosphate of Lime,	2·67
Silica,	1·50
	2402·00

All these ingredients are highly soluble in water, except the first and the last four in the list. If, therefore, all these compounds were equally insoluble, the incrustation of a boiler using the water should consist almost entirely of sulphate of lime, with a small proportion of carbonate of lime, and a mere trace of magnesia. Sulphate of lime is, however, about a hundred times more soluble than the carbonates of lime and magnesia—at least in water free from carbonic acid—so that a considerable quantity of the sulphate must be carried away in the water discharged from time to time from the boiler. The following examples may be given as illustrations of the general characters of these crusts. No. 1 was from the Cunard steamer *Asia*, $\frac{7}{8}$-inch thick, and was in three layers; No. 2 was a homogeneous cake, $\frac{5}{8}$-inch thick, from the *King Orry;* No. 3, from the *Cosmopolitan;* No. 4, source unknown:—

	No. 1.	No. 2.	No. 3.	No. 4.
Sulphate of Lime,	33·95	68·88	74·21	72·85
Carbonate of Lime,	—	—	—	·34
Magnesia,	40·05	18·96	14·95	13·18
Water, with traces of Carbonic Acid,	24·67	11·66	6·89	8·27
Phosphate of Lime, Alumina, and Oxide of Iron,	1·33	·50	1·34	2·40
Silica,	traces.	traces.	·57	·80
Chloride of Sodium,	traces.	traces.	2·04	2·16
	100·00	100·00	100·00	100·00

These crusts differ from the insoluble matter obtained by simply evaporating sea-water in open vessels; for that contains nearly four times as much carbonate of lime as carbonate of magnesia; while the crusts contain a large quantity of magnesia, and little or no carbonate of lime. The decomposition of soluble magnesian salts by carbonate of lime, under the influence of a liquid boiling at a high temperature (say 270°), is exceedingly interesting. Sulphate of magnesia and carbonate of lime, boiled with water under ordinary circumstances, do not re-act upon each other in the slightest degree; but it is evident that the result is brought about under pressure. The re-action with oxide of manganese, which is isomorphous with magnesia, is exactly similar, and is taken advantage of in the recovery of the manganese used in the preparation of chlorine, as practised at the St. Rollox Chemical Works. The solution of chloride of manganese is first treated with chalk or lime in an open boiler, when all the *iron* is precipitated, but none of the *manganese.* The clear liquor is then boiled under pressure, with a fresh quantity of chalk, when the manganese is completely precipitated, while the chalk is dissolved.

Again, the condition in which the magnesia occurs is peculiar. We should expect a basic carbonate; but I find little more than a trace of carbonic acid in any of the crusts. The magnesia exists essentially as the hydrate. The sulphate of lime appears to occur as the hydrate described by the late Professor Johnson as having been found by him in a distinctly crystallized condition in a high-pressure steam-boiler, its composition being represented by the formula 2 (CaO, SO_3) + HO.

The crust formed in steam-boilers was formerly supposed to consist essentially of carbonate of lime, and the substances proposed as remedies had for their object the prevention of the precipitation of this compound. The distinguished German analyst, Fresenius, was, I believe, the first to correct this erroneous notion. He found, experimentally, that waters containing no sulphate of lime, although highly charged with carbonate, gave no crust, but only a loose, incoherent precipitate, which made the water muddy; and he found that the various boiler-crusts which he had an opportunity of examining consisted of carbonate of lime and other matters, *bound together by sulphate of lime.* The result of Mr. James Napier's analyses, and those given in this paper, amply confirm this statement, so far as sea-water is concerned. The crusts formed by river-water vary much in composition; but, so far as my experience goes, they all contain sulphate of lime, and their degree of hardness appears to depend on the proportion of that salt which they contain.

The crust-forming ingredient of water being sulphate of lime, the preventive substance must be a body that will either decompose it or prevent its adhesion to the boiler. We have thus mechanical and chemical preventives. Among the former the following substances have been recommended, and used with greater or less success:—Potatoes, tallow and other fats and oils, sawdust, clay, oak bark and spent tar, oakwood, treacle and molasses.

There is, practically, only one chemical preventive—carbonate of soda. Carbonate of potash has the same action, but is far too expensive. Under the influence of carbonate of soda the sulphate of lime is converted into the still more insoluble carbonate; but this compound is not capable of attaching itself to the boiler-plates, but remains suspended in the water. Some preparations for preventing incrustation are said to dissolve off a crust already formed; but these are mere deceptions. All the mixtures I have examined consist essentially of an alkaline carbonate; and I have found that a boiler-crust, such as No. 2, may be boiled with a strong solution of carbonate of soda, without suffering the slightest diminution of weight. There can be no doubt, as regards land boilers using river-water, that incrustation can be easily and completely prevented, and that without risk of corrosion, priming, or other inconvenience, by the use of carbonate of soda; and this may be done at a very trifling cost. When, however, we have to deal with sea-water, which contains 100 grains per gallon of sulphate of lime, the case is very different; and it becomes a question of calculation whether the blowing-off method or the chemical method is the more economical. The calculations given in Mr. J. R. Napier's paper appear to me quite correct; but I would suggest one or two considerations in addition to those taken into account by Mr. Napier. The crust is a bad conductor of heat, and some loss of heat is likely to occur from this circumstance. Again, the slow conduction of heat through the crust must render the boiler-plates and tubes much hotter than they would be if in immediate contact with water—thus causing them to wear away faster than they would if kept cool. Then there is said to be some danger of explosion, arising from the peeling off of the crust, and the consequent exposure of the highly heated metal below. On the other hand, it will be found in practice that the exact amount of alkali calculated from the sulphate of lime will not suffice for the prevention of crust, but that a very considerable excess will be required. Again, the soda will elevate slightly the boiling point of the liquid; but probably the difference of temperature would be trifling.

Upon the whole, it appears that the saving effected, even in long voyages, would not be found in practice quite so great as Mr. Napier's calculation indicates. The use of efficient brine-chests, such as he described, would seem to be more economical, and involve less trouble, than the chemical method. While, therefore, carbonate of soda is invaluable as a crust-preventing agent for boilers using river-water, its application to marine boilers would not probably be attended with a saving of money, except in very rare instances. The question can be decided only by practical trials; and it is to be hoped that Mr. Napier will continue his investigations until he is able to furnish satisfactory and reliable results.

Dr. Wallace next read a paper "On Electrical Discharges in Rarefied Media," illustrated by numerous experiments. The Ruhmkorff coil employed in the illustrations is said to be the largest ever constructed, the secondary coil containing about eight miles of wire. By electric discharges in rarefied air and other gases and vapours, the appearance, in miniature, of the aurora borealis was exhibited, and stratified bands of light were produced. In rarefied air, obtained by means of the air pump, the current presented a reddish-purple glow of light, divided into bands or rings. In different gases and vapours, rarefied in the same manner, the glow of light assumed a variety of colours. The apparatus was furnished by Mr. J. W. Stone, Philosophical Instrument-maker.

PROCEEDINGS

OF THE

PHILOSOPHICAL SOCIETY OF GLASGOW.

MARCH 21, 1860.

PROFESSOR ANDERSON, *the President, in the Chair.*

Mr. C. Greville Williams was elected a member of the Society.

On Trap Dykes between Cordon and South End of Whiting Bay, Island of Arran. By MR. JAMES NAPIER, Chemist.

THE results of some observations made by Mr. Napier on the trap dykes on the sea-shore between Invercloy and Lamlash Bay were communicated to the Society in 1854. From the composition of these dykes, and their relation to some of the neighbouring trap hills, it was inferred that when there are large and sudden upheavals of trap, the rock through which it bursts will have a tendency to crack and fall away from the outburst, and that the fluid trap will flow into the fissures thus produced, and form dykes. Similar observations were made subsequently on the dykes occurring along the shore from Cordon to the south end of Whiting Bay. With the aid of a plan of the locality, Mr. Napier described the dykes in detail, and showed that their direction went to confirm the opinion he had formed of their origin.*

In large beds of trap will be found masses of sandstone so altered by vitrification that it requires a close examination to distinguish it from the trap in which it is imbedded; also curious stratifications of sandstone and trap, as if the sandstone rock had split open horizontally in different portions, and the fluid trap had flowed in and forced its way for a long distance, forming complete strata. This circumstance suggests a high state of fluidity in the trap, as it has flowed into some of the finest cracks; and the trap found here would, from its composition, not only fuse easily, but flow easily. There is evidence also in this place in favour of several overflowings, some at very short intervals, as where one layer rests upon another, while others indicate a considerable interval; not, however, a geological interval, as the whole has probably been eruptions during one period of time. As we proceed from a precipitous overflow resting on sandstone towards Whiting Bay, and down on the level part of the beach, there is a beautiful columnar pavement, where the columns stand on end. The

* Mr. Napier called particular attention to Kingscross Point, where a great many interesting phenomena are seen.

surface of the pavement is formed by the tops of the columns; each column has a regular shape; the edges are slightly worn, giving each stone a rounded appearance, the whole having the look of a mosaic pavement. This pavement is also an overflow of a depth of from four to five feet, the columns having been formed, as stated in the former paper, by rapid cooling. Under this pavement is found a thin layer of trap slate, lying horizontally, and in fragments formed evidently by deposition, which lies on the top of another large bed of fine-grained trap. So that we have first and lowermost a bed of trap; whether this has been also an overflow was not positively ascertained; but it is more than probable, from its having also a sort of columnar appearance, the columns standing perpendicular; then we have a thin bed of slate, varying in thickness from three inches to eighteen; then over this is the trap pavement just referred to, which forms a miniature of the Giant's Causeway. After passing this pavement, and keeping by the sea-line, there occurs again the regular series of dykes, interrupted by a large sand-beach, passing which we come to the level rock-beach, in front of the village of Whiting Bay, where the dykes are seen protruding through the sandstone rock in all shapes and forms, and intersecting and crossing one another at different angles; but with one or two exceptions, such as where a dyke runs between, and joins two other dykes, they all run in a line less or more direct from the land to the sea. Many of the dykes divide and branch off into several parts, some of which terminate within a few yards of the main dyke; but most of them continue their course towards the land.

At the south end of the bay there rises a rugged mass of trap within the tide-mark, and from this point may be traced, at a few yards distant, several small dykes running either to or from it. When we meet with such a mass of trap, rising far above the rocks around it, and see dykes apparently emanating or radiating from it, we may reasonably conclude that the dykes have been formed in consequence of the upheaval of the mass, causing the solid rock to crack round about it, the fissures being filled up by the fused mass. But this is somewhat different from those level dykes branching off into radiating arms. By a careful examination of some of those dykes and their branches, it was found that the sandstone between the arms branching off were masses of sandstone resting upon and imbedded in the trap, and not connected with the parent rock; it is therefore probable that during the great upheaval of the trap-hills in the neighbourhood, the sandstone got shattered, and the trap not only flowed up into the cracks, but spread horizontally, lifting up large masses of fractured sandstone. The sandstone on the top of this overflowed mass of trap is partially worn away by the sea, exhibiting part of the bed of trap, and the portions of sandstone still left with the cracks give to the radiating dykes the appearance of coming from this bed. Whether this may be the true explanation of these phenomena remains for further inquiry; but one thing is certain, that many of these apparent dykes are separated from each other by mere pieces of stone lying upon and imbedded in the underlying trap while in fusion.

The whole results of the continued observations on these dykes do not lessen my belief in the opinion stated in the former paper, as to the dykes being cracks from a central upheaval of large masses—not that all dykes are thus formed, for a dyke may be produced in a rock without any central upheaval; but that all sudden upheavals of trap will be found surrounded by a number of dykes radiating less or more in a straight line from the centre.

Owing to many of the dykes branching off into several smaller dykes, the number seen upon the water line will vary according to the different states of the tide, and the line taken by the observer, which will account for the difference mentioned in Dr. Bryce's work on Arran, of the dykes enumerated between Brodick and Lamlash by Philips, Necker, and myself. If we take the gross number visible, with all their branches, between low water mark and the soil, there will be found more dykes from Glen Sannox to Whiting Bay than M. Necker estimates for the whole of the Island. The fact that in a stripe of a few miles and a few yards broad, there will be seen not less than 300 dykes, varying in size from one foot to 100 feet, gives the whole subject an attractive interest; and when we find not less than 95 per cent. of the whole running towards the hills, or great upheavals, we are warranted to conclude that there must be an intimate connection between them.*

Many of the large boulders at Kingscross Point are penetrated by little dykes of a fine-grained trap. This may have been caused by sudden cooling over the surface, producing small cracks, which have been filled up even during the same upheaval. The internal structure of trap rocks is greatly influenced by the rate of cooling to which they have been subjected while under the pressure of the solid crust, before being upheaved, allowing the formation, in the fluid mass, of different compounds, forming into distinct crystals; and the rock, when solidified, would thus acquire an amygdaloid or porphyritic character, which may be defined by reference to some analogous phenomena.

* To embrace the idea that the direction of these dykes has a relation to the magnetic line, as has been stated by Necker, would necessitate the belief that this line embraces the whole round of the compass.

When different salts are dissolved in water, and the water gradually evaporated, the salts will crystallize from the water separately and distinctly. Carbon and hydrogen will combine and form distinct and differently constituted compounds according to the temperature they have been submitted to. In the same way when we have a number of bodies, as silica, alumina, lime, iron, magnesia, &c., kept for a long time in a fluid state by heat, and this heat is gradually withdrawn, analogous to the slow evaporation of water, these substances will group themselves together according to their affinities, which, with the simultaneous action of the crystallizing force, while the compound is passing into the solid state, will form crystals large or small, according to circumstances. From their specific gravity being little different from the fluid they are formed in, these crystals will remain diffused. This supposition would of course infer that all crystals forming porphyritic traps are less fusible than the matrix in which they are imbedded, and from which they have been formed; and this is actually the case, so far as I have been able to judge. This production of crystals within the trap forming porphyry must not be confounded with ordinary crystalline trap, such as the hornblendic, where the whole mass is crystalline, having assumed that form in cooling, or rather setting, similar to what is often found to take place in slag or scoria from smelting furnaces.

Mr. George Blair described and experimentally illustrated some new apparatus for measuring, weighing, and regulating the force of the voltaic current. He placed the following instruments before the Society :—

1. A rheostat, constructed of tinned paper, $\frac{1}{4}$-inch in breadth; resistance 1 inch = 400 feet of telegraph wire, No. 8. It gave resistance without induction.

2. A Gaugain's tangent galvanometer, with needle and shade and stand in one piece. Ring = 9 inches in circumference; six coils of different sizes of wire, from No. 34 to No. 16.

3. A galvanometer balance needle, lifting power = 44 grains; is turned with force of 50 grains in a powerful current.

Mr. B. remarked that Kohbrausch had found sometimes the negative, sometimes the positive electricity preponderate in three batteries, when one pole was put to the earth; and no doubt this arose from the fact that the earth is not quite neutral. Say negative pole, tension, 42; positive, 40; earth, 1. Hence there must be currents; and the existence of currents proves that the earth is not neutral. He had found that sheet gutta percha is a better insulator than varnished glass, unless the shellac is laid on when hot; but when the glass is quite dry and warm, it is the best of the two.

PROCEEDINGS

OF THE

PHILOSOPHICAL SOCIETY OF GLASGOW.

APRIL 4, 1860.

Dr. Bryce *in the Chair.*

Mr. Robert T. Middleton, Drysalter, was elected a member.

Historical Notes of Copper Smelting. By F. H. Thomson, M.D.

It is with some hesitation that I venture to approach a subject which has been so often and well discussed by others having greater opportunities, not only of pure metallurgic education, but placed in positions of acquiring, both practically and theoretically, a true and just experience of the best chemical means by which the largest per centage of metal can be extracted in the purest state, and at the least expense, from the ores of copper.

Copper smelting, and the various questions arising from the consideration of the complicated operations employed in the reduction from the ore of pure and marketable copper, have given rise to much inquiry and scientific discussion, and in no country so much required as England, where nearly one-half of the copper used in the world is smelted.

A question of such vital importance in the commercial prosperity of this great country well deserves the exercise of the best means to ascertain the best mode of reducing, not only our own low per centage ores, but those brought from foreign countries.

The working of copper, and the various processes employed in the reduction of the metal from its ores, have been made the subject of much antiquarian research. But although well ascertained from the works of Pliny and others, that the ancients knew smelting practically, and the use of copper, at a very early date, much definite information has not been elicited by these historians as to the means of metallic extraction. Many quotations might be taken from Pliny, showing that metals were worked to a great extent in his own times. He says King Numa, the immediate successor of Romulus, founded a fraternity of brass founders; and it is evident that copper was not at least a scarce metal. Much of it was imported from Cyprus, of a very fine quality. This was probably metallic or native, of which large masses existed in that island; and the very name indicates that this was the metal imported and used by the Romans for ornamental purposes, such as theatrical ornaments, crowns, &c., and denominated coronarium by some writers. Copper of a coarser quality was mined in the Campagna di Roma, and used for the commoner articles in use among the ancients; but this fine copper, combined with tin, was the material from which warlike and cutting instruments were formed, previous to the common use of iron. We have even Scripture evidence to show a knowledge of smelting. In Job, chap. xxviii. 2, it is written, copper is molten out of the stone. Tubalcain is denominated a worker in metals. But it is not my object to invade the antiquarian regions of smelting previous to the Roman empire, or even to discuss at great length the various hypothetical questions involved; and it may be sufficient introduction to the subject of smelting in Great Britain merely to review shortly what was known at the time Pliny wrote.

The brass of the ancients was, and has been even in later times, matter of discussion; for although almost the same in its equivalents as modern brass, it seems to have been smelted at one and the same time as the copper. Hence our forefathers for many ages fancied it was a distinct metal. The copper ore, and zinc earth or calamine, sometimes called cadmia, were often found in combination, or in the same mine, and being fused together, produced the brass, which, from its resemblance to gold, was much valued. Subsequently the same metal was produced by adding calamine to copper; but as this art of making brass with the lapis calaminaris was not so well understood, and produced at a greater cost, it was comparatively rare. Procopius* says that brass, inferior to gold in colour, is almost equal to silver in value.

It may be presumed from the silence of writers on this subject that smelting was either so simple as not to be worthy of remark, or that it was kept a profound secret. The first is the most likely; for by simply melting an oxide or carbonate ore with native calamine, and adding charcoal, the result would be a brass. It is quite consistent with the metallic reduction of certain ores that the knowledge of the ancients did not go beyond mere fusion with wood. At any rate our information is not definite.

It is also probable that the mines were never worked to any great depth, but that our forefathers used the out-cropping and native copper, which is often found in great masses in laminated strata between

* *De Aedificiis Justiniani*, lib. 1, cap. 2.

the trap formations.* Native copper is also found to this day in large masses in the serpentine rocks, which never contained any copper ore, and where no copper mine ever existed.

Copper found in the metallic state is generally very pure, and easily adapted to manufacturing purposes, and although sometimes obtained in masses at great depths, and difficult of extraction, our forefathers must have used this supply previous to any great knowledge of smelting.

This species of deposit is to be found all over the world, and in later times immense blocks have been discovered, weighing many tons, on Lake Superior.

The Phœnicians seem to have known more of metallurgy than any other nation; for in any analysis of the weapons or ornaments ascribed to them cobalt is generally found. This would prove that they were in the habit of smelting the sulphuret ores. They therefore must have known and practised the art scientifically. Pliny stated that many ores of copper were found in Cyprus, and as the Phœnicians peopled that country it is probable they used them as well as the native copper. At the same time he is of opinion that copper smelting from certain ores was known long before they were a people.

The first method of smelting was doubtless very simple, and consisted in placing the mineral in heaps with successive layers of wood, which being kindled, first roasted, and then reduced a portion of the metal. In Macedonia large heaps of slag are found. The Peruvians also, we are told, melted their ores, when they were of a refractory nature, by means of furnaces, built on an eminence, so as to have the benefit of draught. Discoveries in Russia show that smelting and mining was known in ancient times. In Siberia Gmelin found nearly 1,000 furnaces made of small bricks, about two feet high and three wide; they were furnished with holes for the escape of the metal and the introduction of bellows, all indicating that smelting had at one period been carried on to a great extent.

The inhabitants of Great Britain could not have known much of metallurgy previous to the invasion by the Romans; for although tin was the most ancient production, and one of the temptations of conquest, Cæsar and Strabo both state that the Britons obtained their copper from foreign countries. Tin was smelted by being placed in a hole in the ground, the sides of which were lined with pieces of wood. These, when ignited, reduced the metal by simple deoxidation—a small

* A striking instance of this may be noticed in a whinstone quarry, ten miles from Glasgow, on the property of Mr. Graham Barns of Limekilns.

channel leading to another hole being the receptacle. Many of these rude furnaces have been discovered in Cornwall, in which have been found charcoal, slags, and even the reduced metal. It is just possible that copper was reduced in Britain by the same simple means; for in many of the northern districts carbonate and oxide ores of copper exist at this date. A great deal might be written on this very interesting subject; but so much has been ably done by others, that it may be only necessary to name authorities for those requiring a deeper knowledge than can be attempted in a paper of this limit. Mr. Napier, in his recent work on the *Ancient Workers in Metals;* Messrs. Philips and Darlington, in their *Records of Metallurgy;* and Messrs. Hunt and Mitchell, in a series of papers published in the *Mining Journal* of 1848, 1849, and 1850, give much and valuable information. It will not be necessary to trace copper smelting in this country further back than 1823, when Mr. Vivian described the process then in use as an illustration of the best mode; and although there is much of historical interest in mining statistics, showing the working of the trade from the twelfth century, the process of reduction, so far as ascertained, did not much differ. In fact, no very definite information was ever published regarding the process till Mr. Vivian's communication in the Twenty-first Volume of the *Annals of Philosophy.* The copper trade has always, in this country, been a monopoly, and the process of smelting, till described by him, a secret.

Mr. Vivian thus describes the process of smelting, which I give in a condensed form, as it is of importance to institute a comparison of what was known at that date, and the state of the art at the present time.

The copper ores, being conveyed from Cornwall and Devonshire to Swansea on account of the coal products in that district, are first placed in calcining furnaces, eleven or twelve feet long and fourteen to sixteen feet wide, of a hexagonal form, to undergo the first process, calcination, the charge being about three and a-half tons. This continues for twelve hours, and during that period both sulphur and arsenic are got rid of—the former in the state of both sulphurous and sulphuric acid. The copper and iron are both oxidized.

The second process is to place the calcined ore in furnaces eleven and a-half feet long by seven and a-half feet wide, the object being to melt the charge. When fusion takes place, the mass is well rabbled, to allow the metallic sulphuret to subside, and when the slag, or earthy matter, becomes liquid, it is skimmed off, and fresh charges of ore added, till the furnace can contain no more, and it begins to flow out at the door.

The furnace is now opened at the tapping-hole, and the product allowed to flow into a pit of water. In this process the product becomes much enriched; in fact, about one-third copper, or four times as rich as the average ores formerly used. Should the slags from this process contain copper, which they generally do, the smelter returns them, to go through the operation again. Often the ores are refractory or tough when fused. The addition of a little fluor-spar corrects this.

The calcination of the coarse metal, or the third process, is simply a repetition of the first. The heat is kept up for twelve hours: this is denominated calcining the coarse metal.

The fourth is the melting of the calcined coarse metal, and is conducted in a furnace similar to number two, some slags, containing oxide of copper, being added, along with pieces of furnace bottoms impregnated with metal.

In this operation the oxide of copper in the slags becomes reduced by a portion of the sulphur which combines with the oxygen, and passes off as sulphurous acid gas, while the metal thus reduced enters into combination with the sulphuret. Sometimes a little uncalcined ore is added, to assist the operation, which it does by the sulphur which it contains.

The slag being skimmed off, the charge is either tapped into water or run into sand beds. The metal now contains 60 per cent., and is called fine metal.

Fifth, is calcination again.

Sixth, melting of the calcined fine metal. This again is a mere repetition of the melting process.

The resulting metal contains from 80 to 90 per cent., and is called coarse copper. It is run into moulds or pigs.

Seventh is chiefly an oxidizing process, and the furnaces are called roasters, and of the same construction as the melting ones. The pigs are exposed in these furnaces to the action of the air at a high temperature, till fusion takes place. By this means all volatile matter is expelled and the metal oxidized. This continues from twelve to twenty-four hours, according to the state of the furnace, and then run into sand beds. It is now called blistered copper, and has a spongy appearance, from the escape of the gas disengaged in the process of cooling. It is now fit for the refining, being almost, if not altogether, free from foreign matter.

The eighth and last process, called refining or toughening, is a very delicate operation, and requires the skilled workman to conduct it. The furnace is much the same as the common melting furnace, only with an inclination to the front door. The heat is at first kept moderate, so as to complete the oxidation, in case the copper should not be quite fine. After the heat is well up, the door is taken down, and the slags, if any, skimmed off. An assay is taken out and tested by hammering, so as to ascertain whether it is in a fit state for the toughening operation. At this time the fracture is, in all probability, crystalline, the colour deep red, and judgment is necessary to ascertain what amount of carbon is necessary to bring it to the proper pitch, or, in other words, fit for practical purposes.

The first step towards toughening is covering the whole mass with charcoal. A pole or young tree, generally birch, is then introduced and held down in the melted metal, causing considerable ebullition and escape of gaseous matter. This is continued, and more charcoal added, till the refiner, by his assays often repeated, perceives the grain to have become fine, close, silky, and light red. He tests its malleability and toughness by beating it when hot on the anvil. If the bead of metal does not crack he is satisfied, and proceeds to have it ladled out, the ladles being covered with clay. From them it is run into moulds of the size required by the manufacturer. The usual capacity is twelve inches wide by eighteen in length.

I have not thought it necessary to enter into a description of the various ores, either native or foreign, employed by the British smelter, as I am anxious to give a short diagnostic review of all that has been attempted since Mr. Vivian wrote, in 1823, to improve the process of copper smelting, and render less expensive the production of a metal so important in all our manufacturing interests.

From the year 1823 till 1848 little or nothing was published descriptive of copper smelting in England. In that year, however, M. Le Play published a work, showing that, with one or two exceptions, the operation was much the same all over Europe; and that, in fact, simple calcination and fusion was the only principle involved. So far he brings the matter up in a more scientific manner, and selects his ores with some reference to a definite chemical result. He insists much on classification, and, with material of a certain per centage, does not calcine, but fuses at once, and calcines the product, which of course is a regulus or sulphuret. He also adds rich and pure ores in the formation of his third metallic product, and the same in getting blistered metal for his fourth product, previous to refining and toughening. This result he does not gain without the addition of certain reducing agents, and, as before stated, with only a certain class of ores; but when treating the ordinary ores of all per centages and qualities, he requires nine operations—*A*, calcination of ores with pyritous gangue.

A—Melting of calcined ores, or with the poorest and most impure rough ores, forming first metal.

B—Calcination of metal *A*.

B—Melting of calcined metal *B*, with ores of mean per centage and purity. Formation of second metal.

C—Calcination of metal *B*.

D—Melting of calcined metal.

C—With rich and pure ores. Formation of third metal.

E—Calcination of metal *D*.

C—Melting of calcined metal *E*, with very rich and pure ores. Formation of black copper.

D—Refining of black copper.

But although in reality so many operations are noted, the classification may be reduced to five, as the repeated calcinations are purely for the purpose of getting rid of arsenic and antimony by volatilization. Metals, such as nickel, cobalt, &c., separate under the influence of calcination and melting, by which all substances, more oxidizable than copper, are by preference converted into oxides and silicates; but in order to expel all the arsenic contained in certain ores, it is necessary to repeat many times the alternate calcinations and meltings of the metal before obtaining black copper.

Mr. Mitchell writes a paper in the *Mining Journal* for 1850, page 489, and at some length gives a summary, combining Le Play's, his own, and Mr. Vivian's experience of the best method of smelting copper ores of all classes; and although displaying great chemical knowledge, and containing much valuable information as to the different groups, and the best methods of treating each particular class, yet it all results in the same principle being carried out.

He says that "the chief characteristic of the Welsh method is the facility offered for the rapid and sure working of all the ores and copriferous products which mining or industrial art can furnish. No other process seems to possess this peculiarity, and to be so well adapted to the continuous extraction of copper contained in substances unexpectedly and continually varying in per centage and chemical composition." This method, considered in its minutest details, is not identical in all smelting works. There exist slight variations either in manipulation or in the form of apparatus, according to the skill or the peculiar ideas of the manager, the period at which the works are established, the nature of the ores worked by preference, or the quality of the product required. The ores thus treated in a metallurgical point of view contain substances which may be divided into three groups:—

1. Silica, the earthy oxides, and ready formed silicates, all of which, after various reactions, nearly entirely pass into the slags.

2. The sulphuretted and oxidized compounds, containing all the

copper to be extracted during the process, and whose other elements pass into the slags, or are dissipated in the gaseous state.

3. The water and carbonic acid, which are volatilized by the first contact of heat either in the calcination or melting.

In speaking of the Welsh ores, Mr. Mitchell judges correctly; for by no quick or patent process can poor ores be treated alone, with a speedy result, unless by the addition of rich ores. And as the importation of the high class reguline and carbonate ores only began twenty years anterior to 1848, it is of the former class he principally writes.

Certain modifications are now inculcated, to meet the rich additions made to the smelter's heap by the importations from Australia and the western coast of Africa, South America, Cuba, &c., but it is merely for the purpose of getting a better quality of copper, as the operations, instead of being lessened, are increased to 10.

1. Calcination of the ores—calcination of sulphuretted ores and medium per centage, with pyritous gangue.

2. Melting for coarse metal—melting of poor ores crude and roasted.

3. Calcination of coarse metal.

4. Melting for white metal—fusion of calcined coarse metal with rich ores.

5. Melting for blue metal—melting of calcined coarse metal with the calcined ores of medium richness.

6. Smelting of slags—fusion of slags, from operations 4, 7, and 8.

7. Roasting of white metal—manufacture of extra white metal, or roasting of blue metal. No. 5.

8. Roasting for regulus—roasting of extra white metal.

9. Roasting manufacture of black copper, or roasting of ordinary white metal and regulus.

10. Refining or toughening.

The ores *now* treated in Wales may be classed into two grand divisions. The first composing the product of all the Cornish, Devon, and Irish mines; the second, those imported from abroad,—the native furnishing the poor, and the foreign the rich. The sales in Cornwall include the former—those in Swansea, the latter.

This gradual increase in the proportion of high-class ores imported, and the heavy smelting charges, now led practical and theoretical men to the train of thought, that a shorter process might be instituted for the purpose of a more speedy unadulterated reduction, and with less expense; for the charges upon ten consecutive calcinations and fusions were of course very heavy.

Patent after patent was now ushered into existence—one more scientific than the other—and all supposed to be improvements on the old system. The race began about the year 1828, shortly after the first importations of foreign ore, by a Mr. Brunton of London.

He is followed, on the 17th of July, by a Mr. Jones of Anglesea, who patents a new process for the reduction of copper ores. In 1830 only one patent was taken out; the same in 1832; in 1835, two; in 1838, three; and in 1839 the plot thickens,—five different patentees tried their luck. But to do more than merely hint at these early attempts of applied science, however interesting historically, would be needless, and I shall therefore only review a few of the most practical amongst the sixty or seventy included in the patent records.

The first containing matter of any importance was a patent taken out by our respected townsman, Mr. James Napier, for the purpose of smelting copper by electricity.

He commenced by roasting the sulphuretted ore as usual, then fused it in a reverberatory furnace, having a black-lead hearth, and caused a very powerful current of electricity to traverse the fused mass, conducted by the hearth and a plate of cast iron kept on the surface of the melted metal. The apparent result was, the separation of metallic copper from the fused ore.

Having got certain definite results, a doubt arose as to the true cause of this separation, and a set of experiments were instituted simultaneously by Mr. Napier and Messrs. Rivot & Philips, who ascertained that although a voltaic current furnished by thirty elements of a Bunsen battery seemed to exercise an indubitable decomposing action on the copper ore, and separated copper in a metallic state, yet the coal of the graphite hearth, and the plate of cast iron employed as a pole, were alone capable, without the aid of electricity, to produce the same effect.

Messrs. Rivot and Philips were led by these results—seeing that in the ordinary process, consisting of a series of roastings and successive castings, much fuel was lost, and also much copper carried off, if not conducted with great care—to attempt a process for the reduction of copper by one roasting and one melting.

They submitted the ores to a roasting sufficiently complete to dis-sulphurize and transform the iron and copper into oxides, then added reducing substances, which would produce a slag somewhat of the composition of a bisilicate of the protoxide of iron and lime, and in addition a certain quantity of charcoal, or coal in small pieces, so that the oxygen in the ore might transform the carbon thus added,—one half into carbonic acid and the other into carbonic oxide.

When at the melting point the carbonaceous matter separated a large quantity of copper, leaving in the slag but two or three per cent. At this point of the operation bars of iron were plunged into the mass, which had the effect of reducing the small per centage of copper left.

The more carbon used in this process, the less will be required of the iron,—that is to say, if constant layers of charcoal or coal be kept on the surface, it prevents the surroxidation of the protoxide of iron. The process, therefore, consisted in the formation of a fusible silicate, the addition of charcoal, and the completion of the operation by means of metallic iron.

The patent was taken out in France in 1846, and the experiments conducted at Paris and Grenoble; but this ingenious process has never been worked on anything like an extensive scale, as in most instances, arsenic being present in the ores, and not carried off, the metal was to a certain extent deteriorated. The expense also, in the destruction of iron, was very great, constituting a serious objection to its practical adoption.

Mr. Napier again comes on the field in 1846, 1847, and 1848, in a more practical form, and his object seems to be the separation of the metal, by a judicious mixture of ores, so as to form a liquid slag. In this way ores rich in the earths and oxides of iron are commonly added to those containing much silica, and *vice versâ*, so that, by a proper mixture, the reduction is perfected at a much less expenditure than would be required for their separate treatment. Mr. Napier thus brings down the operations from ten, the usual curriculum now in practice at Swansea, to five. In his first melting he procures a reguline matt, ranging from 30 to 50 per cent., and after withdrawal of the slags from the surface he adds soda, ash, or salt cake in the proportion of 1 cwt. to 1½ cwt., along with 20 or 30 lbs. of fine coal, to every ton of the said matt.

When these substances have been allowed a certain time, to admit of the reduction of the sulphate of soda by the action of the charcoal, which takes place in a few minutes, the regulus is tapped into sand beds or moulds. When sufficiently hard, these blocks are thrown into a tank of water, where disintegration takes place. The powdered matter is now calcined till all sulphur be expelled, which being effected, the product is mixed with a proper quantity of malachite, or any carbonate or oxide ore containing silica, a requisite quantity of carbon, and again fused for six or eight hours. The product from this is metallic copper and a clean slag.

The tin, antimony, arsenic, and other impurities, are carried off by the solution of sulphide of sodium, produced in the decomposition of the salt cake when the reguline pigs are thrown into water.

Mr. Napier also adds lime and common salt, and, with rich oxides and carbonates, containing a large proportion of silica, iron scales, in the proportion of 2 to 3 cwts. per ton of charge. Sometimes also may be used the native carbonates of iron, also scrap iron.

His principal claim under these patents is the application of iron with alkaline substances, and disintegration by water.

I have described Mr. Napier's process as containing in its subject matter the substance of almost all the patented principles, viz., the application of fusible silicates in combination with iron and carbon.

A Mr. Law, in 1848, patents the application of a compound of oxide of manganese, plumbago, nitrate of potash, nitrate of soda or lime, and carbon.

Another patentee, in 1849, claims the use of silicious and carbonaceous matters, also dissulphurization without the use of iron or alkali.

Mr. Parks of Birmingham, also in 1849, produced two elaborate patents, which do not differ much in principle from those of his fellow-labourers in this peculiar field of science.

He uses sulphuret of lime of soda, baryta, or potash, and holds that a richer regulus is the result, and a more speedy metallic reduction produced than by any other process.

Early in 1849, being impressed with the idea that the practical application of a fusible silicate, easily procurable in a dense form, and containing the chemical qualifications necessary in smelting a certain class of ores, might be attainable, I instituted a set of experiments on such a scale as would place me beyond the mere laboratory investigator. The result was a patent specified by me on the 14th September, for the application of whinstone as a flux, being a fusible silicate, including all the varieties, such as trap, basalt, sienite, and the like.

The claim was, the smelting of copper ores by the use of what is commonly called whinstone, or other like stones, broken into fragments, as a flux, or by the use of what is commonly called iron slag, all having carbon added, and either with or without alkali as an improved flux.

I might dilate at some length on the various phenomena elicited in the course of my investigations, but feel I cannot do so with justice to the time of the Society on this occasion. I may mention, however, that the results were beyond my expectation; for with one roasting, one melting of the matt, recalcination, and fusion, for tough copper, I got metal of 99·80 of purity.

These experiments were all eight or nine cwt., and many of them a ton to the charge, and although much may be urged by smelters and metallurgists in contravention of whinstone as a flux, in all cases of rich ores there cannot be a doubt of its effect. The great objection is its bulk; but so much saving in fuel is effected by the shortness of the process, this cannot constitute a practical difficulty.

It is matter of much doubt whether the mixture of the poor class ores of home with the rich foreign importations produces the same quality of copper as that smelted entirely from high per centage ores. In Russia, where much fine copper is made, and is a prominent feature in the mercantile interests of that great country, being all smelted from the rich carbonate or malachite ores, even so far back as 1830, 27 mines and 200 furnaces were continually employed in the production of this metal, the annual product being 4,661 tons. In Hamburg, in our own Colonies, in North and South America, and in fact everywhere that copper is smelted without much admixture of the poor with the rich ores, copper of a better quality is the result. Chili, although sending a large quantity of smelted copper, gave to England in 1854 12,000 to 15,000 tons of rich ore; but this quantity has much diminished lately, owing partly to a heavy differential duty. Since then the great proportion is sent to Hamburg and elsewhere, to be smelted alone, by the addition of fusible silicates.

From these sources all the north part of Germany is supplied, and with better bar copper than can be got in England. The Australian copper, smelted on the spot by Messrs. Schneider, under Mr. Napier's process, is all sent to India.

It may well be asked, why are the smelters of England behind those of other countries, and how is copper smelting not carried out by the best methods extant? The reason is patent to the world, and notorious.

Monopolies in all ages have been hindrances to science in every department, and in copper smelting most especially so; for since the trade existed, a few rich houses have held the reins, and by large capital determinately opposed any increase of speculation. They have coerced the miner, forcing him to sell on their own terms, according to fixed regulations laid down by their council, and in all times past have managed to keep the trade in their own hands. They not only command the miner but the manufacturer, the former often receiving payment for his ore before it is smelted, the latter getting long credit, and often becoming so deeply indebted to the smelter, that neither can sell or buy elsewhere. Be this from want of union among themselves, poverty of capital, or other causes, it is quite certain that neither miner or manufacturer have ever been able to act independently, and the clique laugh to scorn any attempt to dislodge them from their dictatorial throne.

The difficulty of procuring rich foreign ores to mix with the poor ones indigenous to this country is of course a great bar to any independent smelting operations by the miner; and if any such attempt were to be made in Swansea, the smelting corporation would lower the price of copper, so that not only would their own, and the works opposed to them, suffer, but the mining interest generally, especially that class producing ores of a poor quality.

Many will urge that this suicidal course would in time cure itself, and tire even the patience of the smelter; but the plan has been, on more than one occasion, carried out, to the utter ruin of many smelting establishments who started, led away by the great profits derived by the smelter.

A temporary fall in the price of copper under this coercive system is soon rectified, for one house is known to have held nearly half a million of copper bars to force a corresponding rise, when the necessity for depression no longer existed.

By the present system the smelter has delivered to him 21 cwt. for every ton of ore he purchases. To this may be added the overplus profits of the assay, which is all in his favour, so that the poor miner is at once mulcted in about 15 per cent.

According to the price of copper in the market, the smelter has a roving profit of from £20 to £30 per ton of copper, enough to tempt the poor miner into the vortex, and oppose small capital to the combined and determined systematic opposition of the millionaire smelter.

When one calculates the quantity smelted by one house, about 5,000 to 6,000 tons of copper per annum, and also that the total amount smelted in England was, in 1855, 21,485½ tons, of the value of three millions, it cannot be wondered that all private attempts fail, when brought into competition with the holders of such a capital.

Of late years many companies have been got up, more especially with the view of getting hold of the foreign ores, easy of reduction by many of the late patents; but all, with the exception of one or two with large means, have been utterly ruined, and expunged from the trade. A Mr. Benjamin Smith of London erected large works at Bow Common some years ago, and so long as his arrangements with foreign houses lasted, all went merry as a marriage bell; but when he attempted to buy and depend on his supplies from the ore sales, and share the privileges of the English smelters, the screw was put on. Gradually copper fell and ore rose, till his works, from lack of material, sank to rise no more, and he died, I believe, shortly after. This is one of the many instances that could be adduced of the vast power of this great monopoly.

One gentleman attempted copper smelting in Glasgow, in 1848-49, having previously arranged for consecutive cargoes of Australian ores. The works were erected, and two cargoes turned into copper, but whether he had begun at a bad time, or bought his ore too dear I know not, but he found after a little that the ore unsmelted produced more in proportion at Swansea than he could make by any metallurgic operation, so the ores were sold to arrive, and as he had begun to see the hopelessness of solitary competition, the works were taken down, and copper smelting in Glasgow was strangled in its birth.

Much might be arranged in Scotland by a determined and well regulated union of smelters and importers; for to Glasgow merchants a large proportion of the rich Cuban and Cobre ores are consigned.

They are of course forced to sell at Swansea, subject to the regulations of the assay court, instead of bringing their ships and cargoes direct to the Clyde, where they ultimately come in ballast, to be reladen for the foreign markets. The ores might be sold in Glasgow similar to corn, cotton, or any of our foreign importations; and as in Scotland much copper is used in all our great engineering and manufacturing departments, the smelter would find no difficulty in making his metal sales. Coal, and all the material for reduction, are at the door; and if some of our large capitalists were to unite heart and soul in this branch of metallurgy, as a commercial feature in this great and increasing city, there could not be a doubt of success; for with our cheap labour, coal abundant, and the foreign and British merchants determined to lend their aid, the smelting clique might be set at nought.

Of course the English smelters do not carry out these constringent laws and regulations without much abuse; but what do they care; for so long as the mining interests are so mulcted in the sale of their ores the balance must always be in their favour.

The smelting of copper, as now conducted at all the great works, does not differ much from the process in use when Mr. Vivian wrote in 1823, except that it is a little longer and more tedious.

The operations as laid down by Mr. Philips, the latest writer on copper smelting, are ten in number.

1. Calcination of the ores of the finest and second classes.
2. Melting for coarse metal, or fusion of the roasted ores with minerals of the third class, not calcined.
3. Calcination of the coarse metal.
4. Melting for white metal, or fusion with the coarse metal, with the addition of rich minerals belonging to the fourth class.
5. Melting for blue metal, or fusion of the calcined coarse metal with roasted minerals rich in copper.

6. Remelting of slags, or fusion of the rich slags obtained from the operations 4, 7, and 8.

7. Roasting for white metal, or production of white metal of extra quality. This operation includes the roasting of the blue metal obtained in process 5.

8. Roasting for regulus, or preparation of extra white metal.

9. Preparation of crude copper by the roasting and fusion of ordinary white metal, regulus, &c.

10. Refining and toughening of the crude copper, and production of malleable metal.

It is quite possible that all these different processes may, to a certain extent, be prudent in the reduction of the very poor ores, but certainly not where the per centage of metal ranges from 20·30, or 40 per cent.; for the deterioration in the quality of the metal by the admixture of the high class with the poor is more than enough to balance any advantage derivable from the fusible matrix, combined with the latter, and which is necessary for the reduction of the Cuban and rich foreign ores, having comparatively none. Indeed all the ores brought to this country from South Australia, Chili, Peru, and Cuba, range from 40 to 60 per cent., and could easily be reduced by three or four operations at most. By simple calcination and fusion with a proper flux, such as many of those noted by Napier, Mitchell, Philips, and others, a regulus of 70 or 80 per cent. could always be obtained. This, disintegrated, calcined, and fused again in a refining furnace with charcoal, would produce a metallic copper of great purity. I have on many occasions got this result by the application of whinstone, even with much lower class ores.

The great objection to the admixture of the poor class with the rich consists in the combination of sulphur, arsenic, and other deteriorating principles, always present in the former, requiring much and repeated calcinations for their eradication, and lowering the quality of the metallic result, also adding expense to the process.

STATISTICS OF THE IMPORTS AND EXPORTS.

Having thus far attempted to trace copper smelting, its early history and present practical results, it may not be amiss to give a slight statistical digest of the quantities raised in England and derived from other countries; also the quantities exported and imported, wrought and unwrought. In tracing this portion of my subject, I have abstracted so much as may be sufficient in a paper of this limit, from Mr. Hunt's valuable *Records of the School of Mines,* and from Messrs. Philips and Darlington's *Records of Mining and Metallurgy,*—the best and latest authorities on the subject—bringing the information, in a tabular form, down to 1857.

The quantity of copper ore raised in Cornwall and Devon, and chiefly sold by public ticketings, during 126 years, ending 1855, was 7,884,305 tons, which realized £50,964,388 sterling. The mean price per ton of the whole was £6 9s. 3d., and the average yield for seventy years was 8 per cent. of fine copper. The return for ten years ending 1855 was twenty-five times greater than from 1726 to 1735. The average produce for ten years ending 1785 was 12 per cent., and for a corresponding period to the end of 1855, it had declined to $7\frac{1}{2}$ per cent.; for 1857 it was about $6\frac{3}{4}$ per cent. These figures clearly show the economic value of the improvements effected in working mines.

The average produce of the common ore of Cornwall has been estimated at 2 per cent; consequently, this calculation, applied to the number of tons sold during 126 years, will bring the quantity produced no less than 31,537,220 tons.

These ores are sold by a process called ticketing, and is thus arranged:—The ore is thrown into a heap, and three average samples are taken. One of these is assayed on the part of the mine, another for the smelters, whilst the third is retained in case of dispute. The sales or ticketings take place at Redruth, Truro, and Poole, where the agents offer for the small samples to be disposed of. When all have delivered their offers or tickets the results are published in a tabular form. In this list a red line distinguishes the highest bidder, who becomes the purchaser.

In a commercial point of view the copper mines of Chili, Cuba, Spain, and Australia are, after those of England, by far the most important, and send large quantities to be smelted. For instance, there was imported into England from the different foreign mines in 1857, 75,832 tons of ore and 19,262 tons of regulus. Four or five years previous to the discovery of the Australian gold fields, the increase of copper ore was very definite. The produce of the Burra Burra mine, which in 1846 was $6{,}359\frac{1}{2}$ tons ore, increased in 1850 to 18,692 tons. Since then, by the abstraction of the miners to the gold fields and other circumstances, the product has been reduced in 1857 to 4,182 tons. Foreign copper imported into this country and the product of the foreign ores by smelting, were, previously to 1842, almost wholly re-exported. The duty on copper ore, when taken or smelted for home use, being so heavy as to cause it to be exported in an unwrought state.

For 1842 the duty was much reduced, and in 1853 repealed, hence the great increase in the imports of ore for smelting, and the application of the metallic copper to home use or exportation indifferently.

As the terms standard and produce are not generally understood, it may be as well to explain here what is meant by the expressions. The former is the term used to indicate the value of a sufficient quantity of copper ores required to produce a ton of copper, including an amount called returning charges, which comprehends all expenses incurred from the time the ores are purchased till they are smelted in a metallic state fit for the market. The latter term is used to specify the per centage for metal contained in the ores; for example, a ton of ore of 12 produce contains $\frac{12}{100}$ths of a ton of metal.

The standard of Swansea, from 1815 till 1848 inclusive, averaged about £103·15, the produce about $12\frac{1}{4}$.

The total quantity of copper ores sold, 873,658 tons, averaging per year 25,696 tons. The total amount realized for copper ores, £10,011,685, averaging per year £294,461. The total quantity of metal produced from said ores, 124,690 tons, averaging 3,669 tons annually.

Mr. Hunt states that the produce of copper and copper ore, and of the value of the ore from British mines in the United Kingdom in 1857, was 218,687 tons of ore, producing 17,375 tons of copper, amounting to £1,560,922 11s. 6d. sterling.

France, the East Indies, Holland, the Hanse Towns, Turkey, Egypt, the United States, are the greatest markets for British copper. Thus, in 1857, the value exported to France was £676,971; India, £592,169; Holland, £247,868; Hanse Towns, £196,638; Turkey, £140,631; Egypt, £153,940.

The largest quantity of copper ores sold for one single year between the above dates was 55,520 tons in 1844, which averages 5,460 tons per calendar month. In this year also the greatest amount ever obtained was realized for copper ores,—viz., £882,568, or say £73,547 per calendar month; and from these ores more metal was produced than ever before within a similar period,—viz., 11,107 tons. The smallest quantity of copper ores sold for any single year since 1815 was 287 tons in 1818, or say twenty-four tons per calendar month, which realized £4,089, being about £344 per month, and from which was produced thirty-nine tons of metal,—a great contrast with the production of 1844.

Mr. Hunt, in a series of elaborately compiled tables, shows the gradual increase of copper ores, and the produce from all sources from 1848 down to 1852, and in a general summary shows the exports and imports.

FROM ENGLISH MINES.

	Ore.	Copper.				Value.		
	Tons.	Tons.	Cwts.	Qrs.	Lbs.	£	s.	d.
1848, ...	147,701	12,241	19	2	5	720,090	17	0
1849, ...	146,326	11,683	13	0	22	763,614	19	0
1850, ...	155,025	12,253	10	2	21	840,410	16	0
1851, ...	150,380	11,807	8	2	18	782,947	8	6
1852, ...	165,593	11,776	17	2	24	975,975	14	0
	765,025	59,943	9	3	6	4,083,039	14	6

FROM IRISH, WELSH, AND FOREIGN MINES, SOLD AT SWANSEA.

	Ore.	Copper.				Value.		
	Tons.	Tons.	Cwts.	Qrs.	Lbs.	£	s.	d.
1848, ...	49,363	8,672	18	0	15	562,418	11	0
1849, ...	43,593	7,540	2	3	22	564,585	16	0
1850, ...	41,586	7,108	8	1	11	549,258	3	6
1851, ...	37,241	6,015	0	2	17	463,953	3	0
1852, ...	31,654	4,901	18	3	6	464,314	16	0
	203,437	34,238	8	3	15	2,604,530	9	6

TOTAL OF COPPER SMELTED AT SWANSEA DURING THE ABOVE FIVE YEARS.

	Ore.	Copper.				Value.		
	Tons.	Tons.	Cwts.	Qrs.	Lbs.	£	s.	d.
English Mines,.......	765,025	59,943	9	3	6	4,083,039	14	6
Foreign, Irish, and Welsh Mines,......	203,437	34,238	8	3	15	2,604,530	9	6
	968,462	94,181	18	2	21	6,687,570	4	0

COPPER IMPORTED.

	Ore.		Regulus.		Copper.		Value.		
	Tons.	Cwts.	Tons.	Cwts.	Tons.	Cwts.	£	s.	d.
1848,......	50,053	2	124	2	1,749	13	9,200	9	5
1849,......	46,237	4	667	12	2,169	5	25,338	11	10
1850,......	40,388	6	5,473	12	5,324	13	35,946	13	6
1851,......	35,683	18	6,442	5	5,590	7	30,073	13	9
1852,......	37,817	13	5,226	0	6,172	16	19,234	10	0

BRITISH COPPER EXPORTED.

	Ore.		Copper.		
	Tons.	Cwts.	Tons.	Cwt.	
1848,........	......		13,466	7	
1849,........	......		27,480	3	
1850,........	150	10	21,307	13	
1851,........	1	3	17,555	11	
1852,........	15	0	16,936	1	

The average price per ton being £124, the comparative quantities exported, derivable from all sources, during the three years ending 1857, he puts down in the following tabular form :—

ACCOUNT OF THE VALUE AND QUANTITIES OF THE DIFFERENT DESCRIPTIONS OF COPPER EXPORTED FROM THE UNITED KINGDOM DURING EACH OF THE THREE YEARS ENDING 1857.

	Quantities.			Values.		
	1855.	**1856.**	**1857.**	**1855.**	**1856.**	**1857.**
	Tons.	Tons.	Tons.	£	£	£
Copper in Bricks and Pigs,	5,119	6,096	7,196	585,702	673,224	852,017
Copper in Specie, Nails, &c., including Yellow Metal,...	10,432	14,378	13,702	1,664,274	1,664,648	1,167,772
Copper, Wrought, of other sorts,..........................	1,106	1,430	3,243	152,146	189,181	451,312
Brass of all sorts, ...	841	959	1,100	106,784	121,206	144,790
	17,498	22,863	25,211	2,110,916	2,618,259	2,815,831

I have to offer many apologies to the Society for the rambling nature of these jottings; but the subject is one of such magnitude that anything but a general view would have been impossible.

I sincerely trust that although I may not have added much to the information of any present, my notes may be acceptable as showing at least my desire to follow out the wishes of the section to which I have the honour to belong.

PROCEEDINGS

OF THE

PHILOSOPHICAL SOCIETY OF GLASGOW.

APRIL 18, 1860.

DR. ANDERSON, *the President, in the Chair.*

On a New Process of Ornamenting Glass. By Mr. JAMES NAPIER, Chemist.

So early as 1670 it was observed, that when the mineral fluor spar and sulphuric acid were mixed in a glass vessel, the glass was corroded, and also that the fumes given off by this mixture produced the same effect; but it was not till a century after that the cause of this action upon glass was explained by Scheele, who referred it to the disengagement of an acid from the fluor spar, which he termed fluoric acid; and it was not till forty years after Scheele, that the true composition of that acid was known. It was then found to be a compound of the two elements, hydrogen and fluorine, and consequently was named hydrofluoric acid. The peculiar difficulty attending the investigation of this compound is its strong affinity for almost all articles used in these operations. It can only be kept in vessels of gold, silver, platinum, lead, or gutta percha. Its attraction for silica, with which it forms a soluble compound, renders glass quite soluble in this acid.

When the nature and properties of hydrofluoric acid were known, the idea of etching upon glass with it was a natural one, and many attempts were made to bring this application into use for printing from. The mode of etching upon glass was similar to that of etching upon metals, namely, by covering the surface of the glass with some unctuous or resinous matter, capable of resisting altogether, or for a time, the action of the acid. The pattern or figure required was then made upon this resist, and with a suitable instrument the resinous coating was cut through to the glass. On this being done the glass was submitted to the acid fumes, given off by mixing ground fluor spar and sulphuric acid together in a leaden vessel, and exposing to a gentle heat for a short time. Those parts of the glass exposed by means of the graver were acted upon by the acid fumes; and after removing the whole resinous coating from the glass, the figure or pattern was found etched into the glass.

This simple process embraces the principle of all the etching yet done upon glass; nevertheless, many useful modifications have been introduced, both in the matters used as a resist and in the mode of applying the acid. The gaseous fumes being combined or dissolved in water, the acid is now generally applied in a liquid state.

The application of these operations to the ornamenting of glass is of very recent date, and for this purpose various methods have been adopted. In some cases the figure to be produced upon the glass was drawn upon it by a substance capable of resisting the acid, and then the glass was submitted to the acid for a short time, after which the pattern remained in relief. If the glass had a coloured veneer or coating upon it, the acid was allowed to dissolve the coating off, and the preserved pattern was then left coloured upon the now colourless glass. Of course, such a process as this required an artist and much time. The more common process, however, to effect this purpose, was by stencilling, as when the desired pattern was cut out in thin lead and laid upon the glass; the resisting coating or varnish was then brushed on the glass through these cut parts, and, on removing the lead, the varnish remained, forming the pattern. Or the reverse of this; thin pieces of lead, paper, or gutta percha are cut out, forming the pattern, and these laid upon the glass with some adhesive matter easily removed; the remainder of the glass is then covered over with the resisting varnish, and when dry or hard these patterns are removed, the glass under them is cleaned and the acid applied, and the figures or patterns are thus eaten out; and if the glass has been coloured by a veneer, the figure will appear white on a coloured ground. Such are the principles, with different modifications, by different manufacturers, upon which many of our window glasses are ornamented. More recently a variety of patents have been taken out for extending this branch of manufacture, some of them producing articles of considerable beauty and design, although wanting in the light and shade essential to a good picture. A recent modification seems to be the subject of several patents, which is, to print a picture from stone upon paper, using for an ink a mixture of resinous and oily matters, thick, soft, and adhesive, and, when newly printed, the paper is laid upon the glass, the ink-side down, and gently pressed, so as to cause the composition to adhere to the glass. The paper is then carefully removed; the figure thus transferred to the glass is examined, and if any defect is seen, it is touched up with the hand, after which, and while the ink is still soft, some charcoal dust is sprinkled over it, which adheres to the resinous ink. When the ink gets completely dried on the glass, all the loose charcoal is blown off, and the glass, with the figure upon it, is subjected to the hydrofluoric acid.

This, as will be seen, leaves the picture in relief. It is necessary, in all these processes, that the surface of this glass be either coloured, enamelled, or ground, otherwise these patterns would not be visible but with difficulty, and at certain angles of light.

My object in these remarks is to lay before the Society another and more simple and cheap method of getting pictures or designs upon glass by etching, and at the same time obtain pictures wherein the light and shade of a print are preserved upon the glass.

I take an ordinary picture or print upon paper, and paste it upon the glass, the ink-side to the glass, with ordinary paste, such as starch, taking care not to let air remain between them, and allow the paste to dry thoroughly. The glass, with the paper upon it, is then put into hydrofluoric acid, until the paper and paste are moistened, but not loosened; this requires from three to four minutes. I then wash the whole off, so that no trace of acid may remain, when there is formed in relief a *facsimile* of the picture upon the glass. When the glass is finely ground previously, the picture appears white; when the glass has been stained or coated with a coloured enamel, the picture remains coloured on a white ground or clear ground. The veneering on the glass requires to be so thin that the acid will dissolve it away in the short time that can be allowed in this process. The stained glass of Bohemia is well fitted for this purpose.

Although any picture or print (and old prints, as well as new) will do, they are more suitable when the lines of the print are bold. This is particularly necessary for window panes, or doors, or gas moons, as they have to be looked at from a distance.

Again, the commonest printers' ink suits best; hence the pictures found in children's picture-books are found to serve the purpose; but when the best ink is mixed with some varnish before printing, it is found equally good.

It is a curious circumstance that we can make a negative picture—that is, one in which the ink lines appear clear. This is done by keeping it in the acid only half the usual time, and is accounted for, no doubt, by the fact, that when the paste is merely moistened, and removed immediately, the glass is whitened by the operation; so that in the short-time operation the paste, where there is no ink, is in that state which whitens the glass; while the parts upon which the ink is have not been affected. But in the longer time, the parts where there is no ink are considerably affected and less whitened; while the parts where the ink is has only been newly affected, and are consequently in the maximum state of whiteness.

These operations have not yet been carried out to any great extent, nor much beyond the laboratory. But they afford to practical men a cheap and simple method of transferring works of art to glass, which appears to me worthy of the consideration of those engaged in such manufactures. When a picture is transferred to colourless glass the figure is not seen by looking directly through it; but as every line and feature may be traced, it can easily be painted or coloured over, to bring out all the beauty and art of the original, without further aid from an artist. Tumblers and glasses, having a coloured band put round them, may have any suitable figure produced upon them, and at a cost little more than the price of the printed paper. The only requirement on the part of the operator is attention to the pasting of the picture on the glass, and the time it is exposed to the acid.

Professor Allen Thomson exhibited with microscopes a series of preparations, illustrative of the minute structure of the spinal cord and nerves, and gave a description of these preparations, together with remarks upon the subject which they illustrated, from his own observations and from those of Dr. Thomas Reid, by whom a large series of very beautiful microscopic preparations of the nerve-structures had been made.

The method followed in the construction of these preparations was a modification of that recently employed by inquirers into this subject viz., hardening fresh portions of the nervous texture by immersion for some weeks in solutions of chromic acid, tinting them with a solution of carmine, and, after various other subordinate processes of preparation, mounting them in Canada balsam.

Dr. Thomson pointed out the peculiar advantages of this process, which have enabled microscopic inquirers in later times to investigate with greatly increased success the more delicate textures of the nervous system; and, in proof of this, he contrasted the very exact knowledge of these textures which is in the course of being obtained by anatomists of the present day, with the results of the imperfect mode of dissection which was followed previous to the introduction of the newer method.

In particular, he adverted to the great advantages obtained, in the first place, by the use of chromic acid, in hardening the specimens so as to admit of thin sections being made of them, while the minutest structural characteristics are preserved and increased; and, in the next place, by the process of tinting with carmine, which has the peculiar property of colouring some parts of the nervous tissue more strongly than others, and leaving some parts unaffected, so as to mark more clearly the difference between minute parts which could not otherwise be distinguished. It is more especially the delicate central filament of the primitive nerve-tube which receives a deep colour from the carmine; and though, in many cases, these fibres are not more than $\frac{1}{10000}$ to $\frac{1}{20000}$th of an inch in diameter, yet they are made so distinct that they can be followed with the greatest ease, and their course and connections traced in situations in which, from their minuteness and complexity, it would otherwise have been quite impossible to recognize them.

The nerve-cells also, and particularly the multipolar cells of the gray substance of the spinal marrow, are rendered more distinct by this process; and Dr. Thomson pointed out a number of instances, in the preparations exhibited, in which it was probable that the radiating prolongations appeared to be spreading from various sides of these cells in actual connection with the central filaments of nerve-fibres.

In the preparations shown the various parts of the nerve-tubes, viz., the external tubular sheath, the medullary substance, and the central filament, were shown with great distinctness.

Dr. Thomson gave some account of the views of recent inquirers as to the course and direction of fibres in the different parts of the cord, and their connection with the roots of the spinal nerves,—alluding more particularly to the statements of Stilling, Schröder Van der Kolk, Lockhart Clarke, and Kölliker.

The preparations shown illustrated very fully the structure of the central canal of the cord, with its epithelial lining; upon which Dr. Thomson remarked that, like the ventricular cavities of the brain, it was to be regarded as an involuted portion of the original external surface of the germinal membrane, and that the epithelial lining might be looked upon as indicative of this origin, and also as interesting in connection with the peculiar structures which are now known to be appended to the extremities of the nerves of special sense (olfactory optic, and auditory), seeing that the extremities of these nerves are probably rather expansions of circumscribed parts of the original central nervous organ, than new developments in peripheral structures.

In regard to the structure of the substance of the spinal cord, Dr. Thomson stated the view which he and Dr. Reid were inclined to take from their observations, that it is everywhere pervaded by a framework of delicate fibrous or areolar substance, in which the nerve-cells and nerve-fibres are placed, and through which run the blood-vessels when present.

In the cross section of the spinal cord this delicate framework presents itself most obviously, in the form of radiating processes, passing from the gray substance internally towards the external surface, where it is completed by a thin covering of the same tissue. It is well seen also surrounding the larger multipolar cells of the anterior vesicular columns, so as to furnish delicate sheaths or inclosures for these cells, through which the radiating processes run into the neighbouring parts

Dr. Thomson gave a general account of the facts which the specimens exhibited as to the course of fibres in the cord; but he confessed that the knowledge of this subject must still be considered as extremely imperfect. In fact, there are no more complicated problems in anatomy than those relating to the course of fibres in the nervous centres; and a vast number of observations, made in different modes, will be required to render the results of inquiry satisfactory in this part of the subject.

His observations, and those of Dr. Reid, confirmed the fact of the fibres of the anterior roots running in numbers, and very directly, towards the multipolar cells of the anterior horns of gray matter; the passage of a certain number of the fibres of the anterior roots through the anterior commissure to the opposite side; and the junction of a part of these fibres both with the anterior and lateral fibrous columns of the cord on the same side.

The structure of the anterior and posterior, and also of the lateral vesicular columns, was very clearly demonstrated, and specimens were shown, illustrating the peculiar nature of the posterior cornua of the gray substance.

Into these last the fibres of the posterior roots were seen to enter, to bend round, and subsequently to pass in three directions—1*st*, forwards towards the vesicular columns and anterior roots; 2*d*, into the posterior vesicular, and into the posterior and lateral fibrous columns; and, 3*d*, in considerable numbers to cross or decussate both in the anterior and posterior parts of the commissure. At the same time, Dr. Thomson stated that he did not consider our present knowledge of the connection or course of these fibres as sufficient for physiological or pathological application. In particular, the difference between the reflex motory and sensory fibres has not yet been shown, nor has the physiological difference between the crossing of the effects of lateral injury of the cord on the sensory and motory functions received its anatomical explanation from the examination of the structure of the cord.

Dr. Thomson expressed his belief, however, that at no very distant period, from the number and ability of the inquirers at present engaged in researches on this subject, we may hope to see important light thrown upon many parts of it. He stated his belief in the existence of frequent communications between certain fibres of the sensory and motory roots in the spinal marrow (and that probably by means of nerve-cells), as the means by which reflex motions are excited; and he adverted to the explanation which might thus be given of the greater size of the posterior than of the anterior roots of the spinal nerves. He farther supposed the cells to establish communication between groups of the spinal nerves, so as to co-ordinate their motive influences on groups of muscles; and finally, he stated his belief that when sufficient deduction was made for such fibres as might be supposed to remain within, or to belong to the spinal cord itself, it was probable that all the true sensory fibres of the posterior roots, and the volunto-motory fibres of the anterior roots, ascended through the spinal cord to the basal portions of the brain, there to be brought into new connections with the gray matter and medullary substance of that organ, in connection with the functions of volunto-motory influence and sensation. At the same time, he expressed his opinion that the existence of these communications between nerve-fibres and cell-processes, as matter of direct observation, had been greatly overstated by Schröder Van der Kolk, and some other authors. He gave an account of the measurement of the fibres of the roots of the nerves, and of the spinal cord at different parts, with estimates of the number of fibres in different places, which apppeared to be confirmatory of these views.

Dr. Thomson gave an account of micrometric measurements made by Dr. Reid and himself, of the size of the nerve-fibres in the spinal marrow, in the anterior and posterior roots, and in the compound nerve beyond the ganglion; and stated as the result, that very little change occurs in the size of the greater number of the nerve-tubes themselves in their course, but that the apparent change in the size of the roots as compared with the spinal marrow, and of the compound nerves as compared with the roots, depends in a great measure upon the difference in the amount of sheath-substance, or adventitious tissue, which comes to be interposed between and around the fibres. This is especially the case with the primitive nerve-tubes when they leave the spinal marrow and pass through the pia mater, and at their subsequent passage through the dura mater. At the first place they receive a finer sheath-matter, which runs intimately between all the nerve-fibres; but at the second, the addition of a coarser sheath-substance takes place chiefly round each fasciculus, and on the exterior of the whole nerve, while the fibres within each fasciculus are not more separated than before.

Dr. Thomson stated the result of a number of measurements of the area of section of the whole anterior and posterior roots of the spinal nerves, from which it appeared that the bulk of the posterior is usually from a third to twice as large as that of the anterior; and, further, as the individual nerve-tubes of the posterior roots are on an average about a fourth smaller in diameter than those of the anterior roots, the number of fibres must be generally considerably more than double, perhaps three or four times more numerous in the posterior than in the anterior roots.

As examples of the bearing of these measurements upon the structural and functional relations of the spinal cord and nerves, and of some of the other nerves, the following may be extracted:—

It was found that about 250 fibres (nerve-tubes) were to be observed in $\frac{1}{100}$th of an inch square of the cross section of the spinal marrow. This would equal about 200,000 in $\frac{2}{5}$ths of an inch square—the area of the spinal marrow in the dorsal region. The number might be 300,000 for the upper part of the spinal cord.

The fibres in the posterior or sensory roots alone surpass these in number, and if we add those of the motor roots, it seems improbable that all the fibres of the roots ascend through the spinal marrow. Although the white substance does increase in thickness in the upper parts, that increase does not appear to be commensurate with the size of the roots of the nerves, and both the white and gray matter in the lumbar and axillary enlargements are considerably greater than in the parts above them. The conclusion seems irresistible, that a number of fibres must remain within, originate in, or communicate with each other in the cord, without reaching the brain.

To take a rough estimate in another way. If we take the diameter of the fibres at $\frac{1}{1600}$th, and if, making allowance for the sheath-matter, and the difference between the circle and the square, we take the section of a nerve-fibre as equal to an area of $\frac{1}{2000}$th of an inch square. This would give 4,000,000 of fibres in a square inch, or nearly 500,000 in ·12 of a square inch, which is the average sectional area of all the posterior roots in a grown person.

If we take the external surface of the body as equal to fourteen feet, and suppose all the sensitive nerves to reach the surface, and to be equally distributed over it, this would give nearly $2\frac{1}{2}$ nerve-fibres for each square tenth of an inch; but making allowance for the difference in the amount of sensory nerves in the more and less sensitive regions of the skin, it seems probable that in the more sensitive there may be a fibre for each $\frac{1}{000}$th of an inch square, and for the least sensitive not more than one fibre for each $\frac{1}{5}$th of an inch square.

The area of section of the optic nerve is nearly ·04 of a square inch. The diameter of the nerve-fibres is probably from $\frac{1}{7000}$ to $\frac{1}{8000}$. If we suppose one to occupy each square of $\frac{1}{6000}$ in section, we shall have 1,400,000, or nearly one million and a-half of fibres in each optic nerve. But numerous as these fibres appear, their number is greatly inferior to the peculiar bodies of the outer layer of the retina with which they are connected, or in which they terminate, viz., the baccillary layer of rods and cones.

If we take the central spot of the retina or seat of perfect vision, which is entirely occupied by cones, as equal to an area of $\frac{1}{50}$th of an inch square, and the diameter of each cone as equal to a square of $\frac{1}{5000}$th of an inch, there would be about 10,000 of the cones in the central spot.

If the area of the whole retina be taken as equal to two square inches, and we make a rough calculation of the relative proportion of rods and cones over the whole retina, it seems probable that there may be about five millions of cones and 160 millions of rods, and accordingly many more of these bodies than of nerve-fibres. It seems probable, therefore, that a subdivision of the nerve-fibres may take place before they communicate through the nerve-cells of the retina with the cones, and it is believed that in the granular layer of the retina a frequent subdivision of the ultimate nerve-fibres occurs before they reach the rods. The cones are probably the media through which separate impressions of light are perceived, their distance from each other in the central part of the retina corresponding nearly with that indicated by the limits of most minute vision.

With reference to the relation of the nerve-fibres to the muscles, it is to be observed, that if the number of fibres in one square inch of the cross section of a muscle be about 25,000, and if we take the cross section of muscular substance in the human body as equal to 100 inches, we shall thus have not less than 2,500,000, or two and a-half millions of muscular fibres in the body. But the motor roots are scarcely a half of the size of the sensory roots, and the diameter of their fibres is somewhat greater, so that there must be less than a half of the number of fibres contained in them, that is, the half of 500,000, or 250,000 fibres in all the motor roots of the spinal nerves, and therefore not more than one nerve-fibre for ten muscular fibres, and of these fibres it is not certain that all pass up the spinal cord to the brain. Farther, considering the obliquity of the direction of muscular fibres in muscles, the above estimate of the number of fibres in all the muscles is probably much too low, and consequently, the number of muscular fibres in the body is greatly superior to that of the motor nerve-fibres, which are the means of exciting muscular action.

PROCEEDINGS

OF THE

PHILOSOPHICAL SOCIETY OF GLASGOW.

MAY 2, 1860.

WALTER CRUM, Esq., *in the Chair.*

Professor Rogers read a paper "On the Distribution and Probable Origin of the Petroleum, or Rock Oil, of Western Pennsylvania, New York, and Ohio."

On the Distribution and Probable Origin of the Petroleum, or Rock Oil, of Western Pennsylvania, New York, and Ohio. By PROFESSOR ROGERS.

PROFESSOR ROGERS stated that his main object in this communication was to give some account of the geological relations of the petroleum, or native parafine oil, of the great Appalachian coal-field of the United States. In attempting this he should first sketch its geographical position and distribution, and show its relations to the coal and other formations of the country; he should next describe the conditions under which it appears naturally, or is artificially procurable; and he should then proceed to consider the question of its mode of origin, or of the actions, vital, chemical, and physical, which engendered it, and placed it where it is.

The geographical and geological situations of the native oil were pointed out upon a small geological map of the United States, a larger one of the State of Pennsylvania, and some general and local geological sections. It was shown to abound chiefly in the coal strata along the north-west margin of the Appalachian coal basin, from Western Pennsylvania through Western Virginia to Tennessee, appearing throughout this zone of country in sparsely distributed "oil springs," invariably associated with more or less gaseous carburetted hydrogen, or mingled with the briny waters artificially brought to the surface in the Artesian "salt wells," so called, numerously sunk into the lower coal-measures to various depths, amounting in some instances to 1,000 feet, in quest of brine for conversion into "table-salt." Only those springs or fountains which emit, along with their waters, a very sensible quantity of the rock-oil, in a sufficiency admitting of its being collected by skimming or sopping up with cloths, are usually termed "oil springs;" nevertheless, nearly all of the far more numerous class commonly called "burning springs," from their evolving the gaseous carburetted hydrogen, reveal appreciable traces of the petroleum in the form of a thin oily scum. Indeed, all the phenomena naturally and artificially presented, prove abundantly that both classes of the hydro-carbon compounds, the liquid and the gaseous, exist almost universally diffused in the coal strata throughout the district above specified. But these inflammable products are by no means evenly distributed. The geological conditions connected with their greater or less copiousness—the second main topic of the paper—are therefore next to be noticed. Superficially, the gas- and oil-emitting springs, within the coal-field, are chiefly found upon the anticlinal flexures of the strata, and those external to the coal formation, in proximity to the outcrops of the black bituminous slate subjacent to that formation, in localities where the gas-evolving slate lies at the moderate depth of a few hundred feet below the soil.

The petroleum, or oil, appears to be in its greatest abundance in that part of the coal-field of Western Pennsylvania which is limited by the Alleghany River on the east, and which embraces its western and north-western tributaries north of the Clarion River; but the district promising a profitable product in it, extends to Mercer and Butler counties, Pennsylvania, and even into some of the eastern counties of the State of Ohio. Perhaps the tract where it is most accessible and abundant is the valley of *Oil Creek*, so named from the existence there of several natural oil springs. French Creek also exhibits indications of the material in various places, while symptoms of it appear on the Brokenstraw and various other upper feeders of the Alleghany, as far as the Oil Creek or the Olean Creek of New York.

Stratigraphically, the gas and the petroleum seem chiefly to accompany the briny waters copiously diffused in the pores of the loosely aggregated sandstones, but not imbuing as abundantly the more water-tight shales and slates. A long experience has taught the sinkers of the Artesian wells this contrast, so that it is now a matter of common notoriety throughout Western Pennsylvania and Western Virginia, Eastern Ohio and Eastern Kentucky—the districts where the strata are perforated by these borings—that the inflammable products gush up only upon the chisel's penetrating certain beds, especially certain thick pale sandstones of open texture, most abundant near the bottom of the lower coal-measures. It would seem that the imperviousness of the argillaceous strata, except where these are fissured, as they are apt to be on the anticlinal flexures, serves to hold down the elastic or volatile products, as evinced by their often sudden and copious effusion when the mud-rocks are perforated, and the more porous grits are entered by the boring tool. Recent experience, however, has shown that the gas and petroleum are lodged plentifully in the more superficial strata of the coal-measures, throughout a wide area bordering the Alleghany River, large quantities being evolved from borings from 100 to 200 feet in depth; whereas the wells affording the steadiest supplies of richest brine are usually between 500 and 1,000 feet deep. The most successful holes hitherto sunk, especially in quest of the oil, do not exceed 200 feet of depth, while many of the borings begin to bring it up copiously before they are down 100 feet. The proportion of petroleum to water procured from these borings varies, of course, with the locality, and especially the strata penetrated; but it is safe to say that it generally amounts to 1-10th part. The commercial value of this product will be appreciated, when it is understood that many of the "borings" yield as much as 500 gallons of the oil alone, per day, its present market price being about 65 cents, or 2s. 8d. sterling, per gallon. With these facts it is easy to account for the eagerness at present manifested by the people of Western Pennsylvania to secure the best oil-producing localities. Indeed, the "petroleum fever," though less widely diffused, has recently reached almost as high a pitch as ever did the "gold fever" in its intensest days.

Advancing to the third subdivision of his subject—the origin of the petroleum and gas—the author of the paper undertook to show that the presence of these inflammable products in the strata is but one phase of a very widely diffused metamorphism, by subterranean heat, which all the palæozoic formations, the coal-measures included, have undergone. First, he called attention to the fact, that the coal strata, especially the beds of coal themselves, are, of all known sedimentary deposits, those which disclose best the various degrees or shades of metamorphic action; the coal, from its superior susceptibility to permanent change of texture and chemical decomposition, with extrication of its more volatile ingredients under a moderate heat, being, indeed, a sort of *very sensitive natural register thermometer*, recording the different grades of temperature to which the strata have been exposed. Many of the larger coal basins of Europe display more or fewer of these lesser shades of metamorphism in their coal, the basin of Belgium, and the still grander one of South Wales, showing them in regular gradations through a wider scale from non-hydrogenous anthracites to the fat, inflammable, so-called bituminous varieties; but no coal tract upon the globe discloses the whole gradation or gamut of metamorphism in a sequence so full, so uninterruptedly progressive, and geographically so extensive. Appealing to his geological map of the United States, and to several transverse geological sections constructed from his own surveys, Professor Rogers established this position, by pointing out the distribution of all the respective kinds of coal, showing that the anthracite variety, destitute of the hydro-carbon compounds, is restricted to the closely compressed basins ranging along the south-east side or margin of the Appalachian mountain-chain; the semi-anthracite, with from 5 to 7 per cent. of hydro-carbon, to the middle zone of the same range; the semi-bituminous coal, containing 15 or 20 per cent., to the north-west margin of the mountain belt; and the richly bituminous or normally-hydrogenous kinds, to the wide and very slightly disturbed tracts still more to the north-west, or beyond the mountains, and more interior in the continent.

Accompanying this gradation, which embraces between its extremes a breadth of country of more than 200 miles, there is traceable, *pari passu*, an equally well marked transition in all the symptoms of metamorphism affecting the other strata, or those not including the coal seams, and a gradation not less conspicuous in the flexures of the strata, evincing a progressive abatement north-westward in the energy of the subterranean forces which undulated them, and left the eastern half of the coal region in the form of a series of long, slender, parallel troughs. The main point of the author's paper was to show that the copious presence of gaseous hydro-carbon (illuminating gas), and hydro-carbon in its liquid form (petroleum or rock oil), is simply one phase in this gradation, marking a particular stage in the metamorphic process, at which the expulsion of the volatile constituents of the coal beds had ceased. Appealing to the now well established fact, that within the great Appalachian coal-field we can nowhere meet with any igneous rocks—no outpours nor dykes of trap—no intrusive mineral veins—none even in the most undulated and altered portions of the anthracite-yielding coal-measures of Eastern Pennsylvania, nor, indeed, within twenty-five or thirty miles of their border; and referring to his repeatedly published views of the volatilizing and discharging agency of subterranean steam, issuing hot and dry through the crevices of the strata, during convulsive earthquake upheaval and oscillation of the coal measures, he infers that the petroleum and burning gas of Western Pennsylvania and Western Virginia were extricated or distilled from the already framed hydrogenous coal seams, and merely not wholly expelled into the atmosphere as in the anthracite region, but arrested in the pores and crevices of the overlying strata at a stage short of their total expulsion.

In the districts south-east of the oil-producing tract these volatile matters were not only set loose from the coal by the chemically decomposing function of the compressed hot steam, but were dislodged from the strata altogether by its well-known carrying agency; and thence resulted the hard, compact, flinty anthracite, or the semi-anthracite or semi-bituminous coals, as the discharge was complete or less or more imperfect; while in the regions north-west of the inland frontier of the Appalachian coal-field, where every feature in the geology manifests a maximum of subterranean igneous force, this steaming agency was less; wherefore the coal there retains more nearly its original full proportion of the volatile matters, and the including rocks show a commensurately less amount of the native oil and gas.

The contrast here sketched as to the impregnation and non-impregnation of the rocks of the respective regions with the petroleum and carburetted hydrogen gas, is not to be understood as absolute; for the gas or "fire damp" does exist to some extent in the anthracite coal-measures, but with no traces of the petroleum; while, on the other hand, some gas and a little oil do imbue the strata of the western coal-fields where the volatile matter in the coal attains its maximum. In the one case the expulsion of the hydro-carbons was not entire, in the other the decomposition of the coal had proceeded a certain length.

Professor William Thomson exhibited his "Portable Atmospheric Electrometer."

Mr. Hunt reproduced some of the Cinephantic Colour Experiments on an enlarged scale.

The Shotts Iron Company exhibited a sample of their Bathgate Gas Coal, with some of the Oils, Candles, &c., manufactured from the coal.

APPENDIX.

On the Ageing of Mordants in Calico Printing.

By Walter Crum, F.R.S.

(*Postponed Paper, Read to the Society December* 14, 1859, *vide* p. 263.)

The process of "ageing" in calico printing is that by which a mordant, after being applied to a cotton fabric, is placed in circumstances favourable to its being incorporated with and fixed in the fibre; and the method usually employed has been to suspend mordanted goods in an apartment in single folds, exposed to the atmosphere.

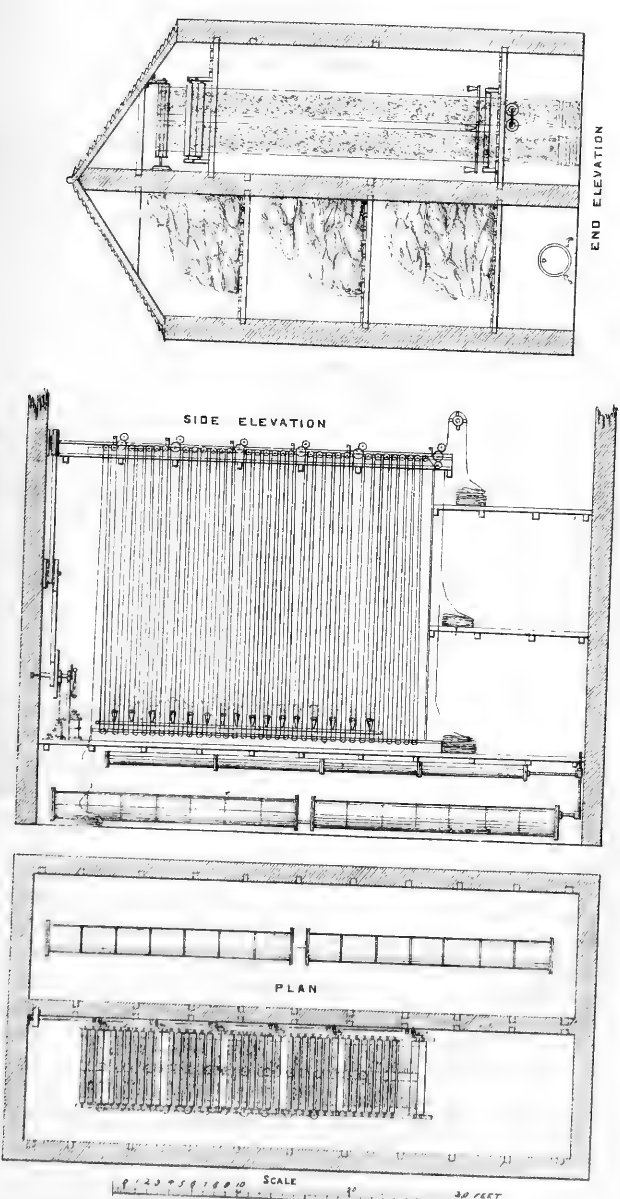
The object is to moisten the acetates of iron and of alumina in order to their decomposition; and, in ordinary circumstances, a pound of water is gradually absorbed by fifteen pounds of printed cloth. The protoacetate of iron is thus enabled, by imbibing oxygen, to become a sesquiacetate like the bisalt of alumina. Each then proceeds to give off acetic acid, and to deposit a tersesquihydrate upon the fibre.

Various methods have been employed in this country for adding to the natural moisture of the air, but with no great advantage until Mr. Jones introduced into Messrs. Schwabe's Works, near Manchester, a system of ageing which he had seen in operation at Mulhausen, and succeeded, by the direct introduction of steam underneath, greatly to increase the heat and moisture of the large apartment in which his mordanted goods were hung, and thus to render the process of ageing not only more speedy, but much more perfect than before. But the employment of steam was in that case limited in amount, chiefly by the discomfort to which it subjected the workpeople in the apartment, and by the damage produced by drops of water falling from their persons upon the goods.

In the summer of 1856, Mr. Jones visited Thornliebank, and described that method of ageing. It became then not difficult to conceive that, by a further increase of heat and moisture in an apartment sufficiently capacious, and by employing a great number of rollers, goods might become sufficiently moistened without manual labour, by being merely passed through such an atmosphere; and that thus, the pieces being stitched end to end, a continuous process might be substituted for that of hanging goods over wooden rails, and leaving them there until the ageing is completed.

The idea of passing printed goods through an atmosphere artificially

STEAM AGEING STOVE AT THORNLIEBANK.



moistened was not new. It had even been patented by Mr. John Thom of Manchester; but the apparatus of that gentleman was too small to be practically useful. The present improvement consists in rendering the process a practicable one, and the various adaptations introduced for that purpose will appear in its description.

A building is employed 48 feet long inside and 40 feet high, with a mid wall from bottom to top running lengthwise, so as to form two divisions each 11 feet wide. The manner in which they are fitted up will be understood by reference to the drawing.

In one of these divisions, the goods first receive the moisture they require. Besides the ground floor, it has two open sparred floors 26 feet apart, upon each of which is fixed a row of tin rollers, all long enough to contain two pieces of cloth at their breadth. The rollers, being threaded, as shown in the side elevation, are set in motion by a small steam-engine, and the goods to be aged, which are at first placed in the ground floor, are drawn into the chamber above, where they are made to pass over and under each roller, issuing at last at the opposite end (on the right-hand side of the drawing), where they are folded into bundles on one (at a time) of the three stages which are placed there. These stages are partially separated from the rest of the chamber by a woollen partition.

While the goods are traversing these rollers, they are exposed to heat and moisture, furnished to them by steam, which is made to issue gently from three rows of trumpet-mouthed openings. The temperature is raised to from 80 to 100°, or more, of Fahrenheit—a wet-bulb thermometer indicating at the same time 76° to 96°, or always 4° less than the dry-bulb thermometer. In this arrangement 50 pieces of 25 yards are exposed at one time, and as each piece is a quarter of an hour under the influence of the steam, 200 pieces pass through in an hour. Although workpeople need scarcely ever enter the warmest part of this chamber, a ventilator in the roof is opened, when there is any considerable evolution of acetic acid.

The mordant having thus received the requisite quantity of moisture, must be left one or two days in an atmosphere still warm and moist; and in some cases it is advantageous to pass the goods a second time through the rollers.

It had been ascertained long before at Thornliebank, that exposure in single folds after moistening was not necessary. Mr. Graham's experiments on the diffusion of gases through small apertures had served to suggest that, for the absorption of the small quantity of oxygen required, the goods might as well be wrapped up and laid in loose heaps. Accordingly, in the operation in question, the moistened goods are carried in bundles into the building on the opposite side of the mid-wall already mentioned, and deposited upon the sparred floors which are placed there at heights corresponding with the stages in the first apartment, on which the goods are folded down. Upon these floors five or six thousand pieces, of twenty-five yards long, can be stored at a time. It is necessary, of course, that an elevated temperature, and a corresponding degree of moisture, be preserved in the storing apartments day and night, and 80° Fahr. is sufficient, with the wet bulb at 76°. To effect that object a large iron pipe is placed along the ground-floor underneath, and moderately heated by steam, while a row of small jets, in the same position, are made to project steam directly into the air of the apartment. The whole building is defended from external cold, and consequently from condensation of steam, by a warmed entrance-room, and by double windows and double roof. Small steam-pipes are also placed at other points where they seem to be required; and the apartment with rollers is specially heated, when not in use, by a couple of steam-pipes, which are placed under the ceiling of the ground-floor.

The process of ageing, as thus detailed, was in operation at Thornliebank in the autumn of 1856. About a year afterwards it began to be adopted by other printers, and now (in September, 1859) it is already in use at at least sixteen different printing establishments in Scotland and in Lancashire.

ABSTRACT OF PROCEEDINGS OF SESSION 1858-59.

The Session commenced on the 3d of November. On taking the chair Professor William Thomson announced the death of Mr. William Murray of Monkland, and moved that, as a mark of respect to his memory, the Society do now adjourn till the next ordinary meeting, and that the Secretaries be instructed to prepare a memorial of Mr. Murray, to be engrossed in the minute-book. The motion was seconded by Mr. Walter Crum, and agreed to.

The late William Murray, Esq. of Monkland.

Mr. William Murray was born in Glasgow in September, 1790. He was therefore in his sixty-ninth year when he died on the 2d of November, 1858. His father, Mr. Francis Murray, who was the son of William Murray of Belridden, in Dumfriesshire, came to this city early in life. That gentleman was at first engaged in a West India business, and afterwards, about the middle of the century, commenced the Monkland Steel Works, in conjunction with the late Mr. John

Buttery. He was also engaged in colliery operations at Banknock, near Denny, and sent his son William, when a very young man, to superintend them. Mr. William Murray, the subject of this notice, was admitted a partner of the Monkland Steel Company in 1824, and soon afterwards, on the retirement of his father, Mr. James Murray joined his brother and Mr. Buttery in carrying on the business. The collieries were at the same time transferred to Mr. William Murray.

During Mr. Murray's residence at Banknock he was well known and much esteemed in the neighbourhood. He was a frequent visitor at Cumbernauld House, and took a prominent part in promoting the return of Admiral Fleming for the county of Stirling at the first election under the Reform Act.

Mr. Murray was married in 1824 to Miss M'Leod, an English lady who had been residing at Underwood House, near Banknock. He had the misfortune to lose his wife in 1837—his family then consisting of three sons and three daughters, all of whom survive him, except one daughter.

In 1826 the Monkland Company added the manufacture of pig-iron to their other departments, and the business generally having been extended so as to require all Mr. Murray's attention, he disposed of his collieries in the year 1835 to the father of the present Mr. Wilson of Banknock. In 1840 the company entered largely into the manufacture of malleable iron. Mr. Murray thus took an important part in the extraordinarily rapid development, during the last thirty years, of the coal and iron trade in Scotland.

Of late years Mr. Murray became so far relieved of the details of his own business that he could give a great deal of attention to matters of public interest. In 1850 he was elected into the Town Council, and all along took his full share of the duties of that body; but during the two last years of his life he especially distinguished himself as chairman of the committee of the Loch Katrine Water Works, devoting much of his time to the promotion of that most important undertaking; and not only meeting with the engineers and superintending the operations, but making all the necessary arrangements with the various landlords through whose property the works were carried.

In matters of science—a taste for which he acquired in the chemistry and natural philosophy classes in Anderson's University—Mr. Murray was chiefly interested in geology and mechanics; and on both occasions when the British Association met at Glasgow, he not only energetically promoted the general arrangements, but presented to that body a section and series of specimens illustrating the strata connected with the beds of coal and iron in this rich mineral district.

Mr. Murray joined the Philosophical Society in 1837. In 1844 he was elected a member of Council, which office he held, with the exception of one year, till the time of his death. He took an active part in promoting the Society's Exhibition in the City Hall in 1846. In Vol. I., page 113, of the Society's printed Proceedings, appears an account of the Section of the Lanarkshire Coal Field, prepared under the direction of Mr. Murray for the Glasgow Meeting of the British Association in 1841.

Mr. Murray was elected the President of Anderson's University in September, 1844. In a year or two after his election a sum of £893 was raised by subscription, enabling the managers to pay off an arrear of interest on the debt which had been accumulating at the Bank of Scotland, and to make the first considerable additions to the practical class-rooms of chemistry and anatomy. He held this office at the period of his death.

November 17.—Professor William Thomson *in the Chair.*

The following gentlemen were elected members of the Society, viz.:—Mr. John Dennison, C.E.; Mr. J. Hall Smith; Laurence Hill, LL.B.; Dr. A. K. Irvine; Mr. William Wakefield; Mr. James Buchanan; Mr. Wilhelm Schierbeck.

Mr. Cockey, Treasurer, gave in an abstract of the accounts, showing a balance in favour of the Society, after meeting the expenditure, of £98 3s. 2d. The Exhibition Fund of 1846, with interest, amounts at this date to £739 3s. 3d.

The Society proceeded to the Fifty-seventh Annual Election of Office-bearers.

The following were elected:—

President.

Dr. Thomas Anderson.

Vice-Presidents.

Dr. W. J. Macquorn Rankine. | Mr. Robert Hart.

Librarian.

Dr. Bryce.

Treasurer.

Mr. William Cockey.

Secretaries.

Mr. Alexander Hastie. | Mr. William Keddie.

Council.

MR. CHARLES GRIFFIN.	MR. JOHN CONDIE.
MR. JAMES NAPIER.	MR. JAMES COUPER.
MR. ALEXANDER HARVEY.	MR. WALTER CRUM.
DR. ALLEN THOMSON.	MR. ROBERT BLACKIE.
MR. J. P. FRASER.	PROF. WILLIAM THOMSON.
MR. GEORGE ANDERSON.	MR. GEORGE SMITH.

Professor William Thomson gave a report on recent progress in Thermodynamics.

December 1, 1858.—DR. ANDERSON, *the President, in the Chair.*

Mr. James Brown, one of the Magistrates of Glasgow, and Mr. John D. Campbell, Sub-Inspector of Factories, were elected members.

The President gave an account of the relations of the Plant to the Atmosphere and the Soil.

The Society agreed to memorialize her Majesty's Government, expressing the deep interest felt by the Society in the establishment of telegraphic communication between this country and America, and praying the Government to extend its patronage and aid in furtherance of that object.

December 15.—*The* PRESIDENT *in the Chair.*

Mr. John Robertson, Mr. James Dunn, Mr. George W. Brown, Mr. Robert Cassills, Mr. John Fulton, Mr. T. Currie Gregory, C.E., and Mr. William Teacher, were elected members.

Mr. Walter Crum read "Suggestions for Diminishing the Risk from Fires in Ships at Sea."

The Orrery of the late Mr. John Fulton was exhibited to the Society by his brother, Mr. Thomas Fulton.—Thanks voted.

January 12, 1859.—*The* PRESIDENT *in the Chair.*

Dr. Allen Thomson gave an account of the Homologies of the Vertebrate Skeleton.

January 26, 1859.—DR. BRYCE *in the Chair.*

Mr. David Robertson was elected a member.

Professor William Thomson read a paper on Atmospherical Electricity, illustrated by experiments.

February 9, 1859.—*The* PRESIDENT *in the Chair.*

Mr. Mortimer Evans, Mr. Thomas Menzies, and Mr. Alexander Sime, were elected members.

Mr. Harvey exhibited an apparatus for signalling on shipboard, and also a new construction of Bilge Pump.

A communication was read from Dr. Ross, Busby, containing notices of a survey of part of the Middle Island of New Zealand, by Mr. John Buchanan.

The President read a paper on the Composition of some Mineral Phosphates.

February 23, 1859.—MR. HART, *Vice-President, in the Chair.*

Mr. Henry D. Rogers, Professor of Natural History in the University of Glasgow, was elected a member of the Society by acclamation. Mr. Robert Lumsden was elected a member.

Mr. Laurence Hill read a paper "On the Purification of the Clyde, or the Utilisation of the Sewage of Glasgow."

The Society instructed the Council to appoint a committee to inquire into the practicability of Mr. Hill's plan.

March 9, 1859.—*The* PRESIDENT *in the Chair.*

Professor William Thomson read a paper "On Telegraphic Signals through Submarine Conductors," and exhibited the apparatus invented by him for the Atlantic Telegraph.

March 23, 1859.—*The* PRESIDENT *in the Chair.*

Mr. John Henry Macfarlane was elected a member.

Professor Rogers read a paper "On Fossil Footmarks."

Mr. John Downie described a new design for "River Steamers of Improved Construction for Passenger Traffic," illustrated by a model and diagrams.

April 6, 1859.—DR. BRYCE *in the Chair.*

Dr. Donald Dewar and Mr. H. Constable were elected members.

Dr. Francis H. Thomson read "Notes on Copper Smelting."

April 20, 1859.—PROFESSOR MACQUORN RANKINE, *Vice-President, in the Chair.*

Mr. Thomas Currie Gregory read a paper "On Canada: its Physical Features and Main Channels of Internal Communication."

May 4, 1859.—*The* PRESIDENT *in the Chair.*

Mr. James Henderson exhibited the British Sewing Machine lately invented and patented by Mr. S. C. Blodgett.

Professor Rankine read "A Provisional Classification of Machines according to their purposes, with a view to the appointment of a Committee upon the several Classes."

Dr. Wallace read a paper on Sugar refining.

On some Points in the Chemistry of Sugar Refining. By WILLIAM WALLACE, Ph.D., F.C.S.

THE manufacture of sugar is a strictly chemical process, although involving, like many other processes which depend upon chemical principles, many important mechanical details. There are, perhaps, few manufactures of such importance as sugar refining, of which so little is known by the general public; and I trust, therefore, that a brief description of the process, together with an explanation of the scientific principles involved, will not be unacceptable to the members of this Society. The position of the trade as one of the industrial resources of the West of Scotland will be appreciated, when it is stated that there are in Glasgow, Greenock, and Port-Glasgow, fifteen or sixteen houses which, collectively, are computed to refine annually at least 75,000 tons of raw sugar, worth about £3,000,000. There is one house in Glasgow, and one or two in Greenock, which turn out each 200 tons a-week, or at the rate of 100 pounds per minute.

There are many varieties of sugar, of which the three most important kinds are cane sugar or *sucrose* ($C_{12} H_{11} O_{11}$), fruit sugar or *fructose* ($C_{12} H_{12} O_{12}$), and grape sugar or *glucose* ($C_{12} H_{14} O_{14}$). The two last varieties, indeed, are often confounded together, and many chemists consider them identical; but the generally received opinion now entertained is, that there is no such thing as grape sugar produced by the vital functions of plants, but that it is formed, under particular circumstances, from fruit sugar, by the assimilation of two equivalents of water. Indeed, all the other sugars seem to change readily into glucose; and even starch and lignine, as is well known, are easily converted into this substance by the action of acids. In all cases the change is owing simply to the absorption of the elements of water. Very weak acids, with the aid of heat, effect the conversion of cane sugar first into fruit and then into grape sugar: an elevated temperature alone, in presence of water, accomplishes the same transformations, but much more tardily. The following experiments, made with a solution of pure sugar in distilled water, will illustrate the danger of keeping syrups at an elevated temperature for a lengthened period of time. In the first experiment a quantity of the syrup was heated in a sand bath until a large proportion of the sugar crystallized out; more water was then added, and the evaporation and solution repeated two or three times. A thick syrup was thus obtained, which refused to give any crystals when kept for weeks over oil of vitriol. Analysis gave fourteen parts of fruit to one of cane sugar. In the next experiment the syrup was kept in the bastard loft of a sugar-house (temperature 90° to 100°) for several months, water being added from time to time. A thick, almost semi-solid, syrup was thus obtained, which did not show the slightest appearance of crystals even under the microscope. At this time it contained only one part of cane to ten of fruit sugar. The syrup was left exposed in the same vessel for some time afterwards without undergoing any apparent change, when suddenly the whole was transformed into a soft solid mass, consisting of distinct but microscopic crystals of grape sugar. Weak acids give rise to the formation of grape sugar; but this change does not appear to begin until all the cane sugar has first been converted into fructose. I have never observed crystals of grape sugar in any of the ordinary products of the sugar-house, even in the strongest and heaviest syrups. It is true that minute crystals generally appear in heavy syrups and molasses, when kept for some time, but these are seen, on examination by a low power of the microscope, to consist of cane sugar crystallized in the usual form. Fruit sugar does not crystallize at all, but forms, on evaporation, a tenacious semi-solid mass. Grape sugar crystallizes readily enough, from a tolerably strong solution which has not been exposed to too high a temperature.

With regard to the natural distribution of the two varieties of sugar, it appears that all sweet vegetable juices, which are alkaline or neutral, contain cane sugar only; while those that are acid, contain fruit sugar only. The two sugars have never been found mixed together in the juices of plants. It is unfortunately but too easy to change cane sugar into fruit or grape sugar, but the reverse process cannot be effected by artificial means.

Cane sugar crystallizes readily in four-sided prisms with rhomboidal base, but the crystals have generally a cubical appearance; and sometimes, by truncation, they assume the aspect of six-sided prisms. The crystals are always sharp in the edges and solid angles, even when produced from the most impure syrups, Cane sugar is distinguished from all other bodies by its intensely sweet taste, which is best observed when the sugar is in fine crystals, as the sensation of sweetness depends very much upon the rapidity of solution. We frequently hear one kind of sugar called sweeter than another, the specimens being equally pure, as if sugar could be anything but sugar; and it is a fact that many refiners refuse to purchase fine large-grained muscovado, and prefer smaller crystals, inferior in point of purity, simply because the larger crystals dissolve less rapidly in the mouth, and thus appear less sweet. It appears almost incredible that such ignorance as this should exist in a country where the standard of general education is so high.

Cane sugar is devoid of odour and colour. It is highly soluble in water, which takes up, at the comparatively low temperature of 48°, about an equal weight. With increase of temperature the power of solution is very much augmented, and at the boiling point of the liquid the capacity of water for dissolving sugar is almost unlimited. At the degree of heat at which syrups are boiled down in the vacuum pan (150° to 160°), water does not by any means possess this power of unlimited solution.

Fruit sugar is uncrystallizable, but forms, when dried in vacuo, at the ordinary temperature of the air, a gummy semi-solid mass. It possesses a peculiar action upon polarized light, which distinguishes it from grape sugar, to which it is closely allied in many respects. I have never found this variety of saccharine matter, as produced artificially, in a pure state, but always mixed with cane sugar. It exists abundantly in golden syrup, molasses, and treacle. Cane sugar refuses to crystallize from a syrup which contains rather more than an equal weight of this variety, and I have found that a syrup which contains less than eight parts of cane to ten of fruit sugar is absolutely undrainable at any temperature.

Grape sugar, as already stated, never occurs in any of the products of the sugar manufacture. It crystallizes in fibrous masses or tufts radiating from a centre, presenting a very beautiful appearance when examined with a lens. The crystals are soft and minute, and no definite crystalline form has as yet been ascribed to them. Grape sugar is frequently called uncrystallizable sugar; but this is evidently a misnomer, arising from its being confounded with fructose. It has little economic value, its sweetening power being 2½ times less than that of cane sugar. Fruit sugar soon changes to grape sugar if no cane sugar is present. We frequently find tufts of this substance in raisins and other dried acid fruits, the skins of which have been ruptured. The whiteness and viscousness of old honey is owing to the presence of crystals of glucose. I have seen jelly and other preserves, in which all the cane sugar introduced had been altered by heat and acid, become opaque and semi-solid from the same cause. This phenomenon must not be confounded with the much more common one of cane sugar forming a hard crisp crust upon the surface of the jelly.

The action of ferments, so far as these are concerned in the process of sugar refining, next claims our attention. This is a subject which presents many points of difficulty, yet it is too important to be wholly omitted in such a discourse as the present. If sugar-canes are cut during the rainy season, and allowed to lie over for a few days before the juice is expressed, no crystallized sugar can be obtained from them—only molasses, and even these of an inferior description. Again, if the char-washings of the refinery are permitted to stand aside for a similar period of time before they are boiled down, the sugar which they contain is almost entirely destroyed. Occasionally the whole of the syrups in a sugar-house undergo a peculiar kind of fermentation, converting the syrups into a viscid condition, in which they refuse to drain away from the crystallized sugar. This condition is known technically as "smear," and its entrance into a sugar-house is considered analogous to the advent of a plague into a city, or of glanders into an extensive stable. I have devoted considerable time to the study of this highly obscure subject, and I think I have at last succeeded in assigning a cause of which this smear is the probable result.

It is well known that sugar is liable to a variety of kinds of fermentation, depending upon the presence of certain substances in a state of change, the strength of the solution, its temperature, and other causes. Thus, when the solution is rather weak, and vegetable fibrine is present (as in grape juice), the yeast plant, the sporules of which are constantly floating in the atmosphere, readily vegetates, and the result is the breaking up of the sugar into alcohol and carbonic acid. Again, when the liquid contains caseine, as in milk, and the liquid is in a condition favourable to the putrefactive decomposition of this nitrogenous principle, the sugar is converted into lactic acid. When the temperature is high (90° to 110°), on the other hand, and some nitrogenous matter is also present, the sugar undergoes the viscous fermentation, in which a mucilaginous matter, mannite, and other substances, are formed. The viscous fermentation occurs with peculiar rapidity in the expressed juice of the beet and many other vegetables; and in the manufacture of rum in the West Indies it has to be kept in check by the addition of sulphuric acid. In the sugar-house we have many of the conditions fulfilled which are necessary for the development of the viscous fermentation, and although the mucilaginous matter is never formed in such quantity as to separate from the liquid, yet I have no doubt that this, or some other allied body with which we are yet unacquainted, is the cause of syrups becoming smeary. It occurred to me that the spread of this fermentation through the different floors of a sugar-house, from mould to mould, until all assumed the same aspect, might be connected with the vegetation of a microscopic plant resembling yeast, and that the alteration of a solution of pure sugar into fructose, and ultimately into glucose, as already noticed, might be owing to the same agency. On examining a specimen of smeary syrup with a microscopic power of 200 diameters, I found numerous protophytes, mostly of a green tint, but some brown. These consisted of single cells, enclosing frequently smaller cells; and some were seen burst at one side, with the smaller organisms making their escape. I did not perceive any ciliary motion in any of these bodies; but probably the viscid nature of the liquid tended to check the exertion of the ciliary force generally observed in these protophytes at a particular stage of their existence. I have since examined several specimens of smeary syrup, and of grape and fruit sugar solutions formed in the manner already described, and have in all cases found abundance of these protophytes, mostly of the commoner sorts. I do not presume to state that these plants are the true cause of the production of smear; but I think that this is by no means improbable. The occurrence of smear in a sugar-house is almost always the result of want of cleanliness, and nothing will produce it more rapidly than having dirty spars of wood in the char cisterns and elsewhere. In like manner, a piece of wood kept moist with water, and at a temperature of 60°, or upwards, soon acquires a "confervoid" odour from the growth of a similar class of plants in the water surrounding it. Again, sulphurous acid, which is well known to be inimical to vegetable life, is one of the few chemical agents which check the ravages of this fermentation, and this substance is now largely employed, generally in the form of bisulphite of lime, both in the beet sugar factories of France and Belgium, and in our own colonies. It is to be regretted that the sulphate of lime thus produced exercises a prejudicial influence upon the charcoal of sugar refineries. A sugar-house in which a tendency to smear begins to show itself should be at once fumigated with sulphurous acid, as the best means of checking the advance of fermentation; but there is little danger of this occurring where everything is clean and orderly, and the liquors are not kept too long. The old system of treacle pots is a very absurd one, and should in every case be discontinued, and the pots replaced by copper gutters.

It is but too well known to sugar refiners that molasses, apparently good, frequently give a perfectly undrainable mass when boiled down. This seems to depend in many cases simply upon the presence of an undue amount of fruit sugar, together with acid, by which the quantity of fruit sugar is greatly increased in the boiling. In other instances brought under my notice, this explanation was inadmissible, and the undrainable nature of the resulting "bastards" must have been owing to the presence of the mucilaginous matter already referred to. Molasses, especially if very sour, should be passed through char before being boiled down.

The power possessed by sugar of combining with common salt and other saline substances, and the property of the salts of preventing the sugar from crystallizing, are matters of which little is known by our refiners, but they constitute an evil of considerable magnitude to the beet sugar manufacturer. The beet sugar that is now imported largely into the Clyde, and which is the third or fourth crop of crystals, always contains 1½ to 2½ per cent. of soluble salts, and in more than one sample I have found as much as 4½ per cent. of nitrate of potash. When the sugar is refined alone the salts accumulate in the syrup and communicate to it a distinct saline flavour; but the common custom is to use three parts of muscovado to one of beet.

[Dr. Wallace occupied the remainder of his paper with a description of the methods of manufacturing and refining sugar, dwelling chiefly upon those details which involved chemical principles, and particularly upon the action of the animal charcoal used in decolourizing the syrup. Specimens of all the varieties of colonial and foreign sugars were shown, and likewise samples of all the products of the refinery. Specimens of canes from Demerara, drawings of sugar machinery, and Soleil's polariscope for the estimation of sugar, were exhibited.]

The following Table contains the average results of many analyses of several kinds of raw sugar, *as imported into Greenock and Glasgow,* and of the different products of a Greenock sugar-house:—

	West India.	Beet.	Date.	Lumps.	Pieces.	Bastards.	Green Syrup.	Golden Syrup.	Molasses.	Treacle.
Cane Sugar,...........	94·4	95·7	95·4	97·3	87·7	68·3	62·7	39·0	48·0	32·5
Fruit Sugar,..........	2·2	·3	1·8	·5	6·0	15·0	8·0	33·0	18·0	37·2
Extractive and Colouring Matter,....	·3	·4	·1	—	·5	1·2	·6	2·8	1·5	3·5
Ash,.....................	·2	1·6	·2	·2	·8	1·5	1·0	2·5	1·4	3·4
Insoluble Matter,....	·1	—	1·7	—	—	—	—	—	—	—
Water,.................	2·8	2·0	0·8	2·0	5·0	14·0	27·7	22·7	31·1	23·4
	100	100	100	100	100	100	100	100	100	100

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